HAZLETON
ENVIRONMENTAL SCIENCES
A DIVISION OF HAZLETON LABORATORIES AMERICA, INC.
1509 FRONTAGE ROAD, NORTHBROOK, ILLINOIS 60062, U.S.A.

REPORT

TO THE

IOWA ELECTRIC LIGHT AND POWER
CEDAR RAPIDS, IOWA

ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM FOR THE DUANE ARNOLD ENERGY CENTER

CEDAR RAPIDS, IOWA
Docket No. 50-331

ANNUAL REPORT - PART I
SUMMARY AND INTERPRETATION
JANUARY-DECEMBER 1982

FOR SUBMITTAL TO
THE NUCLEAR REGULATORY COMMISSION

PREPARED AND SUBMITTED
BY
HAZLETON ENVIRONMENTAL SCIENCES
PROJECT NO. 8001-101

Approved by: L. G. Huebner
L. G. Huebner
Director, Nuclear Sciences

8304040332 830328
PDR ADOCK 05000331
R PDR

24 February 1983

PHONE (312) 564-0700 o TELEX 28-9483 (HAZES NBRK)

PREFACE

The staff members of the Nuclear Sciences Department of Hazleton Environmental Sciences, a Division of Hazleton Laboratories America, Inc. (HES), were responsible for the acquisition of data presented in this report. All environmental samples, with the exception of aquatic, were collected by personnel of DAEC. Aquatic samples were collected by Ecological Analysts, Inc. personnel.

The report was prepared by C. R. Marucut, Section Supervisor, under the direction of L. G. Huebner, Director, Nuclear Sciences. She was assisted in the report preparation by L. Nicia, Group Leader, and other staff members of the Nuclear Sciences Department (HES).

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

This report summarizes and interprets results of the Environmental Radiological Monitoring Program conducted by Hazleton Environmental Sciences at the Duane Arnold Energy Center, Cedar Rapids, Iowa, during the period January - December, 1982. 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, 1983) available at the Iowa Electric Light and Power Company, Nuclear Support Services Department.

Duane Arnold Energy Center (DAEC) is located in Linn County on the Cedar River, Iowa, and is operated by Iowa Electric Light and Power Company. Duane Arnold I Nuclear Station is a 538 MWe boiling water reactor. Initial criticality was attained on 23 March 1974. The reactor reached 100% power on 12 August 1974. Commercial operation began on 1 February 1975.

2.0 SUMMARY

The Environmental Radiological Monitoring Program required by the U.S. Nuclear Regulatory Commission (NRC) Technical Specifications for the Duane Arnold Nuclear Generating Plant is described. Results for 1982 are summarized and discussed.

Results obtained for gross beta in airborne particulates collected during the first quarter of 1982 show a moderate effect of fallout from atmospheric nuclear detonation of a 200 kiloton to 1 megaton range device on 16 October 1980. Presence of other fission products, mostly strontium-90 and cesium-137, in some of the sampling media indicates a long range effect on the environment from fallout resulting from previous atmospheric nuclear tests.

No effect on the environment due to the operation of the Duane Arnold Nuclear Plant is indicated.

3.0 ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM

3.1 Program Design and Data Interpretation

The purpose of the Environmental Radiological Monitoring Program at the Duane Arnold Energy Center (DAEC) is to assess the impact of the plant on its environment. For this purpose, samples are collected from the air, terrestrial, and aquatic environments 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 DAEC operation must be distinguished from those due to other sources.

A major interpretive aid in assessment of these effects is the design of the monitoring program at the DAEC which is based 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 station effect would be indicated if the radiation level at an indicator location was significantly larger than that at the control location. 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 environmental samples collected from the DAEC site. The DAEC's monitoring program includes analyses for strontium-89, strontium-90, and iodine-131, which are fission products, and tritium, which is produced by cosmic rays, atmospheric nuclear detonations, and also by nuclear power plants. Most samples are also analyzed for gamma-emitting isotopes with results for the following groups quantified: zirconium-95, cesium-137, and cerium-144. These three gamma-emitting isotopes were selected as radiological impact indicators because of the different characteristic proportions in which they appear in the fission

product mix produced by a nuclear 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 nuclear 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).

The other group quantified consists of niobium-95, ruthenium-103, and -106, cesium-134, barium-lanthanum-140, and cerium-141. These isotopes are released in small quantities by nuclear power plants, but to date their major source of injection into the general environment has been atmospheric nuclear testing. Nuclides of the next group, manganese-54, cobalt-58, and -60, and zinc-65, are activation products and arise from activation of corrosion products. They are typical components of nuclear power plant's effluents, but are not produced in significant quantities by nuclear detonations. Nuclides of the final group, beryllium-7, which is of cosmogenic origin, and potassium-40, a naturally-occuring isotope. were chosen as calibration monitors and should not be considered radiological impact indicators.

Characteristic properties of isotopes quantified in gamma-spectroscopic analyses are presented in Table 5.1. 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 DAEC'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.

3.2 Program Description

The sampling and analysis schedule for the environmental radiological monitoring program at the DAEC is summarized in Table 5.2 and is briefly reviewed below. Table 5.3 defines the sampling location codes used in Table 5.2 and specifies for each location its type (indicator or control) and its distance, direction, and sector relative to the reactor site. The types of samples collected at each location and the frequency of collections are presented in Table 5.4 using codes defined in Table 5.5.

To monitor the air environment, airborne particulates are collected on membrane filters by continuous pumping at sixteen locations. Also, airborne iodine is collected by continuous pumping through charcoal filters at eight of these locations. Twelve of the sixteen locations

are indicators and four are controls (D-1, D-2, D-12, and D-13). Filters are changed and counted weekly. Particulate filters are analyzed for gross beta activity and charcoal filters for iodine-131.

Charcoal filters are analyzed on two composites: one from locations D-8, D-12, and D-14, and one from locations D-4, D-5, D-7, D-11, and D-15. If iodine-131 is detected, each cartridge is analyzed individually. Quarterly composites of airborne particulates from each location are analyzed for strontium-89, strontium-90, and gamma-scanned on a Ge(Li) detector.

Ambient gamma radiation is monitored at fifteen (15) air sampling locations. In addition, gamma radiation is monitored at forty-eight (48) special locations: sixteen (16) in a circle within 0.5 mi radius of the DAEC stack; sixteen (16) in 22.5° sectors within 1 mi of the DAEC stack; and sixteen (16) in 22.5° sectors between 1 and 3 miles of the DAEC stack. The sensors are placed in quintuplicate at each location and are exchanged and analyzed monthly. Additionally, a second set of dosimeters is placed at the same locations and exchanged and analyzed annually.

Precipitation samples are collected monthly from one location and analyzed for gross beta and tritium.

Milk samples are collected monthly from nine locations during the non-grazing season, October through April, and weekly during the grazing season, May 1 through September 30. Two of the locations are control (D-102 and D-105) and the rest are indicators. During the non-grazing season, milk samples from all indicator and all control locations are composited separately, and analyzed for iodine-131. If the level of iodine-131 in any of the composites equals or exceeds 2.4 pCi/l, the milk is resampled from each location and analyzed individually for iodine-131. During the grazing season, milk from five locations within a five mile radius of the DAEC stack is analyzed individually for iodine-131 and gamma-emitting isotopes. Milk from two locations within a ten mile radius of the DAEC stack and from two control locations are composited separately and also analyzed for iodine-131 and gamma-emitting isotopes. If the level of iodine-131 in any of the composites equals or exceeds 2.4 pCi/l, the milk is resampled and analyzed individually for iodine-131. In addition, monthly composites of weekly collections from each location are analyzed for strontium-89, strontium-90, and elemental calcium.

For additional monitoring of the terrestrial environment, grain and broad leaf natural vegetation samples are collected annually from eleven locations (two controls and nine indicators). Grain is analyzed for gamma-emitting isotopes and broad leaf vegetation is analyzed for iodine-131. Meat and poultry are collected annually during or immediately following a

grazing period from animals fed on crops grown within and outside ten miles of DAEC. The samples are analyzed for gamma-emitting isotopes. Wildlife, squirrel or rabbit, is collected annually and analyzed for gamma-emitting isotopes. Also, potable ground water is collected at least every two hours from a treated municipal water system (D-53), daily from the inlet to the municipal water treatment system (D-54), and monthly from five additional ground water locations. The samples are composited into monthly and quarterly composites for each location. Gross beta analysis is performed on all monthly composites. Gross beta and tritium analyses are performed on all quarterly composites.

Soil samples are collected three times per year at two control locations (D-102 and D-105) and eleven indicator locations (D-15, D-16, D-17, D-58, D-63, D-72, D-93, D-94, D-96, D-101, and D-106). The samples are analyzed for strontium-90 and gamma-emitting isotopes.

Surface water is collected monthly from seven river and pond locations, two control (D-49 and D-73) and five indicator (D-50, D-51, D-52,D-99, and D-103). All monthly samples are gamma scanned. Gross beta, tritium, strontium-89, and strontium-90 analyses are performed on quarterly composites from locations D-49, D-50, D-51, D-52, and D-99.

The aquatic environment is also monitored by upstream and downstream quarterly collection of aquatic biota (periphyton) and semi-annual collections of fish, and river sediment. River sediment is also collected at the plant's intake and discharge. Fish and aquatic biota are analyzed for gamma-emitting isotopes. River sediment is analyzed for strontium-90 and gamma-emitting isotopes.

3.3 Program Execution

The program was executed as described in the preceding section with the following exceptions:

(1) TLD data for several locations was not available for some months because TLDs were stolen, destroyed by either animals or vandals, or lost in the field. The lost TLDs are listed below.

Location	Month Lost
D-1	April
D-7	November
D-13	April, May
D-16	April
D-21	November
D-22	April
D-25	January, April
D-26	January
D-30	March

Location	Month Lost
D-31	January
D-34	January
D-36	March
D-42	April
D-45	November
D-76	January
D-83	January, November
D-86	April
D-88	January

(2) No annual TLD data was available for locations D-38, D-41, and D-45 because they were lost in the field.

(3) No milk was collected from location D-96 on 5-11-82, because the milk was not available.

(4) No ground (well) water was collected from location D-60 during the period January - June 1982, because the pump was either frozen or inoperational.

(5) No ground (well) water was collected from location D-59 (Frantz Cottage in January or February 1982 because the well was frozen.

(6) No surface water sample was collected from D-49 in January because access to Location 49 was blocked by snowdrift.

3.4 Laboratory Procedures

All strontium-89, strontium-90, and iodine-131 analyses in milk were made by using a sensitive radiochemical procedure which involves separation of the element of interest by use of an ion-exchange resin and subsequent beta counting.

All gamma-spectroscopic analyses were performed with a Ge(Li) detector. Levels of iodine-131 in 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 the liquid scintillation technique.

Analytical Procedures used by the Nuclear Sciences Department of Hazleton Environmental Sciences are specified in detail elsewhere (Hazleton Environmental Sciences, 1981). Procedures are based on those perscribed 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).

Details of Hazleton's QA Program are presented elsewhere (Hazleton Environmental Sciences, 1982). The HES QA Program includes participation in laboratory intercomparison (crosscheck) programs. Results obtained in crosscheck programs are presented in Appendix A.

3.5 Program Modifications

Location D-106 replaced D-104 for milk, soil, and vegetation. In July 1982, the Wiley Farm (D-60) was replaced by Camp Farm which is located 45 feet north of the Wiley Farm.

4.0 RESULTS AND DISCUSSION

All of the scheduled collections and analyses were made except those listed in Table 5.6.

All results are summarized in Table 5.7 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 of all indicator and control locations. The locations with the highest mean and range are also shown.

The tabulated results of all measurements made in 1982 are not included in this section, although references to these results will be made in the discussion. The complete tabulation of the 1982 results is contained in Part II of the 1982 annual report on the Environmental Radiological Monitoring Program for the Duane Arnold Energy Center.

4.1 The Effect of Chinese Atmospheric Nuclear Detonation

There were no reported atmospheric nuclear tests in 1982. The last reported test was conducted by the People's Republic of China on 16 October 1980. The reported yield was in the 200 kiloton to 1 megaton range.

There was a moderate effect of this test on the gross beta levels in airborne particulates. The annual mean gross beta activity was about four times lower in 1982 than in 1981. The highest mean activity was reached in the month of January and in the first quarter. By the end of 1982 the activity declined steadily to the level observed in 1980.

4.2 Program Findings

A number of program findings reflect effects of the latest Chinese and previous worldwide atmospheric nuclear tests. The chief environmental indicators of recent test effects were airborne particulates. The residual effect of previous nuclear tests was detected in some of the milk, vegetation, periphyton, bottom sediments. and soil samples (strontium-90 and cesium-137). No Plant effect was indicated.

Airborne Particulates

The average annual gross beta activity in airborne particulates was nearly identical at both indicator and control locations (0.026 pCi/m^3 and control locations (0.027 pCi/m^3) and was about four times lower than in 1981 (0.115 pCi/m^3). The decrease in the activity is attributable to the cleansing of the atmosphere of the radioactive debris produced by the

nuclear test conducted on 16 October 1980. The highest averages for gross beta were for the month of January and the first quarter, then decreased gradually to the 1980 level (0.029 pCi/m^3) by the end of the year.

The elevated activity in January and the first quarter was due to residual fallout from the nuclear test conducted 16 October 1980. The spring peak, which is usually observed in April - May (second quarter), was somewhat obscured by the elevated activity during the first quarter.

This peak has been observed almost annually (1976, 1979 and 1980 were exceptions) for many years (Wilson et al., 1969). The spring peak has been attributed to fallout of nuclides from the stratosphere (Gold et al., 1964). It was more pronounced in 1981 than in 1982 because of the fresh addition of the radioactive debris from the latest nuclear test.

Two pieces of evidence indicate conclusively that the elevated observed activity during the first quarter was not attributable to the Plant. In the first place, elevated activity of similar size occurred simultaneously at both the indicator and control locations. Secondly, a similar pattern was observed at other nuclear power plant locations in the Midwest.

Strontium-89 and -90 was detected in composites for the first and second quarters. The levels measured were identical at both indicator and control locations. Presence of radiostrontium in airborne particulates is attributable to the fallout from the previous and latest nuclear tests.

Trace amounts of cesium-137, cerium-141, and cerium-144 were detected in four composites. Presence of these isotopes in airborne particulates is also attributable to the fallout from the recent nuclear test. Except for beryllium-7, which is produced continuously in the upper atmosphere by cosmic-ray interactions (Arnold and Al-Salih, 1955), all other gamma-emitting isotopes were below their respective LLD levels. None of the activities detected were attributable to the Plant operation.

Airborne Iodine

Airborne iodine-131 results were below the detection limits of 0.006 pCi/m^3 for all indicator locations and below 0.01 pCi/m^3 for all control locations.

Ambient Radiation (TLD's)

The mean monthly doses as measured by the monthly TLDs measured (4.0±0.6) mR/30 days at indicator locations and (3.5±0.5) mR/30 days at control locations. Annual TLDs, normalized to 30 days yielded (4.2±0.5) mR/30

days and (3.8±0.8) mR/30 days for indicator and control locations, respectively. Since standard deviations were larger than the differences, the differences are not statistically significant. No Plant effect was indicated.

Precipitation

Gross beta levels varied widely indicating the relationship between the level of activity and amount of rainfall, and ranged from 1.8 to 16.1 pCi/l. Tritium was below the LLD of 280 pCi/l in all samples. No Plant effect was indicated.

Milk

Iodine-131 results were below the detection limit of 0.4 pCi/l in all samples.

Strontium-89 was below the LLD level of 10 pCi/l in all samples.

Strontium-90 activity was detected in all samples and was nearly identical at both indicator locations (3.4 pCi/l) and control locations (3.2 pCi/l), ranging from 1.6 pCi/l to 9.7 pCi/l. The activity and range were similar to those observed in 1980 and 1981. Strontium-90 levels in this range are attributable to worldwide fallout from previous atmospheric nuclear tests, and reflect the long half-life (28.64 years) of this isotope. Cesium-137 results were below the LLD level of 15 pCi/l in all samples. Cesium-137 is also a long-lived component (with a half-life of 30.24 years) of worldwide fallout and is found in the environment in trace amounts. The apparent absence of the effect of the latest nuclear test (October 1980) on strontium-90 and cesium-137 results is consistent with the low initial production of these isotopes in nuclear explosions (Eisenbud, 1963). No other gamma-emitting isotopes, except potassium-40, were detected in any milk samples. This is consistent with the finding of the National Center for 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). Calcium was measured in all samples and ranged from 1.0 g/l to 1.6 g/l, averaging 1.3 g/l. The measured concentrations of calcium are in agreement with the published national values (National Center for Radiological Health, 1968).

In summary, the milk data for 1982 show no radiological effects of the Plant operation, but the presence of strontium-90 in milk samples does exhibit a long range residual effect of previous atmospheric nuclear test.

Ground Water

Ground water samples were analyzed monthly for gross beta activity. Quarterly composites were also analyzed for gross beta and for tritium. The annual mean for gross beta in monthly measurements was identical to the mean in quarterly measurements (2.8 pCi/l). The location with the highest mean, 5.2 pCi/l, was D-58, Frantz Farm, 0.5 mi distant from DAEC. The levels were similar to those observed in 1980 and 1981. Tritium was below the LLD level of 330 pCi/l in all samples. There was no indication of a Plant effect.

Meat and Poultry

In meat and poultry, naturally-occurring potassium-40 was the only gamma-emitting isotope detected. All other gamma-emitting isotopes were below their respective LLD's. Thus, no Plant effect was indicated.

Wildlife

In wildlife sample (squirrel), collected on the site, the only gamma-emitting isotope detected was naturally-occurring potassium-40. The activity was 3.61 pCi/g wet weight. No Plant effect was indicated.

Vegetation

Iodine-131 results in broad leaf vegetation were below the LLD level of 0.070 pCi/g wet weight in all samples. In corn, strontium-90 activity was below the LLD level of 0.008 pCi/g wet weight in all samples. In hay, strontium-90 was detected in all samples and was slightly higher at indicator locations (0.24 pCi/g wet weight) than at control locations (0.19 pCi/g wet weight). In soy beans strontium-90 was also detected in all samples and was nearly identical at both indicator (0.040 pCi/g wet weight) and control (0.048 pCi/g wet weight) locations. Presence of strontium-90 in hay and soy beans is attributable to the fallout from nuclear tests. No Plant effect was indicated.

Except for potassium-40, which was observed in all samples, all other gamma-emitting isotopes were below detection limits in all samples. No Plant effect was indicated.

Soil

Strontium-90 was detected in all soil samples and averaged 0.14 pCi/g for indicator locations and 0.10 pCi/g for control locations. The difference is not statistically significant.

The predominant gamma-emitting isotope detected was potassium-40. The

measured activity was nearly identical at both indicator and control locations (15.53 pCi/g dry weight and 14.63 pCi/g dry weight, respectively).

Cesium-137 was detected in all samples and the activity was nearly identical at both the indicator locations (0.50 pCi/g) and the control locations (0.43 pCi/g).

Presence of strontium-90 and cesium-137 in soil is attributable to the fallout from recent (October 1980) and previous nuclear tests in the atmosphere. No Plant effect was indicated.

Surface Water

Mean gross beta activity was slightly higher at indicator locations (4.3 pCi/l) than at the control locations (3.4 pCi/l) and was similar to that observed in 1980 and 1981. The difference is not statistically significant. Tritium was below LLD level of 330 pCi/l in all samples. Strontium-89 and strontium-90 were below the LLD levels of 10 pCi/l and 2.0 pCi/l, respectively, in all samples. No gamma-emitting isotopes were detected in any of the samples analyzed. No Plant effect on surface water was indicated.

Fish

All gamma-emitting isotopes, except naturally-occuring potassium-40, in edible portions were below detection limits. No Plant effect on fish was indicated.

Periphyton

Periphyton samples were collected in March, May, August, and November. Cesium-137 was detected in one control sample (0.69 pCi/g wet weight). All other gamma-emitting isotopes, except potassium-40, were below detection limits. No Plant effect was indicated.

River Sediments

River sediments were collected in May and November and analyzed for strontium-90 and gamma-emitting isotopes. Strontium-90 results were below the LLD level of 0.025 pCi/g in all samples but one. The detected activity was 0.043 pCi/g dry weight in a Plant intake sample. Cesium-137 was detected in two samples and was 0.35 pCi/g dry weight and 0.09 pCi/g dry weight, in indicator and control samples, respectively. The presence of trace amounts of strontium-90 and cesium-137 in some of the samples is attributable to the fallout from nuclear tests in the atmosphere. All gamma-emitting isotopes, except potassium-40, were below detection limits in all samples. There was no indication of Plant effect.

5.0 TABLES

Table 5.1 Characteristic properties of isotopes quantified in gamma-spectroscopic analyses.

Designation	Comment	Isotope	Half-life[a]
I. Naturally occurring			
A. Cosmogenic	Produced by interaction of cosmic rays with atmosphere	Be-7	53.2 d
B. Terrestrial	Primordial	K-40	1.26×10^9 y
II. Fission Products [b]	Nuclear detonations constitute the major environmental source		
A. Short-lived		I-131	8.04 d
		Ba-140	12.8 d
B. Other than short-lived		Nb-95	35.15 d
		Zr-95	65 d
		Ru-103	39.35 d
		Ru-106	368.2 d
		Cs-134	2.061 y
		Cs-137	30.174 y
		Ce-141	32.5 d
		Ce-144	284.31 d
III. Activation Products	Typically found in nuclear power plant effluents	Mn-54	312.5 d
		Co-58	70.78 d
		Co-60	5.26 y
		Zn-65	245 d

[a] Half-lives are taken from Appendix E of Environmental Quarterly, 1 January 1978, EML-334 (U. S. Department of Energy, 1978).

[b] Includes fission-product daughters.

Table 5.2. Sample collection and analysis program, 1982.

Medium	Locations		Collection Type/ Frequency[b]	Analysis[c]
	No.	Codes[a] or Description		
Airborne Particulates	16	D-1-16	C/W	GB (GS if GB >10 pCi/m^3)
	16	D-1-16	QC of above	Sr-89,-90
Airborne Iodine	2	Comp. (D-8,12,14) Comp. (D-4,5,7,11,15)	C/W	I-131 (Individual analysis if I-131 is detected)
Ambient Radiation	63	D-1,2,3,4,6-48 76-91	C/M	Ambient gamma
	63	D-1,2,3,4,6-48 76-91	C/A	Ambient gamma
Precipitation	1	Onsite	M	GB, H-3
Milk	2	Comp. (D-63,72,93,94, 96,101,106) Comp. (D-102, 105)	Monthly (during non grazing season)	I-131 (Resample and analyze individually if I-131 ≥2.4 pCi/l)
	5	D-63,93,94,101,106	Weekly (during grazing season)	I-131, GS
	2	Comp. (D-72,96) Comp. (D-102,105)	Weekly (during grazing season)	I-131, GS (Resample and analyze individually for I-131 if I-131 >2.4 pCi/l)

Table 5.2. (continued)

Medium	Locations No.	Locations Codes[a] or Description	Collection Type/ Frequency[b]	Analysis[c]
Ground Water	1	D-53	G/H	
	1	D-54	G/D	
			MC of above	GB (GS if GB >10 pCi/l)
			QC of above	GB, H-3 (Sr-89,-90 if GB >10 pCi/l)
	5	D-55,57,58,59,60	G/M	GB (GS if GB >10 pCi/l)
			QC of above	GB, H-3 (Sr-89,-90 if GB >10 pCi/l)
Meat and Poultry		From animals fed on crops grown within 10 miles of DAEC and outside 10 miles	Annually during or immediately following grazing season	GS (On edible portions)
Wildlife	1	Inside 10 mile radius of plant	Annually	GS on flesh
Vegetation	11	D-57,58,63,72,93,94,96, 101,102,105,106	Annually at harvest time One sample each, grain and broad leaf vegetation	GS (On edible portion on grain samples) I-131 (broad leaf vegetation)
Soil	13	D-15,16,57,58,63,72 93,94,96,101,102 105,106	3 times per year	GS, Sr-90

Table 5.2. (continued)

Medium	Locations		Collection Type/ Frequency[b]	Analysis[c]
	No.	Codes[a] or Description		
Surface Water	7	D-49-52,73,99,103	G/M	GS
	5	D-49,50,51,52,99	G/Q	H-3, GB, Sr-89,-90
Fish	2	D-49,61	1 sample per 6 months (ESM)	GS (On edible portions)
Aquatic Biota (periphyton)	2	D-49,61	Quarterly (as available)	GS
River Sediment	4	D-49,50,51,61	ESM or SA	GS, Sr-90

[a] Location codes are defined in Table 5.3. Control stations are indicated by a (C). All other stations are indicators.

[b] Collection type is coded as follows: C/ = continuous, G/ = grab. Collection frequency is coded as follows: H = hourly, D = daily, W = weekly, M = monthly, Q = quarterly, SA = semi-annually, ESM = every six months.

[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 5.3 Sampling locations, Duane Arnold Energy Center.

Code	Type[a]	Sampling Location: Sampling Point	Location Description	Distance and Direction from Site Stack
D-1	C	1	Cedar Rapids	11 mi @ 135° SE
D-2	C	2	Marion	11 mi @ 125° SE
D-3		3	Hiawatha	7 mi @ 130° SE
D-4		4	Johnson	3 mi @ 140° SE
D-5		5	Palo	3 mi @ 200° SW
D-6		6	Center Point	7 mi @ 0° N
D-7		7	Shellsburg	6 mi @ 255° W
D-8		8	Urbana	9 mi @ 345° NW
D-9		9	Route W26	7 mi @ 295° NW
D-10		10	Atkins	8 mi @ 210° SW
D-11		11	Toddville	4 mi @ 90° E
D-12	C	12	Iowa City	25 mi @ 160° S
D-13	C	13	Alburnett	8 mi @ 70° NE
D-14		14	Alice Substation	7 mi @ 35° NE
D-15		15	On-site, North	0.5 mi @ 305° NW
D-16		16	On-site, South	0.5 mi @ 190° S
D-17		17		0.5 mi N
D-18		18		0.5 mi NE
D-19		19		0.5 mi NE
D-20		20		0.5 mi NE
D-21		21		0.5 mi E
D-22		22		0.5 mi SE
D-23		23		0.5 mi SE
D-24		24		0.5 mi S
D-25		25		0.5 mi SW
D-26		26		0.5 mi SW
D-27		27		0.5 mi SW
D-28		28		0.5 mi SW
D-29		29		0.5 mi SW
D-30		30		0.5 mi W
D-31		31		0.5 mi NW
D-32		32		0.5 mi NW
D-33		33		3.0 mi N
D-34		34		3.0 mi NE
D-35		35		3.0 mi NE
D-36		36		3.0 mi NE
D-37		37		3.0 mi E
D-38		38		3.0 mi SE
D-39		39		3.0 mi SE
D-40		40		3.0 mi SE
D-41		41		3.0 mi S
D-42		42		3.0 mi SW
D-43		43		1.0 mi SW

Table 5.3 (continued)

Code	Type[a]	Sampling Location: Sampling Point	Location Description	Distance and Direction from Site Stack
D-44		44		1.0 mi SW
D-45		45		1.0 mi SW
D-46		46		1.0 mi W
D-47		47		1.0 mi NW
D-48		48		1.0 mi NW
D-49	C	49	Lewis access, upstream of DAEC	
D-50		50	Plant Intake	
D-51		51	Plant Discharge	
D-52		52	Cedar Rapids City Park	7.5 mi SE
D-53		53	Treated Municipal Water	
D-54		54	Inlet to Municipal Water Treatment System	
D-55		55	On-site Well	
D-57		57	Bull (Off-site well)	
D-58		58	Frantz Farm, 0.5 mi of DAEC	
D-59		59	Frantz Farm, 0.5 mi of DAEC	
D-60		60	Wiley, Off-site within 1.0 mi of DAEC	
D-61		61	One-half mile downstream of plant discharge	
D-63		63	Andrews Farm, 1.5 mi NW	
D-72		72	Van Note Farm, within 2 miles of site, SW	
D-73	C	73	Hansen Farm, within 22 miles of site	
D-76		76		0.5 mi NE
D-77		77		0.5 mi NE
D-78		78		0.5 mi NE
D-79		79		0.5 mi E
D-80		80		0.5 mi SE
D-81		81		0.5 mi SE

Table 5.3 (continued)

Code	Type[a]	Sampling Location: Sampling Point	Location Description	Distance and Direction from Site Stack
D-82		82		0.5 mi SE
D-83		83		0.5 mi S
D-84		84		0.5 mi SW
D-85		85		0.5 mi SW
D-86		86		0.5 mi SW
D-87		87		0.5 mi SW
D-88		88		0.5 mi W
D-89		89		0.5 mi W
D-90		90		0.5 mi NW
D-91		91		0.5 mi N
D-93		93	Yarborough Farm	2.8 mi of site, NW
D-94		94	Hines Farm	2.7 mi NE
D-96		96	Keiper Farm	7.5 mi SW
D-99		99	Pleasant Creek	2.2 mi NW
D-101		101	Flecksing Farm	4.0 mi NE
D-102	C	102	McCardle Farm	20.0 mi NW
D-103		103	Park Pond	1.5 mi E
D-104[b]		104	Jim Miller Farm	1.2 mi NE
D-105	C	105	Schulte Farm	21.3 mi SW
D-106		106	David R. Stallman	4.5 mi SE

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

[b] Location D-104 was dropped from the program effective 8-24-82 and was replaced by location D-106.

Table 5.4 Type and frequency of collection.

Location	Loc. Type[a]	Weekly	Monthly	Quarterly	Semi-Annually	Annually
D-1	C	AP	TLD			TLD
D-2	C	AP	TLD			TLD
D-3		AP	TLD			TLD
D-4		AP,AI	TLD			TLD
D-5		AP,AI				
D-6		AP	TLD			TLD
D-7		AP,AI	TLD			TLD
D-8		AP,AI	TLD			TLD
D-9		AP	TLD			TLD
D-10		AP	TLD			TLD
D-11		AP,AI	TLD			TLD
D-12	C	AP,AI	TLD			TLD
D-13	C	AP	TLD			TLD
D-14		AP,AI	TLD			TLD
D-15		AP,AI	TLD	SO[b]		TLD
D-16		AP	TLD	SO[b]		TLD
D-17-48			TLD			TLD
D-49	C		SW	SL	F,BS	
D-50			SW		BS	
D-51			SW		BS	
D-52			SW			
D-53			WW[c]			
D-54			WW[d]			
D-55			WW			
D-57			WW	SO[b]		G[e]
D-58			WW	SO[b]		G[e]
D-59			WW			
D-60			WW			
D-61				SL	F,BS	
D-63			M[f]	SO[b]		G[e]
D-72			M[f]	SO[b]		G[e]
D-73	C		SW			
D-76-91			TLD			TLD
D-93			M[f]	SO[b]		G[e]
D-94			M[f]	SO[b]		G[e],ME
D-96			M[f]	SO[b]		G[e]
D-99			SW			

Table 5.4 (continued)

Location	Loc. Type[a]	Weekly	Monthly	Quarterly	Semi-Annually	Annually
D-101			M[f]	SO[b]		G[e]
D-102	C		M[f]	SO[b]		G[e],ME
D-103			SW			
D-104[g]				SO[b]		G[e]
D-105	C		M[f]	SO[b]		G[e]
D-106			M[f]	SO[b]		G[e]
On-site			P			
Inside 10 mile radius of plant						WL

[a] Control locations are indicated by a "C" in this column. All other locations are indicators.
[b] Soil is collected three times per year.
[c] Collected hourly and composited monthly and quarterly.
[d] Collected daily and composited monthly and quarterly.
[e] Vegetation (G) includes broad leaf vegetation and grain.
[f] Monthly from October through April; weekly from May through September.
[g] D-104 was dropped from the program starting 8-31-82 and was replaced by location D-106.

Table 5.5 Sample codes used in Table 5.4

Code	Description
AP	Airborne Particulates
AI	Airborne Iodine
TLD	Thermoluminescent Dosimeter
P	Precipitation
M	Milk
WW	Well Water
G	Vegetation (broad leaf and grain)
ME	Meat and Poultry
SO	Soil
SW	Surface Water
F	Fish
SL	Periphyton (aquatic biota)
BS	River Sediment
WL	Wildlife

Table 5.6 Missed collections and analyses, 1982, DAEC.

Sample	Analysis	Location	Collection Date or Period	Comments
TLD		D-1	April	Lost in the field
		D-7	November	Lost in the field
		D-13	April, May	Lost in the field
		D-16	April	Lost in the field
		D-21	November	Lost in the field
		D-22	April	Lost in the field
		D-25	January, April	Lost in the field
		D-26	January	Lost in the field
		D-30	March	Lost in the field
		D-31	January	Lost in the field
		D-34	January	Lost in the field
		D-36	March	Lost in the field
		D-42	April	Lost in the field
		D-45	November	Lost in the field
		D-76	January	Lost in the field
		D-83	January, November	Lost in the field
		D-86	April	Lost in the field
		D-88	January	Lost in the field
		D-38,41,45	Jan-Dec, 1982	Lost in the field
Milk		D-96	5-11-82	Milk not available
Well Water	Gross beta	D-59	Jan-Feb, 1982	Well Frozen
	Gross beta Tritium	D-60	Jan-June, 1982	Location temporarily shut off for winter
Surface Water	Gamma-isotopic	D-49	January 1982	Road to the site blocked by snowdrift

Table 5.7 Environmental Radiological Monitoring Program Summary.
Name of facility Duane Arnold Energy Center Docket No. 50-331
Location of facility Linn, Iowa (County, state) Reporting period January-December 1982

Sample Type (Units)	Type and Number of Analyses[a]		LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean		Control Locations Mean(F) Range	Number of Non-routine Results[e]
					Location[d]	Mean(F) Range		
Airborne Particulates (pCi/m^3)	GB	832[f]	0.001	0.026 (621/624) (0.009-0.488)	D-11, Toddville 4 mi @ 90° E	0.031 (52/52) (0.012-0.073)	0.027 (208/208) (0.010-0.064)	0
	Sr-89	64	0.0051	<LLD	-	-	<LLD	0
	Sr-90	64	0.0023	<LLD	-	-	<LLD	0
	GS	64				-		
	Be-7		0.073	0.109 (33/48) (0.079-0.163)	D-10, Atkins 80 mi @ 210° SE	0.132 (3/4) (0.091-0.143)	0.113 (12/16) (0.051-0.164)	0
	Nb-95		0.011	<LLD	-	-	<LLD	0
	Zr-95		0.019	<LLD	-	-	<LLD	0
	Ru-103		0.0079	<LLD	-	-	<LLD	0
	Ru-106		0.051	<LLD	-	-	<LLD	0
	Cs-134		0.0064	<LLD	-	-	<LLD	0
	Cs-137		0.0025	0.029 (1/48)	D-16, On-site South 0.5 mi @ 190° S	0.029 (1/4)	<LLD	0
	Ce-141		0.011	0.013 (1/48) -	D-15, On-site North 0.5 mi @ 305° W	0.013 (1/48) -	<LLD	0
	Ce-144		0.012	<LLD	D-13, Alburnett 8 mi @ 70° NE	0.021 (1/4) -	0.021 (2/16) (0.020-0.021)	0
Airborne Iodine (pCi/m^3)	I-131	104						
(D-4,5,7,11&15 composite)		52	0.006[h]	<LLD	-	-	<LLD	0
(D-8,12&14 composite)		52	0.01	<LLD	-	-	<LLD	0

Table 5.7 (continued)
Name of facility Duane Arnold Energy Center

Sample Type (units)	Type and Number of Analyses[a]		LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean		Control Locations Mean(F) Range	Number of Non-routine Results[e]
					Location[d]	Mean(F) Range		
TLD Monthly (mR/30 days)	Gamma	736	1	4.0 (691/691) (2.4-6.0)	D-31, 0.5 mi W	4.9 (11/12) (3.2-5.8)	3.5 (45/45) (2.4-4.4)	0
TLD-Annual (mR/365 days)	Gamma	60	1	51.1 (56/56) (40.5-66.2)	D-48, 1.0 mi NW	66.2 (1/1) -	46.7 (4/4) (40.5-60.5)	0
TLD-Annual Normalized to 30 days (mR/30 days)	Gamma	60	1	4.2 (56/56) (3.3-5.0)	D-48, 1.0 mi NW	5.4 (1/1)	3.8 (4/4) (3.3-5.0)	0
Precipitation (pCi/l)	GB	12	1.0	6.2 (12/12) (1.8-16.1)	On-site	6.2 (12/12) (1.8-16.1)	None	0
	H-3	12	280	<LLD	-	-	<LLD	0
Milk (pCi/l)	I-131	167	0.4	<LLD	-	-	<LLD	0
	Sr-89	45	10	<LLD	-	-	<LLD	0
	Sr-90	45	0.5	3.4 (35/35) (1.6-7.9)	D-93, Yarborough Farm 2.8 mi of site NW	5.8 (5/5) (4.1-7.9)	3.2 (10/10) (1.8-9.7)	0
	GS	153						
	K-40		100	1510 (132/132) (780-2210)	D-101, Flecksing Farm 4.0 mi, NE	1840 (22/22) (1510-2210)	1250 (22/22) (720-1500)	0
	Cs-137		15	<LLD	-	-	<LLD	0
	Ba-La-140		20	<LLD	-	-	<LLD	0
(g/l)	Ca	45	0.1	1.3 (35/35) (1.0-1.5)	D-93, Yarborough Farm 2.8 mi of site NW	1.4 (5/5) (1.2-1.5)	1.2 (10/10) (1.1-1.6)	0
Ground Water (pCi/l) (monthly)	Gross Beta	76	0.8	2.8 (71/76) (1.0-7.9)	D-58, Frantz Farm 0.5 mi of DAEC	4.8 (12/12) (1.1-7.9)	None	0
Ground Water (pCi/l) (quarterly comp.)	Gross Beta	26	0.5	2.8 (26/26) (0.7-8.0)	D-58, Frantz Farm 0.5 mi of DAEC	5.2 (4/4) (3.2-6.4)	None	0
	H-3	26	330	<LLD	-	-	<LLD	0

Table 5.7 (continued)
Name of facility Duane Arnold Energy Center

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean		Control Locations Mean(F) Range	Number of Non-routine Results[e]
				Location[d]	Mean(F) Range		
Meat and Poultry (pCi/g wet)	GS 6						
	K-40	1.0	2.6 (5/5) (2.31-3.18)	Bill Cook Outside 10 miles of plant	3.18 (1/1) -	2.74 (1/1) -	0
	Mn-54	0.031	<LLD	-	-	<LLD	0
	Co-58	0.047	<LLD	-	-	<LLD	0
	Co-60	0.034	<LLD	-	-	<LLD	0
	Cs-134	0.031	<LLD	-	-	<LLD	0
	Cs-137	0.043	<LLD	-	-	<LLD	0
	Other gammas	0.29	<LLD	-	-	<LLD	0
Wildlife (pCi/g wet)	GS 1						
	K-40	1.0	3.61 (1/1) -	Inside 10 miles of plant	3.61 (1/1) -	None	0
	Mn-54	0.050	<LLD	-	-	None	0
	Co-58,	0.088	<LLD	-	-	None	0
	Co-60	0.050	<LLD	-	-	None	0
	Cs-134	0.056	<LLD	-	-	None	0
	Cs-137	0.064	<LLD	-	-	None	0
	Other gammas	0.39	<LLD	-	-	None	0
Broad Leaf Vegetation (pCi/g wet)	I-131 11	0.070	<LLD	-	-	<LLD	0

Table 5.7 (continued)
Name of facility Duane Arnold Energy Center

Sample Type (Units)	Type and Number of Analyses[a]		LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean		Control Locations Mean(F) Range	Number of Non-routine Results[e]
					Location[d]	Mean(F) Range		
Vegetation-Corn (pCi/g wet)	Sr-90	10	0.008	<LLD	-	-	<LLD	0
	GS	10						
	K-40		0.5	3.31 (8/8) (2.24-5.42)	D-58, Frantz Farm 0.5 mi of DAEC	5.42 (1/1) -	2.92 (2/2) (2.84-3.00)	0
	Cs-134		0.044	<LLD	-	-	<LLD	0
	Cs-137		0.053	<LLD	-	-	<LLD	0
	Other gammas		0.43	<LLD	-	-	<LLD	0
Vegetation-Hay (pCi/g wet)	Sr-90	9	0.050	0.242 (7/7) (0.140-0.344)	D-101, Flecksing Farm, 4.0 mi NE	0.344 (1/1) -	0.190 (2/2) (0.160-0.219)	0
	GS	9						
	K-40		0.5	12.20 (7/7) (7.57-19.20)	D-72, VanNote Farm within 2.0 mi of site, SW	19.20 (1/1) -	12.75 (2/2) (12.10-13.40)	0
	Cs-134		0.15	<LLD	-	-	<LLD	0
	Cs-137		0.15	<LLD	-	-	<LLD	0
	Other gammas		1.16	<LLD	-	-	<LLD	0
Vegetation Soybeans (pCi/g wet)	Sr-90	5	0.0	0.040 (3/3) (0.031-0.055)	D-96, Keiper Farm 7.5 mi SW	0.055 (1/1) -	0.048 (2/2) (0.042-0.054)	0
	GS	5						
	K-40		0.5	11.86 (3/3) (8.09-15.30)	D-96, Keiper Farm 7.5 mi SW	15.30 (1/1) -	13.65 (2/2) (12.61-14.70)	0
	Cs-134		0.065	<LLD	-	-	<LLD	0
	Cs-137		0.089	<LLD	-	-	<LLD	0
	Other gammas		0.75	<LLD	-	-	<LLD	0

Table 5.7 (continued)
Name of facility Duane Arnold Energy Center

Sample Type (Units)	Type and Number of Analyses[a]		LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean		Control Locations Mean(F) Range	Number of Non-routine Results[e]
					Location[d]	Mean(F) Range		
Soil (pCi/g dry)	Sr-90	39	0.01	0.142 (32/32) (0.020-0.297)	D-94, Hines Farm 2.7 mi NE	0.236 (3/3) (0.226-0.254)	0.102 (6/6) (0.038-0.152)	0
	GS	39						
	K-40		0.5	15.35 (32/32) (8.26-19.56)	D-105, Schulte Farm 21.3 mi SW	18.99 (3/3) (18.21-19.58)	14.63 (6/6) (9.80-19.58)	0
	Mn-54		0.087	<LLD	-	-	<LLD	0
	Co-58,-60		0.099	<LLD	-	-	<LLD	0
	Nb-95		0.13	<LLD	-	-	<LLD	0
	Zr-95		0.19	<LLD	-	-	<LLD	0
	Cs-134		0.10	0.168 (1/32) -	D-15, On-site North 0.5 mi @ 305° NW	0.168 (1/32) -	<LLD	0
	Cs-137		0.053	0.501 (32/32) (0.101-1.37)	D-63, Andrews Farm 1.5 mi NW	1.01 (3/3) (0.390-1.37)	0.428 (6/6) (0.328-0.528)	0
	Other gammas		0.79	<LLD	-	-	<LLD	0
Surface Water (pCi/l)	GB	20	1.0	4.3 (16/16) (2.4-7.7)	D-99, Pleasant Creek 2.2 mi NW	5.9 (4/4) (4.2-7.7)	3.4 (4/4) (2.7-4.2)	0
	H-3	20	330	<LLD	-	-	<LLD	0
	Sr-89	20	10	<LLD	-	-	<LLD	0
	Sr-90	20	2.0	<LLD	-	-	<LLD	0
	GS	83						
	Mn-54		15	<LLD	-	-	<LLD	0
	Co-58,-60		15	<LLD	-	-	<LLD	0
	Zr-Nb-95		30	<LLD	-	-	<LLD	0
	Cs-134		15	<LLD	-	-	<LLD	0
	Cs-137		15	<LLD	-	-	<LLD	0

Table 5.7 (continued)
Name of facility Duane Arnold Energy Center

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean		Control Locations Mean(F) Range	Number of Non-routine Results[e]
				Location[d]	Mean(F) Range		
Fish (Edible portion) (pCi/g wet)	GS 11						
	K-40	0.5	3.77 (5/5) (2.94-4.56)	D-61, 0.5 miles down-stream of Plant discharge	3.77 (5/5) (2.94-4.56)	3.58 (6/6) (2.87-4.98)	0
	Mn-54	0.054	<LLD	-	-	<LLD	0
	Co-58,-60	0.078	<LLD	-	-	<LLD	0
	Cs-134,-137	0.061	<LLD	-	-	<LLD	0
	Other gamma	0.52	<LLD	-	-	<LLD	0
Periphyton (pCi/g wet)	GS 8						
	K-40	1.0[g]	5.44 (4/4) (4.03-9.31)	D-61, 0.5 mi down-stream of plant discharge	5.44 (4/4) (4.03-9.31)	3.96 (3/4) (1.87-6.11)	0
	Cs-134	1.11	<LLD	-	-	<LLD	0
	Cs-137	0.23	<LLD	D-49, Lewis Access upstream of DAEC	0.69 (1/4) -	0.69 (1/4) -	0
	Other gammas	2.64	<LLD	-	-	<LLD	0
River Sediments (pCi/g dry)	Sr-90 8	0.027	0.043 (1/6)	D-50, Plant Intake	0.043 (1/2)	<LLD	0
	GS 8						
	K-40	1.0	10.31 (6/6) (8.81-12.27))	D-50, Plant Intake	11.53 (2/2) (10.80-12.27)	9.80 (2/2) (9.79-9.80)	0
	Mn-54	0.055	<LLD	-	-	<LLD	0
	Co-58,-60	0.070	<LLD	-	-	<LLD	0
	Zr-Nb-95	0.14	<LLD	-	-	<LLD	0

Table 5.7 (continued)
Name of facility Duane Arnold Energy Center

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean		Control Locations Mean(F) Range	Number of Non-routine Results[e]
				Location[d]	Mean(F) Range		
River Sediments (pCi/g dry) (continued)	Cs-134	0.080	<LLD	-	-	<LLD	0
	Cs-137	0.058	0.35 (1/6)	D-50, Plant Intake	0.35 (1.6)	0.09 (1/2)	0
	Other gammas	0.52	<LLD	-	-	<LLD	0

[a] GB = gross beta; GS = gamma scan.
[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 5.3) 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] Three unreliable results due to low volume (pump malfunction) were excluded in the determination of the Annual Mean.
[g] One sample resulted in an elevated LLD for K-40 due to small volume of sample available for analysis. The result was excluded in the evaluation of the Annual Mean.
[h] Three (3) results have been excluded in the determination of LLD for I-131. Higher than normal LLDs resulted from delay in receiving the samples causing long decay time.

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Appendix A

Crosscheck Program Results

Appendix A

Crosscheck Program Results

The Nuclear Sciences Department of Hazleton Environmental Sciences has participated in interlaboratory comparison (crosscheck) 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. The purpose of such a program is to provide an independent check on the laboratory's analytical procedures and to alert it to any possible problems.

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. 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 through participation in the environmental sample crosscheck program for milk and water samples during the period 1975 through 1982. This program has been conducted by the U. S. Environmental Protection Agency Intercomparison and Calibration Section, Quality Assurance Branch, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada.

The results in Table A-2 were obtained for thermoluminescent dosimeters (TLD's) during the period 1976, 1977, 1979, 1980, and 1981 through participation in the Second, Third, Fourth, and Fifth International Intercomparison of Environmental Dosimeters under the sponsorships listed in Table A-2.

Table A-1. U.S. Environmental Protection Agency's crosscheck program, comparison of EPA and Hazleton ES results for milk and water samples, 1975 through 1982[a].

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	EPA Result ±3σ, n=1[d]
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	Apr. 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	Jun. 1975	H-3	1459±144	1499±1002
STW-48	Water	Jun. 1975	H-3	2404±34	2204±1044
STW-49	Water	Jun. 1975	Cr-51	<14	0
			Co-60	344±1	350±53
			Zn-65	330±5	327±49
			Ru-106	313±7	325±49
			Cs-134	291±1	304±46
			Cs-137	387±2	378±57
STW-53	Water	Aug. 1975	H-3	3317±64	3200±1083
STW-54	Water	Aug. 1975	Cr-51	223±11	225±38
			Co-60	305±1	307±46
			Zn-65	289±3	281±42
			Ru-106	346±5	279±57
			Cs-134	238±1	256±38
			Cs-137	292±2	307±46
STW-58	Water	Oct. 1975	H-3	1283±80	1203±988

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	EPA Result ±3σ , n=1[d]
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	221±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	Jun. 1976	H-3	2500±44	2502±1056
STW-84	Water	Aug. 1976	H-3	3097±21	3100±1080
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
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	Mar. 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	Apr. 1977	H-3	1690±62	1760±1023

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	EPA Result ±3σ , n=1[d]
STM-130	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	Jun. 1977	Cr-51	<14	0
			Co-60	29±1	29±15
			Zn-65	74±7	74±15
			Ru-106	64±8	62±15
			Cs-134	41±1	44±15
			Cs-137	35±3	35±15
STW-107	Water	Jun. 1977	Ra-226	4.7±0.3	5.1±2.42
STW-113	Water	Aug. 1977	Sr-89	13±0[e]	14±15
			Sr-90	10±2[e]	10±4.5
STW-116	Water	Sep.1977	Gross Alpha	12±6	10±15
			Gross Beta	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-137	Water	Feb. 1978	Cr-51	<27	0
			Co-60	36±2	34±15
			Zn-65	32±4	29±15
			Ru-106	41±2	36±15
			Cs-134	47±2	52±15
			Cs-137	<2	0

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	Concentration in pCi/l[b] EPA Result ±3σ, n=1[d]
STW-138g	Water	Mar. 1978	Ra-226	5.4±0.1	5.5±0.6
			Ra-228	NA[f]	16.7±2.5
STW-150	Water	Apr. 1978	H-3	2150±220	2220±1047
STW-151	Water	Apr. 1978	Gross Alpha	20±1	20±15
			Gross Beta	56±4	59±15
			Sr-89	19±2	21±15
			Sr-90	8±1	10±4.5
			Co-60	19±3	20±15
			Cs-134	16±1	15±15
			Cs-137	<2	0
STM-152	Milk	Apr.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(mg/l)	1503±90	1500±225
STW-154g	Water	May 1978	Gross Alpha	12±1	13±15
			Gross Beta	21±4	18±15
STW-157g	Water	Jun. 1978	Ra-226	4.0±1.0	3.7±0.6
			Ra-228	NA[f]	5.6±0.8
STW-159g	Water	Jul. 1978	Gross Alpha	19±3	22±6
			Gross Beta	28±3	30±5
STW-162	Water	Aug. 1978	H-3	1167±38	1230±990
STW-165g	Water	Sep. 1978	Gross Alpha	4±1	5±5
			Gross Beta	13±1	10±5

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	EPA Result ±3 σ, n=1[d]
STW-167	Water	Oct. 1978	Gross Alpha	19±2	19±15
			Gross Beta	36±2	34±15
			Sr-89	9±1	10±15
			Sr-90	4±0	5±2.4
			Ra-226	5.5±0.3	5.0±2.4
			Ra-228	NA[f]	5.4±2.4
			Cs-134	10±1	10±15
			Cs-137	15±1	13±15
STW-170	Water	Dec. 1978	Ra-226	11.5±0.6	9.2±1.4
			Ra-228	NA[f]	8.9±4.5
STW-172	Water	Jan. 1979	Sr-89	11±2	14±15
			Sr-90	5±2	6±4.5
STW-175	Water	Feb. 1979	H-3	1344±115	1280±993
STW-176	Water	Feb. 1979	Cr-51	<22	0
			Co-60	10±2	9±15
			Zn-65	26±5	21±15
			Rn-106	<16	0
			Cs-134	8±2	6±15
			Cs-137	15±2	12±15
STW-178	Water	Mar. 1979	Gross Alpha	6.3±3	10±15
			Gross Beta	15±4	16±15
STW-195g	Water	Aug. 1979	Gross Alpha	6.3±1.2	5±5
			Gross Beta	42.7±7.0	40±4
STW-193	Water	Sep. 1979	Sr-89	5.0±1.2	3.0±1.5
			Sr-90	25.0±2.7	28.0±4.5
STW-196	Water	Oct. 1979	Cr-51	135±5.0	113±18
			Co-60	7.0±1.0	6±5
			Cs-134	7.3±0.6	7±15
			Cs-137	12.7±1.2	11±15
STW-198	Water	Oct. 1979	H-3	1710±140	1560±1111

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	EPA Result ±3σ, n=1[d]
STW-199	Water	Oct. 1979	Gross Alpha	16.0±3.6	21±15
			Gross Beta	36.3±1.2	49±15
			Sr-89	10.7±0.6	12±15
			Sr-90	5.7±0.6	7±15
			Ra-226	11.1±0.3	11±5
			Ra-228	1.6±0.7	0
			Co-60	35.0±1.0	33±15
			Cs-134	50.7±2.3	56±15
			Cs-137	<3	0
STW-206	Water	Jan. 1980	Gross Alpha	19.0±2.0	30.0±8.0
			Gross Beta	48.0±2.0	45.0±5.0
STW-208	Water	Jan. 1980	Sr-89	6.1±1.2	10.0±0.5
			Sr-90	23.9±1.1	25.5±1.5
STW-209	Water	Feb. 1980	Cr-51	112±14	101±5.0
			Co-60	12.7±2.3	11±5.0
			Zn-65	29.7±2.3	25±5.0
			Ru-106	71.7±1.5	51±5
			Cs-134	12.0±2.0	10±5.0
			Cs-137	30.0±2.7	30±5.0
STW-210	Water	Feb. 1980	H-3	1800±120	1750±340
STW-211	Water	March 1980	Ra-226	15.7±0.2	16.0±2.4
			Ra-228	3.5±0.3	2.6±0.4
STM-217	Milk	May 1980	Sr-89	4.4±2.6[g]	5±5
			Sr-90	10.0±1.0	12±1.5
STW-221	Water	June 1980	Ra-226	2.0±0.0	1.7±0.8
			Ra-228	1.6±0.1	1.7±0.8

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	Concentration in pCi/l[b] EPA Result ±3σ, n=1[d]
STW-223	Water	July 1980	Gross Alpha	31±3.0	38±5.0
			Gross Beta	44±4	35±5.0
STW-224	Water	July 1980	Cs-137	33.9±0.4	35±5.0
			Ba-140	<12	0
			K-40	1350±60	1550±78
			I-131	<5.0	0
STW-225	Water	Aug. 1980	H-3	1280±50	1210±329
STW-226	Water	Sept. 1980	Sr-89	22±1.2	24±8.6
			Sr-90	12±0.6	15±2.6
STW-228	Water	Sept. 1980	Gross Alpha	NA[f]	32.0±8.0
			Gross Beta	22.5±0.0	21.0±5.0
STW-235	Water	Dec. 1980	H-3	2420±30	2240±604
STW-237	Water	Jan. 1981	Sr-89	13.0±1.0	16±8.7
			Sr-90	24.0±0.6	34±2.9
STM-239	Milk	Jan. 1981	Sr-89	<210	0
			Sr-90	15.7±2.6	20±3.0
			I-131	30.9±4.8	26±10.0
			Cs-137	46.9±2.9	43±9.0
			Ba-140	<21	0
			K-40	1330±53	1550±134
STW-240	Water	Jan. 1981	Gross alpha	7.3±2.0	9±5.0
			Gross beta	41.0±3.1	44±5.0
STW-243	Water	Mar. 1981	Ra-226	3.5±0.06	3.4±0.5
			Ra-228	6.5±2.3	7.3±1.1

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	EPA Result ±3σ, n=1[d]
STW-245	Water	Apr. 1981	H-3	3210±115	2710±355
STW-249	Water	May 1981	Sr-89	51±3.6	36±8.7
			Sr-90	22.7±0.6	22±2.6
STW-251	Water	May 1981	Gross alpha	24.0±5.29	21±5.25
			Gross beta	16.1±1.9	14±5.0
STW-252	Water	Jun. 1981	H-3	2140±95	1950±596
STW-255	Water	Jul. 1981	Gross alpha	20±1.5	22±9.5
			Gross beta	13.0±2.0	15±8.7
STW-259	Water	Sep. 1981	Sr-89	16.1±1.0	23±5
			Sr-90	10.3±0.9	11±1.5
STW-265	Water	Oct. 1981	Gross alpha	71.2±19.1	80±20
			Gross beta	123.3±16.6	111±5.6
			Sr-89	14.9±2.0	21±5
			Sr-90	13.1±1.7	14.4±1.5
			Ra-226	13.0±2.0	12.7±1.9
STW-269	Water	Dec. 1981	H-3	2516±181	2700±355
STW-270	Water	Jan. 1982	Sr-89	24.3±2.0	21.0±5.0
			Sr-90	9.4±0.5	12.0±1.5
STW-273	Water	Jan. 1982	I-131	8.6±0.6	8.4±1.5
STW-275	Water	Feb. 1982	H-3	1580±147	1820±342
STW-276	Water	Feb. 1982	Cr-51	<61	0
			Co-60	26.0±3.7	20±5
			Zn-65	<13	15±5
			Ru-106	<46	20±5
			Cs-134	26.8±0.7	22±5
			Cs-137	29.7±1.4	23±5
STW-277	Water	Mar. 1982	Ra-226	11.9±1.9	11.6±1.7
STW-278	Water	Mar. 1982	Gross alpha	15.6±1.9	19±5
			Gross beta	19.2±0.4	19±5

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	Concentration in pCi/l[b] EPA Result ±3σ, n=1[d]
STW-280	Water	Apr. 1982	H-3	2690±80	2860±360
STW-281	Water	Apr. 1982	Gross alpha	75±7.9	85±21
			Gross beta	114.1±5.9	106±5.3
			Sr-89	17.4±1.8	24±5
			Sr-90	10.5±0.6	12±1.5
			Ra-226	11.4±1.0	10.9±1.5
			Co-60	<4.6	0
STW-284	Water	May 1982	Gross alpha	31.5±6.5	27.5±7
			Gross beta	25.9±3.4	29±5
STW-285	Water	June 1982	H-3	1970±1408	1830±340
STW-286	Water	June 1982	Ra-226	12.6±1.5	13.4±3.5
			Ra-228	11.1±2.5	8.7±2.3
STW-287	Water	June 1982	I-131	6.5±0.3	4.4±0.7
STW-290	Water	Aug. 1982	H-3	3210±140	2890±619
STW-291	Water	Aug. 1982	I-131	94.6±2.5	87±15
STW-292	Water	Sept 1982	Sr-89	22.7±3.8	24.5±8.7
			Sr-90	10.9±0.3	14.5±2.6
STW-296	Water	Oct. 1982	Co-60	20.0±1.0	20±8.7
			Zn-65	32.3±5.1	24±8.7
			Cs-134	15.3±1.5	19.0±8.7
			Cs-137	21.0±1.7	20.0±8.7
STW-297	Water	Oct. 1982	H-3	2470±20	2560±612
STW-298	Water	Oct. 1982	Gross alpha	32±30	55±24
			Gross beta	81.7±6.1	81±8.7
			Sr-89	<2	0
			Sr-90	14.1±0.9	17.2±2.6
			Cs-134	<2	1.8±8.7
			Cs-137	22.7±0.6	20±8.7
			Ra-226	13.6±0.3	12.5±3.2
			Ra-228	3.9±1.0	3.6±0.9

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	Concentration in pCi/l[b] HES Result ±2σ [c]	Concentration in pCi/l[b] EPA Result ±3σ, n=1[d]
STW-301	Water	Nov. 1982	Gross alpha	12.0±1.0	19.0±8.7
			Gross beta	34.0±2.7	24.0±8.7
STW-302	Water	Dec. 1982	I-131	40.0±0.0	37.0±10

[a]Results obtained by the Nuclear Sciences Department of Hazleton Environmental Sciences 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, the HES results given as the mean ±2σ standard deviations for three determinations.

[d]USEPA results are presented as the known values ± control limits of 3σ for n=1.

[e]Mean ± 2σ standard deviations of two determinations.

[f]NA = Not analyzed.

[g]Analyzed but not reported to the EPA.

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

Lab Code	TLD Type	Measurement	mR: Hazleton Result $\pm 2\sigma$ [a]	Known Value	Average $\pm 2\sigma$ [d] (all participants)
2nd International Intercomparison[b]					
115-2[b]	CaF_2:Mn Bulb	Gamma-Field	17.0±1.9	17.1[c]	16.4±7.7
		Gamma-Lab	20.8±4.1	21.3[c]	18.8±7.6
3rd International Intercomparison[e]					
115-3[e]	CaF_2:Mn Bulb	Gamma-Field	30.7±3.2	34.9±4.8[f]	31.5±3.0
		Gamma-Lab	89.6±6.4	91.7±14.6[f]	86.2±24.0
4th International Intercomparison[g]					
115-4[g]	CaF_2:Mn Bulb	Gamma-Field	14.1±1.1	14.1±1.4[f]	16.09.0
		Gamma-Lab (Low)	9.3±1.3	12.2±2.4[f]	12.0±7.6
		Gamma-Lab (High)	40.4±1.4	45.8±9.2[f]	43.9±13.2
5th International Intercomparison[h]					
115-5A[h]	CaF_2:Mn Bulb	Gamma-Field	31.4±1.8	30.0±6.0[i]	30.2±14.6
		Gamma-Lab at beginning	77.4±5.8	75.2±7.6[i]	75.8±40.4
		Gamma-Lab at the end	96.6±5.8	88.4±8.8[i]	90.7±31.2

Table A-2. (Continued)

Lab Code	TLD Type	Measurement	mR Hazleton Result ±2σ[a]	Known Value	Average ± 2σ[d] (all participants)
115-5B[h]	LiF-100 Chips	Gamma-Field	30.3±4.8	30.0±6[i]	30.2±14.6
		Gamma-Lab at beginning	81.1±7.4	75.2±7.6[i]	75.8±40.4
		Gamma-Lab at the end	85.4±11.7	88.4±8.8[i]	90.7±131.2

[a]Lab result given is the mean ±2σ standard deviations of three determinations.
[b]Second International Intercomparison of Environmental Dosimeters conducted in April of 1976 by the Health and Safety Laboratory (GASL), 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 using continuously operated pressurized ion chamber.
[d]Mean ±2σ standard deviations of results obtained by all laboratories participating in the 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 ±2σ standard deviations as determined by sponsor of the intercomparison using continuously operated pressurized ion chamber.
[g]Fourth International Intercomparison of Environmental Dosimeters conducted in summer of 1979 by the School of Public Health of the University of Texas, Houston, Texas.
[h]Fifth International Intercomparison of Environmental Dosimeter conducted in fall of 1980 at Idaho Falls, Idaho and sponsored by the School of Public Health of the University of Texas, Houston, Texas and Environmental Measurements Laboratory, New York, New York, U.S. Department of Energy.
[i]Value determined by sponsor of the intercomparison using continuously operated pressurized ion chamber.

Appendix B

Data Reporting Conventions

Data Reporting Conventions

1.0. All activities are decay corrected to collection time.

2.0. Single Measurements

Each single measurement is reported as follows:

$$x \pm s$$

where x = value of the measurement;

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

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

$$<L \; .$$

where L = is the lower limit of detection based on 4.66σ uncertainty for a background sample.

3.0. Duplicate Analyses

3.1. Individual results: $x_1 \pm s_1$
$x_2 \pm s_2$

Reported result: $x \pm s$

where $x = (1/2)\,(x_1 + x_2)$

$$s = (1/2)\;\; s_1^2 + s_2^2$$

3.2. Individual results: $<L_1$
$<L_2$

Reported result: $<L$

where L = lower of L_1 and L_2

3.3. Individual results: $x \pm s$
$<L$

Reported result: $x \pm s$ if $x \underline{<} L$;
$<L$ otherwise

4.0. Computation of Averages and Standard Deviations

4.1 Averages and standard deviations listed in the tables are computed from all of the individual measurements over the period averaged; for example, an annual standard deviation would not be the average of quarterly standard deviations. The average $\overline{x}$ and standard deviations of a set of n numbers x_1, x_2, . . . x_n are defined as follows:

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

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

4.2 Values below the highest lower limit of detection are not included in the average.

4.3 If all of the values in the averaging group are less than the highest LLD, the highest LLD is reported.

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

4.5. In rounding off, the following rules are followed:

4.5.1. If the figure following those to be retained is less than 5, the figure is dropped, and the retained figures are kept unchanged. As an example, 11.443 is rounded off to 11.44.

4.5.2 If the figure following those to be retained is greater than 5, the figure is dropped, and the last retained figure is raised by 1. As an example, 11.446 is rounded off to 11.45.

4.5.3. If the figure following those to be retained is 5, and if there are no figures other than zeros beyond the five, the figure 5 is dropped, and the last-place figure retained is increased by one if it is an odd number or it is kept unchanged if an even number. As an example, 11.435 is rounded off to 11.44, while 11.425 is rounded off to 11.42.

Appendix C

Maximum Permissible Concentrations of Radioactivity in Air and Water Above Background in Unrestricted Areas

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	3×10^6	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.