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STUDIES OF INGESTION DOSE PATHWAYS FROM THE NUCLEAR FUEL SERVICES FUEL REPROCESSING PLANT

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FOREWORD

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W. D. Rowe, Ph.D.
Deputy Assistant Administrator
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PREFACE

The Office of Radiation Programs of the U.S. Environmental Protection Agency, in cooperation with the New York State Department of Environmental Conservation, Nuclear Fuel Services (NFS), and the U.S. Atomic Energy Commission, have over the past several years conducted a study at the nation's first commercial nuclear reprocessing plant operated by NFS in Western New York State. The overall purpose of this study was to determine the requirements of an environmental surveillance program for fuel reprocessing plants. Specific study objectives included: (a) characterization of both the gaseous and liquid waste effluents from the plant, (b) measurement of the environmental concentrations of the discharged radionuclides, and (c) delineation of the important exposure pathways and estimation of the radiation doses to the population living near the plant.

The initial results of this study have been published in a series of four reports which provide background information for this report.

BRH/NERHL 70-1	*An Estimate of Radiation Doses Received by Individuals Living in the Vicinity of a Nuclear Reprocessing Plant*
BRH/NERHL 70-2	*Liquid Waste Effluents from a Nuclear Fuel Reprocessing Plant*
BRH/NERHL 70-3	*An Investigation of Airborne Radioactive Effluent from an Operating Nuclear Fuel Reprocessing Plant*
BRH/NERHL 70-4	*Calibration and Initial Field Testing* ^{85}Kr *Detectors for Environmental Monitoring*

The results of this initial phase of the study indicated that additional information was required to better characterize the important dose pathways and provide more accurate information for dose estimates. Reports on iodine 129 and tritium discharges from NFS and the concentrations of these radionuclides in the environment around the plant have been published:

ORP/SID 72-5	*Iodine-129 in the Environment Around a Nuclear Fuel Reprocessing Plant*, and
EPA/ORP 73-1	*Observation of Airborne Tritium Waste Discharge from a Nuclear Fuel Reprocessing Plant*

Measurements of the concentrations of radionuclides in fish and deer by the State of New York Department of Environmental Conservation had shown that ingestion of strontium 90 and cesium 137 in fish flesh and deer meat represented the critical exposure pathways to individuals from the operation of the NFS plant. Although these pathways were known, more information was needed to refine the estimates of individual and population exposures from these pathways. Further study was needed to: (a) better define the exposed population from these pathways, (b) determine their intake, and (c) estimate their radiation exposure. Likewise, to obtain more information on ingestion pathways additional studies were needed on radionuclide concentrations in locally grown food items and in the diets of the population living in the vicinity of the plant.

This report represents the results of studies on these ingestion pathways and includes the following:

(1) results of a survey of fishing on the Cattaraugus Creek,
(2) results of a survey of venison intakes from deer taken within a 20-mile (32 km) radius of NFS,
(3) dose estimates for the maximum individual and the integrated population dose from fish and deer intake,
(4) measurements of radionuclide concentrations in produce grown around the perimeter of the NFS site, and
(5) measurement of radionuclide concentrations in total diets from the Springville-West Valley, N.Y. area.

The NFS plant suspended operation in the spring of 1972 in order to modify and expand the plant. Present plans are for a throughput of 750 tonnes/yr. Significant changes in the waste treatment systems are expected prior to resumption of operation. The radiation exposures presented in this report apply only to the operation of the NFS plant prior to shutdown and should not be interpreted as being representative of the situation when this plant resumes operation or of other fuel reprocessing plants.

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ABSTRACT

Studies were carried out to evaluate ingestion doses to individuals and the local population resulting from the operation of the Nuclear Fuel Services (NFS) reprocessing plant in West Valley, N.Y. These studies involved evaluations of radionuclide intakes from ingestion of fish, deer, and locally grown food items and included surveys of fishing and deer hunting in the vicinity of the plant.

The maximum dose commitment to an individual from the fish pathway during 1971 was estimated to have been 1.4 millirem whole body and 7 millirem bone. The maximum whole-body dose commitment to an individual from ingestion of venison from deer kills in 1970 was estimated to have been 14 millirem. Dose estimates for the local population from the fish and deer pathways indicated that the integrated whole-body population dose commitments from each of these pathways was about 0.1 man-rem per year. Measurements of radionuclide concentrations in locally grown food items indicated that the operation of the NFS plant had not resulted in any measureable increase in the radionuclide intakes of the population living in the vicinity of the plant from the pathway.

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CHAPTER 1.

DOSE ESTIMATES FOR POPULATION FISHING THE CATTARAUGUS CREEK

1.1 Introduction

Intake of fish from the Cattaraugus Creek was reported to represent one of the major exposure pathways to the local population resulting from the operation of the Nuclear Fuel Services (NFS) plant (1,2). Shleien (1) estimated a dose commitment of 215 millirem to bone for the maximum individual from this pathway for 1968. Shleien's dose estimates were based on rough estimates of fish intake and analyses of whole fish. In order to better define the intakes of fish, the U.S. Environmental Protection Agency, in cooperation with the New York State Department of Environmental Conservation, during the spring and summer of 1971 conducted a fishing survey to obtain demographic data on the population fishing the upper regions of the Cattaraugus Creek near the NFS plant. The purpose of the survey was to determine the maximum intake of fish by an individual and the total intake by the population fishing these regions.[1] This report presents the results of this survey and includes the following information:

(a) a description of the procedures used during the survey and the methods for data handling,
(b) the limitations in the survey procedure and in the data interpretation,
(c) a summary of the survey data obtained and an extrapolation of this data to the entire fishing population,
(d) measurements of radionuclide concentrations in fish collected from the upper regions of the Cattaraugus Creek near the NFS plant during the survey, and
(e) ingestion dose estimates for the maximum individual and integrated population doses from fishing in the regions of the Cattaraugus Creek near the NFS plant.

Although an evaluation of the external radiation dose to the population fishing the Cattaraugus Creek was not included in the original study objectives, the information developed during the study indicated that the doses from this pathway may be as significant as the ingestion pathway. Therefore an estimate of the external doses received by the population fishing the Cattaraugus Creek from NFS discharges has been made and is included in this report.

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[1]No commercial fishing takes place on the Cattaraugus Creek.

Data on concentrations of radionuclides in fish from the Cattaraugus Creek have been reported annually by the New York State Department of Environmental Conservation (3) and by the NFS (4). These data showed detectable concentrations of radionuclides in fish in the upper regions of the Cattaraugus Creek which can be identified as resulting from the NFS waste discharges. Radionuclide concentrations in fish from the regions of the creek near the mouth are lower than the fish from the upper regions. This results from factors such as dilution, sedimentation, and fish entering Cattaraugus Creek from Lake Erie. At the low levels of radioactivity measured in fish from Irving to the mouth of the creek the limited data does not permit discrimination between the NFS contribution and weapons testing fallout. For this reason, the major emphasis during the fishing survey was on the regions of the creek near the plant and dose estimates are presented in this report only for the population fishing these regions.

The information from the upper regions of the Cattaraugus Creek should be adequate to define the maximum individual, since this most probably is an individual fishing the regions of the creek nearest the plant where the radionuclide concentrations in fish are highest. However, it is uncertain as to what percentage the integrated population dose from fishing in upper regions of the creek represents of the total integrated population dose from this pathway. Estimation of the total integrated population dose from ingestion of fish[2] containing radionuclides originating from the NFS liquid discharge was not within the scope of this study.

1.2 Survey Procedures

Each month, April through August 1971, the fishing areas between Bigelow Bridge and Otto Road (Burts) were surveyed for seven consecutive days. Six fishing areas had been identified along the approximately 24 km of stream involved. The fishing areas had been identified by two aerial inspections to assure that all possible fishing areas would be investigated. Each of the identified fishing areas was visited as often as possible each day between the hours of 6 a.m. and 9 p.m. The entire survey was conducted by one person with the exception of the month of April during which four people were utilized. Observations of the number of fishing trips per day were made and interviews were conducted with as many of the people fishing as possible. Information was obtained on the frequency of fishing, length of fishing trip, number of meals of fish eaten, and species eaten. The number, size, and species of fish caught at the time of the interview were also recorded. Copies of the questionnaire and survey log sheet used in this study are presented in appendixes A.1 and A.2.

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[2]This would include ingestion of fish from the mouth of the Cattaraugus Creek, Lake Erie, and other bodies of water influenced by the NFS waste.

1.3 Survey Results

During the 5-month period of the survey, 350 fishing trips were observed and 224 interviews conducted. All observed data were treated on a fishing trip basis and not on an individual basis. Fifty-six of the interviews conducted represented interviews with individuals previously surveyed. Some individuals were observed fishing and surveyed as many as eight times. Table 1.1 presents a summary of the observed data obtained during the survey and table 1.2 summarizes the information obtained in response to the interviewer's questions. The observed edible weight listed in table 1.2 was determined by laboratory measurements made on fish species taken by rod and reel from Cattaraugus Creek during the survey period. All other data in table 1.1 and table 1.2 were obtained from the survey records. The data presented in table 1.2 is limited to the extent that some of the persons interviewed were hesitant to furnish any information and those that did cooperate could not accurately provide the desired information, particularly with regard to the amount of fish eaten by themselves and their families.

Table 1.1 Summary of observed data from fishing survey on the Cattaraugus Creek, 1971

Period of survey	Seven consecutive days each month, April through August 1971
Area surveyed	Cattaraugus Creek, Bigelow Bridge to Otto Road
Fishing trips observed	350
Interviews	224 (56 repeats)
Type of fish caught (trout and suckers)	95% of catch
Fish eaters	68%
Eat trout only	52%
Eat trout and suckers	16%
Average observed catch (all trips):	
Trout	0.42
Suckers	0.69
Average observed catch (fish eaters):	
Trout	0.67
Suckers	2.20
Average observed size:	
Trout catch	9 in.
Sucker catch	8 in.
Average observed edible weight:	
9-inch trout	100 g
8-inch sucker	45 g

Table 1.2 Question response data from fishing survey on the Cattaraugus Creek, 1971

Estimated average	
Duration of time per fishing trip (hours)	[a]3.7
Elapsed time fishing when surveyed (hours)	[a]1.7
Number of fishing trips per year:	
All individuals	6
Fish eaters	13
Number of meals:	
Person	6
Family	22

[a]Essentially the same for eaters and non-eaters.

Table 1.3 presents an extrapolation of the observed data obtained during the survey to the full 5-month period, April through August 1971. The data presented in table 1.3 are subject to many limitations resulting from the design and time period of the stream survey. As a result of these limitations, certain rough assumptions were required in order to extrapolate the observed data to total number of fishing trips, total number of fish caught, and total amount of fish consumed for the 5-month period. The assumptions used in these extrapolations are presented below and represent an effort to convert limited data into rough estimates.

1.4 Assumptions Used in Extrapolation of Observed Data

To correct the observed fishing trips per week to the total fishing trips per week, it was necessary to take into account periods during which the fishing areas were not surveyed. For this purpose each day was divided into five 3-hour periods: 6 a.m. to 9 a.m., 9 a.m. to 12 m., 12 m. to 3 p.m., 3 p.m. to 6 p.m., and 6 p.m. to 9 p.m. A fishing area was considered to have been surveyed for a period if the area was visited sometime during the 3-hour interval. The observed fishing trips were corrected for the 5 weekdays and 2 weekend days surveyed, based on the number of 3-hour periods available, divided by the number of 3-hour periods surveyed. For example, for the week of June 21-27, 1971:

Available weekday time periods	25	Available weekend time periods	10
Time periods surveyed	20	Time periods surveyed	10
Correction factor	1.2	Correction factor	1.0

Table 1.3 Extrapolation of survey data of fishing trips and intakes for April through August 1971

Estimate	
Total fishing trips per period	2000
Fishing trips:	
Trout eaters	[a]1400
Sucker eaters	300
Average catch:	
Trout by trout eaters	1.5
Suckers by sucker eaters	5
Total number:	
Trout eaten	2100
Suckers eaten	1500
Total intake (kilograms):	
Trout flesh	210
Sucker flesh	70

[a]This value includes the 300 trips by individuals who eat both trout and suckers.

To extrapolate the corrected observed fishing trips per week to total fishing trips per month the following procedure was used. The average number of fishing trips during the 5 weekdays surveyed was multiplied by the total number of weekdays in the month. Likewise, the average number of fishing trips during the 2 weekend days surveyed was multiplied by the total number of weekend days in the month.

The average catch per trip was estimated as follows:

$$C = \frac{C_o t}{t_o}$$

where:

C = estimated average catch per fishing trip,
C_o = observed average catch at time of interview,
t = average duration of fishing time, and
t_o = average length of time fishing when interviewed.

1.5 Radionuclide Concentrations in Fish from Cattaraugus Creek

Data on the concentrations of cesium 137, cesium 134, strontium 90, and zinc 65 in fish samples collected by the Environmental Protection Agency during this study from the area of the Cattaraugus Creek covered by the survey, are presented in table 1.4. Other radionuclides were

Table 1.4 Concentrations of radionuclides in fish flesh from Cattaraugus Creek, 1971

Location	Type	No.	Date	Concentration (pCi/kg wet weight ± 2σ)			
				^{137}Cs	^{134}Cs	^{90}Sr	^{65}Zn
Felton Bridge....	Sucker	4	6/71	1113 ± 30	200 ± 25	115 ± 9	493 ± 50
Felton Bridge....	Trout	2	6/71	810 ± 5	138 ± 20	16 ± 3	790 ± 50
Springville Dam..	Sucker	10	6/71	1500 ± 30	295 ± 25	760 ± 10	3021 ± 50
Springville Dam..	Sucker	1	6/71	3300 ± 200	500 ± 185	613 ± 50	3264 ± 360
Springville Dam..	Trout	1	6/71	1460 ± 40	275 ± 35	80 ± 5	787 ± 60
Springville Dam..	Trout	3	6/71	1000 ± 25	171 ± 20	75 ± 5	775 ± 40
Otto Road.....	Sucker	6	6/71	1373 ± 30	206 ± 25	790 ± 10	1717 ± 50
Otto Road.....	Trout	2	6/71	1000 ± 30	188 ± 25	99 ± 7	NA
Otto Road.....	Stone cat	1	6/71	1630 ± 200	400 ± 190	200 ± 30	NA
Felton Bridge....	Sucker	2	4/71	1457 ± 45	259 ± 40	120 ± 10	NA
Felton Bridge....	Sucker	1	4/71	363 ± 50	79 ± 50	43 ± 7	NA
Felton Bridge....	Sucker	1	4/71	966 ± 70	162 ± 70	64 ± 10	NA
Felton Bridge....	Sucker	1	4/71	1428 ± 50	189 ± 45	144 ± 12	NA
Felton Bridge....	Sucker	1	4/71	468 ± 70	60 ± 50	30 ± 8	NA
Felton Bridge....	Sucker	1	4/71	247 ± 30	30 ± 25	33 ± 5	NA
Felton Bridge....	Sucker	10	4/71	1197 ± 30	190 ± 25	91 ± 5	622 ± 50
Route 16[a].....	Trout and sucker	(b)	6/71	< 37	< 34	< 1	< 90
Route 16[a].....	Trout and sucker	(b)	9/71	< 25	< 21	< 1	< 47

[a]Data from State of New York Department of Environmental Conservation (5).
[b]Combined composite samples.
NA, no analysis.

either not detected or were present in very low concentrations, with exception of tritium which was present in concentration of about 10 nCi/kg. Cesium 137 concentrations in fish flesh ranged from 247 to 1630 pCi/kg. Cesium 134 concentrations were about 20 percent of the cesium 137 concentrations. Strontium 90 concentrations ranged from 16 to 760 pCi/kg. and zinc 65 from 493 to 3021 pCi/kg. Average concentrations for these samples weighted according to edible flesh are presented in table 1.5.

In preparing these samples for analysis, great care was taken to completely separate the flesh from bone and skin. Cesium 137 was measured using conventional sodium iodide gamma-ray spectrometry. Cesium 134 and zinc 65 were measured by multidimensional gamma-ray spectrometry using a system similar to that described by Wogman (5). Strontium 90 was measured by low-background beta counting of yttrium 90 following chemical separation of strontium from the sample and ingrowth of yttrium 90.

Data on the concentrations of radionuclides in fish from the Cattaraugus Creek have been reported annually by the State of New York

Table 1.5 Average concentration of radionuclides in fish from Cattaraugus Creek, 1971

Type	Weighted average concentration[a]			
	^{137}Cs	^{134}Cs	^{90}Sr	^{65}Zn
Trout.....	1048	188	65	775
Sucker.....	1142	190	364	1996

[a]Average was weighted according to edible weight of fish flesh in sample.

Department of Environmental Conservation and by NFS (3,4). The data presented in tables 1.4 and 1.5 are in general agreement with these data, although the strontium 90 concentrations in fish flesh reported by New York State for 1971 appears somewhat lower than had been previously reported (6).

In order to evaluate the contribution of the NFS plant discharge to the radionuclide concentrations in fish, it is necessary to compare the concentrations present in the fish from the survey area with information on the levels of radionuclides in fish in the Cattaraugus Creek. For the purpose of this report we will consider samples collected at Route 16, Savage Road, to be indicative of levels of radionuclides in fish in the Cattaraugus Creek. This location is about 24 km upstream of the location at which the waste enters the Cattaraugus Creek. Table 1.4 also presents data on the levels of radionuclides in fish collected by the New York State Department of Environmental Conservation at Route 16 during 1971. These data showed no detectable concentrations of radioisotopes of cesium, strontium, or zinc in these samples. From a comparison of the levels at Route 16 with the measured concentrations downstream from the entry of the waste discharge, it appears that most of the activity present in the fish samples collected from the survey area resulted from waste discharged from NFS. The presence of cesium 134 in fish at concentrations about 20 percent of the cesium 137 concentrations (the same ratio as present in the liquid waste discharge) supports the above observation that the radionuclides in fish resulted from the discharge of waste from NFS.

1.6 Liquid Discharges from Nuclear Fuel Services

Table 1.6 presents the gross beta and strontium 90 discharges in the liquid effluent from NFS for the period 1966 through 1971 (4). The

Table 1.6 Gross beta and strontium 90 in liquid discharges from NFS

Year	Quantity discharged (curies)	
	Gross beta	Strontium 90
1966.....	8	-
1967.....	31	4
1968.....	46	5
1969.....	140	10
1970.....	87	14
1971.....	77	7

plant suspended operations in the spring of 1972, in order to modify and expand the plant. These data show that 400 curies of gross beta and 40 curies of strontium 90 were discharged to the aqueous environment during this period. A report on the behavior of radionuclides in the liquid effluent from the NFS has been published (7). Based on these studies it is estimated that 40-60 curies of cesium 137 was discharged during this period. Data on concentrations of radionuclides in the Cattaraugus Creek have been reported annually by the State of New York Department of Environmental Conservation and the NFS (4).

A new low-level waste treatment facility became operational in the summer of 1971. This facility is expected to significantly reduce the discharges of radioactivity from the plant, particularly cesium 137, cesium 134, and strontium 90.

1.7 Estimated Radionuclide Intakes by the Population Fishing the Cattaraugus Creek During 1971

The maximum number of fish meals eaten by an individual as reported during the survey was 24 meals of trout per year. Three individuals interviewed indicated family intakes of this magnitude representing a total of seven people. Three other individuals interviewed indicated intakes of 16 to 20 meals of trout per year. One individual reported an intake of 12 meals per year of combined sucker and trout.

Using a conservative assumption of 200 grams of fish flesh per meal, the maximum intake of trout flesh was 4.8 kg/yr per person and the maximum intake of sucker flesh was 2.4 kg/yr per person.

Table 1.7 Estimated radionuclide intakes from consumption of fish flesh from Cattagaugus Creek

Radionuclide	Intake (μCi)	
	Maximum by individual	Total by population
Cesium 137.....	5.0×10^{-3}	3.0×10^{-1}
Cesium 134.....	9×10^{-4}	5.3×10^{-2}
Zinc 65.....	4.8×10^{-3}	3.0×10^{-1}
Strontium 90.....	9×10^{-4}	3.9×10^{-2}

Table 1.7 presents the radionuclide intakes from ingestion of fish by the population fishing the Cattaraugus Creek near the NFS plant. As indicated previously essentially all of these intakes resulted from the discharge of waste from the NFS plant. The maximum intakes by an individual were calculated using the maximum fish intakes reported by individuals during the survey and the average concentrations measured in fish flesh as presented in table 1.5. The population intakes were calculated from the data presented in tables 1.3 and 1.5.

1.8 Estimated Dose Commitments from NFS Discharges to Population Fishing Cattaraugus Creek During 1971

Table 1.8 presents a summary of dose commitments due to NFS discharges to the population fishing the Cattaraugus Creek. Estimates are presented for the maximum individual and for the total population fishing the survey regions. These estimates include both internal exposures from ingestion of fish and external exposures received while fishing from radionuclides deposited along the streams.

The whole-body ingestion doses include contributions from cesium 137, cesium 134, and zinc 75. The bone doses are from strontium 90 only. The estimates presented are the total doses delivered over the lifetime of the individual (50-year period) from the ingestion of radionuclides during 1971. These doses were calculated following the procedures utilized by Shleien (1). The dose conversion factors used are presented in table 1.9. The dose from cesium is essentially (< 90 percent) all delivered in the first year after intake. For strontium 90 about 7 percent of the dose is delivered during the first year after intake and for zinc 65 about 70 percent of the dose is delivered in the first year.

Table 1.8 Estimated dose commitments to population fishing the Cattaraugus Creek near NFS plant during 1971

Organ	Mode	Dose	
		Maximum individual (mrem)	Population (man-rem)
Whole body...	Ingestion[a]	0.4	0.02
Whole body...	External	1	0.04
Bone.....	Ingestion[b]	7	0.3

[a]Includes contribution from cesium 137, cesium 134, and zinc 65.
[b]Dose from strontium 90.

The estimates of the external doses received by the population fishing regions of the Cattaraugus Creek near the NFS plant were made using the occupancy data obtained during this survey and dose measurement data obtained with a pressurized ionization chamber by the New York State Department of Environmental Conservation (3).

Table 1.9 Dose conversion factors[a]

Radionuclide	Critical organ	Conversion factor mrem/μCi intake[b]
Cesium 137.....	Whole body	6×10^1
Cesium 134.....	Whole body	8×10^1
Strontium 90.....	Bone	8.4×10^3
Zinc 65.....	Whole body	7

[a]References 1 and 8.
[b]Dose delivered to organ over 50-year period for a particular intake.

The results of the fishing survey had shown that the maximum individual had spent 200 hours and that the total population had spent 7,500 man-hours fishing these regions of the Cattaraugus Creek. The results of the dose rate measurements indicated that the liquid discharges from NFS had resulted in an average dose rate of 5 μR/h above background for the region of the Cattaraugus Creek used in the fishing survey.

The most significant dose commitment to the population fishing the Cattaraugus Creek during 1971 resulted from the ingestion of strontium 90 in fish. The maximum dose commitment to bone of an individual is estimated to have been 7 millirem. The dose commitment to bone for the population is estimated to have been 0.3 man-rem.

The maximum whole-body external dose to an individual fishing the Cattaraugus Creek during 1971 from NFS discharges is estimated to be approximately 1 millirem. This exposure was about 2.5 times higher than the 0.4 millirem estimated whole-body dose from the ingestion of radionuclides in fish flesh.

The integrated whole-body doses from NFS discharges to the population fishing the Cattaraugus Creek are estimated to have been 0.04 man-rem from external radiation and 0.02 man-rem from ingestion of radionuclides in fish.

These dose estimates are considerably smaller than those reported by Shleien for 1968 (1). The differences result mostly from lower estimates of intake based on the fishing survey, but are also partly due to lower concentrations of radionuclides in fish flesh in 1971 than were used by Shleien for 1968.

CHAPTER 2.

ESTIMATE OF INGESTION DOSE TO POPULATION FROM VENISON CONSUMPTION

2.1 Introduction

Venison intake was also reported to represent one of the more significant exposure pathways to the local population from the operation of the NFS plant (1,2). Shleien (1) estimated a whole body dose of 200 millirem to the maximum individual from this pathway in 1968. In order to obtain information on the size of the population involved in deer hunting and the intake of deer meat for this population, the EPA, in cooperation with the New York State Department of Environmental Conservation, conducted a survey of hunters taking a deer within a 32-km radius of NFS during the 1970 hunting season. Although the NFS site is a fenced restricted area and no legal hunting takes place on the site, the deer are able to enter and leave the site. These deer then can be legally killed and consumed by hunters.

The public response to the survey was good and provided excellent information on deer meat intakes by the population involved in hunting in the area of interest. This report presents a description of the survey procedures used and a summary of the results obtained.

Using the maximum deer meat intakes for an individual as determined by the survey and the maximum radionuclide concentrations in deer meat as reported by the State of New York Department of Environmental Conservation (3), a reliable estimate of the maximum dose to an individual was made for the 1970 intake. Unfortunately despite the excellent information on total deer meat intake, an accurate estimate of the integrated population dose from deer meat ingestion could not be made because of the lack of adequate data on the concentrations of radionuclides in deer meat ingested by the population at risk. Only a very small sample of the total deer population (22 out of 20,000) were obtained for analyses. Twelve of these deer were collected on the NFS site and represent a sample which would not be considered representative of the venison ingested by the population surveyed. The integrated population dose, therefore, had to be estimated based on assumptions concerning the number of deer that had grazed on the NFS site that were killed and consumed.

However, despite the limitation regarding the estimation of man-rem dose, the procedures, information, and experience obtained during this

deer intake survey should prove useful to others faced with the necessity of obtaining similar demographic information.

2.2 Survey Procedures

The New York State Department of Environmental Conservation, Division of Fish and Wildlife, requires that each deer killed within the State be reported to them by means of a postcard furnished to the deer hunter when he or she obtains the license.

For the deer hunting season of 1970, approximately 50,000 hunters reported their results to the Division for the entire State of New York. These reporting cards were filed in batches of 50 and a number was assigned to the batch. The batch number, hunter's license number, and the location of deer kill (county and township) was placed on electronic data processing cards. A data printout furnished the information to assist in the location of reporting cards for the 45 townships of interest to the survey. A careful search of the 50,000 cards produced the names of 2531 deer hunters who had reported a kill within a township that was within a 32-km radius of the plant. By means of supplemental checks of hunters during the "open" season for several years (roadside and in the field checks), the Division of Fish and Wildlife has determined that 80 percent[3] of the hunters actually officially report their kills. Correcting the reported kills for this factor, the deer kill for the area of interest as determined by the survey was about 3200. The estimated deer population in the area within a 32-km radius of the plant was estimated by the New York State Department of Environmental Conservation to be about 20,000 deer.

Of the 2531 deer kill reports, 2100 were sufficiently legible to provide adequate information to be included in the survey. A questionnaire and cover letter (appendixes B.1 and B.2) were prepared and mailed to those 2100 deer hunters, with a postage-paid, return envelope furnished. Forty-five questionnaires were returned undelivered and 1558 completed forms were received, representing about 75 percent return. Of the completed questionnaires, 1455 provided sufficient information to be useful in the data evaluation. From these questionnaires, information was obtained on: (a) the number of deer taken by a hunter, (b) the dressed and edible weights of the deer, (c) the number and ages of individuals consuming the venison, (d) the amount of venison given away, and (e) amounts of venison received from other sources. From this information an estimate was made of the total and average consumption of venison by the population at risk. This information is presented in the following section.

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[3]Fifty-two percent of the kills were reported under a party permit license while the remaining 48 percent of the kills were reported under a big game license.

Table 2.1 Summary of survey data on venison intakes from deer taken within a 32-kilometer radius of NFS during 1970

Deer hunters surveyed	1455
Individuals consuming venison in hunters' households	6100
Average venison consumption	2.7 kg
Maximum venison consumption by an individual	44.8 kg
Total venison consumption:	
Within surveyed households (from own deer)	[a]16.7×10^3 kg
Outside surveyed households (given away by hunters)	6.5×10^3 kg
Inside and outside surveyed households	2.3×10^4 kg

[a]There was an additional 2×10^3 kg of venison consumed within surveyed households which was received from an outside source. This was not included in the listed values since it was assumed to have been received from a deer taken outside the 32-km radius. If it were from deer taken within the 32-km radius then this value would be somewhat low, but the intake would be included in the value for venison given away and the total consumption values would reflect this intake.

2.3 Estimation of Venison Intakes Using Survey Data

This report will represent only a brief summary of the venison intake data obtained during the survey and these data are presented in table 2.1 The survey data showed that there were 6100 individuals consuming venison in the households of the 1455 deer hunters from whom usable survey data was obtained. The average consumption for this population was 2.7 kg per person. The maximum intake reported from individuals was 44.9 kg. The total consumption of venison from deer taken within a 32-km radius of the NFS, by the families of the 1455 deer hunters surveyed, was 16,700 kg. A total of 6500 kg of venison was given away by the surveyed hunters, making a total of 23,200 kg of venison consumed from deer taken within the 32-km radius of the NFS.

The determination of consumed venison was based upon individual deer hunter estimates of the dressed and edible weights. The various weights are defined as follows:

W_d (dressed weight) = live weight (W_1) less entrails,
W_e (edible weight) = dressed weight less skin, head, hooves but including bone, and
W_c (consumed weight) = hindquarter edible weight less bone and fat (essentially muscle only).

Based upon approximate relations determined by the Fish and Wildlife Division of the New York State Department of Environmental Conservation, the following conversion factors were used:

$$W_d = 0.78\ W_l$$
$$W_e = 0.75\ W_d$$
$$W_c = (0.30\text{-}0.35)\ W_d = 0.33\ W_d$$
$$= 0.44\ W_e.$$

In order to check upon the reliability of the hunters' estimates of deer weights, the edible/dressed weight ratios were computed for the survey data. The distribution of these ratios were approximated by a normal distribution (mean = 0.67, standard deviation = 0.13).

In order to extrapolate the data from the households surveyed to the total population consuming venison from legally taken deer in the area of interest, the survey data were corrected for the return of usable questionnaires and for the number of deer taken which are not reported. This correction factor was calculated as follows:

$$\frac{1455\ \text{(usable questionnaires)}}{2531\ \text{(reported deer kill)}} \times 0.80\ \text{(fraction of deer kill reported)} = 0.47$$

Table 2.2 presents a summary of the extrapolated data for the consumption of venison by the total population involved in deer hunting in the area of interest. The total weight of venison consumed from deer taken legally within a 32-km radius of the NFS for 1970 was estimated to be 5.0×10^4 kg.

It should be emphasized that all the data on venison intakes obtained during this survey and presented in tables 2.1 and 2.2 resulted from legal hunting. It is estimated that only about 50 percent of the deer deaths in the State of New York result from legal hunting. Road kills, illegal hunting, sickness, and a variety of other causes account for the remainder of the deer deaths. What percentage of these deer (killed by means other than legal hunting) are used for human consumption is not known.

Table 2.2 Extrapolated venison intakes from legally taken deer within a 32-kilometer radius of NFS during 1970

Persons consuming venison in hunters' households.....	14,500
Venison consumed:	
In hunters' households.....	3.6×10^4 kg
Outside hunters' households (given away).....	1.4×10^4 kg
Total weight.....	5.0×10^4 kg

2.4 Radionuclide Concentrations in Venison from the Vicinity of NFS During 1970

Data on the concentrations of cesium 137, cesium 134, strontium 90, and zinc 65 in venison samples obtained from deer kills in the vicinity of the NFS during 1970 are presented in table 2.3. The data presented were obtained either by the New York State Department of Environmental Conservation (3) or by the Environmental Protection Agency as noted in the table. Concentrations are presented for 22 samples; 12 of these deer were killed within the boundary of the 3300-acre NFS site. Table 2.4 presents concentrations of radionuclides in venison from deer kills in the Albany, New York area (3) and these data can be used as a background sample for comparison purposes.

Table 2.3 Radionuclide concentrations in venison obtained from vicinity of NFS during 1970

Collection location	Analyzed by	Date (1970)	Concentration (pCi/kg wet weight)				Ca (g/kg)
			^{137}Cs	^{134}Cs	^{90}Sr	^{65}Zn	
NFS site.....	NYS	Feb.	146 ± 23	< 12	< 2	NA	NA
NFS site.....	NYS	Mar.	419 ± 42	50 ± 16	< 2	NA	NA
NFS site.....	NYS	Mar.	4687 ± 292	784 ± 65	12 ± 2	NA	NA
NFS site.....	NYS	Mar.	4060 ± 255	704 ± 59	28 ± 3	NA	NA
NFS site.....	NYS	Mar.	200 ± 27	< 16	< 2	NA	NA
NFS site.....	NYS	Mar.	92 ± 18	< 12	< 2	NA	NA
NFS site.....	NYS	Dec.	1122 ± 85	129 ± 21	< 1	67 ± 33	NA
NFS site.....	NYS	Dec.	233 ± 28	34 ± 13	< 1	< 25	NA
NFS site.....	NYS	Dec.	1815 ± 128	372 ± 38	16 ± 2	107 ± 38	NA
NFS site.....	NYS	Dec.	349 ± 36	31 ± 13	< 2	< 25	NA
NFS site.....	NYS	Dec.	627 ± 55	97 ± 19	< 2	96 ± 35	NA
NFS site.....	NYS	Oct.	519 ± 48	62 ± 17	< 3	57 ± 31	NA
Mean.....	.....	.....	1189	192	6	63	
Offsite:							
Salamanca....	EPA	Fall	480 ± 20	< 15	20 ± 2	< 25	0.29
Salamanca....	EPA	Fall	470 ± 20	< 15	6 ± 2	< 25	0.13
Salamanca....	EPA	Fall	290 ± 10	< 5	< 2	< 26	0.05
Elliotville..	EPA	Fall	200 ± 10	< 15	39 ± 4	< 30	0.40
Ischua.....	EPA	Fall	180 ± 10	< 15	10 ± 2	< 25	0.19
Eden.....	EPA	Fall	160 ± 10	< 15	6 ± 1	< 25	0.11
Holland.....	EPA	Fall	380 ± 20	< 15	2 ± 1	< 25	0.10
Sardinia.....	EPA	Fall	68 ± 10	< 10	14 ± 2	< 20	0.28
Ashford.....	NYS	Aug.	318 ± 36	< 12	< 2	NA	NA
Ashford.....	NYS	Sept.	293 ± 35	< 12	< 2	NA	NA
Mean.....	.....	.....	284	< 15	10	< 30	0.19

NA, no analysis.

Table 2.4 Radionuclide concentrations in venison from Albany, N.Y. area

Date collected	Concentration (pCi/kg wet weight)		
	Cesium 137	Cesium 134	Strontium 90
5/70.....	116	ND	ND
5/70.....	43	ND	ND
6/70.....	140	ND	ND
6/70.....	53	ND	ND

ND, nondetectable.

The concentrations of cesium 137, cesium 134, and zinc 65 present in onsite deer were significantly higher than in deer taken offsite or in the background deer. The mean concentrations in onsite deer in pCi/kg were cesium 137 = 1189, cesium 134 = 192, and zinc 65 = 63. The mean concentrations in offsite deer in pCi/kg were cesium 137 = 284, cesium 134 = <15, and zinc 65 = <30. It appears that most of the cesium 137, cesium 134, and zinc 65 present in the onsite deer resulted from waste discharged from the NFS. The presence of cesium 134 concentrations at 10 to 20 percent of the cesium 137 concentrations verifies the origin of the cesium radioisotopes as coming from the NFS operations.

The picture for strontium 90 is not clear. The contribution of the NFS operations to the strontium 90 concentrations in venison cannot be determined from the available data. The strontium 90 concentrations in onsite deer do not differ significantly from the deer taken offsite, although the strontium 90 concentrations in both the onsite and offsite deer appear to be higher than the deer taken in the Albany area. Additional data are necessary to determine if the deer grazing on the NFS site accumulated strontium 90 due to the NFS operations.

Cesium 134 and zinc 65 were not detected in deer taken offsite and this indicates that these deer were probably not influenced by the NFS waste discharges. The radionuclide concentrations in these samples are probably more representative of background levels in the area than are the samples collected at Albany.

2.5 Radionuclide Intakes from Ingestion of Venison from Deer Taken Within a 32-km Radius of NFS

The maximum intake of venison by an individual as reported during the survey was 45 kg. This intake represents the consumption of the

edible portion of two deer. Five individuals indicated intakes of 20 to 25 kg. All other reported intakes were less than 20 kg.

The radionuclide intakes for the maximum individual were calculated using the maximum venison intake reported by an individual during the survey and the maximum concentrations of radionuclides measured in a deer collected onsite.

To reliable estimate the intake by the total population from the deer pathway from the operation of the NFS, much more data are needed than is presently available on the concentrations of radionuclides in the deer population potentially influenced by the waste discharge. A large sample of the deer population would be necessary to obtain this information and more detailed information on background levels for the region would also have to be obtained, and even then the data may be inconclusive. The data presented in table 2.5 are, therefore, only a rough estimate of the population intake determined using the following approach:

Deer freely enter and leave the NFS site. They accumulate radionuclides only while grazing onsite. Approximately 125 deer constitute the onsite deer population at any given time, assuming the deer density to be the same as in the surrounding area. The maximum concentrations of radionuclides measured in a deer collected onsite constitute the amounts which would be accumulated by a deer grazing onsite for a full year. By applying the maximum concentrations to all 125 deer, we can approximate the amounts of activity which would be accumulated by the entire deer population grazing onsite during the year (the equivalent of 125 grazing years). Of course the actual accumulation would be

Table 2.5 Estimated radionuclide intakes from consumption of venison obtained from deer kills in the vicinity of NFS, 1970

Radionuclide	Intakes (μCi/yr wet weight)	
	Maximum by individual	Total by population
Cesium 137.....	1.8×10^{-1}	1.4
Cesium 134.....	3.2×10^{-2}	2.5×10^{-1}
Zinc 65.....	NA	2.2×10^{-3}
Strontium 90.....	1.3×10^{-3}	9.8×10^{-3}

NA, no analysis.

distributed among many more deer involved in grazing for shorter periods of time. Based on the deer kill data for the area, 22 deer from the population grazing on the NFS site would be killed by hunters. The venison intake from these deer would represent ~350 kg, using a value of 16 kg of consumed venison per deer. The radionuclide intake from these 22 deer would then represent an estimate of the radionuclide intake for the total population.

2.6 Estimated Dose Commitments to Population Consuming Venison from Deer Kills within a 32-km Radius of NFS

Table 2.6 presents a summary of the dose commitments to the population consuming venison from deer killed in the vicinity of NFS. Estimates are presented for the maximum individual and for the total population. The maximum whole-body dose an individual could have received was 14 millirem. The maximum bone dose to an individual from strontium 90 was 11 millirem and as indicated previously the strontium 90 dose cannot be attributed to the NFS operation. These doses are the maximum doses an individual could have received. Most probably the dose that an individual actually did receive was considerably smaller than the doses listed in table 2.6 since the probability is extremely small that the individual with the maximum intake would consume venison from two deer with the maximum concentrations of radionuclides.

The integrated whole-body population dose from the deer pathway is estimated to have been about 0.1 man-rem.

Table 2.6 Estimated dose commitments from consumption of venison obtained from deer kills in the vicinity of NFS, 1970

Organ	Maximum individual (mrem)	Population (man-rem)
Whole body[a]..	14	0.1
Bone[b].....	11	0.1

[a]Includes contribution from cesium 137, cesium 134, and zinc 65.
[b]Dose from strontium 90 but not directly attributed to NFS.

CHAPTER 3.

RADIONUCLIDE CONCENTRATIONS IN DIETS OF POPULATIONS LIVING IN VICINITY OF NUCLEAR FUEL SERVICES

3.1 Introduction

In September 1970 "market basket" diet sampling, similar to the AEC HASL Tri-City diet studies (9,10), was conducted in Springville, New York to provide information for estimating the dietary intake of radionuclides by the population of that area. At the same time, for comparison purposes, a similar sampling was carried out at Winchester, Mass. In addition to this supermarket sampling the following samples were collected:

(a) selected dietary items purchased in Riceville and West Valley, N.Y. which could have originated locally,
(b) homegrown garden vegetables and fruits from seven homeowners around the plant perimeter which were consumed by the family and not sold commercially, and
(c) vegetables and fruits from produce farms in Chaffee, N.Y. and Winchester, Mass. to serve as controls.

These samples were analyzed for gamma emitters, strontium 90 and tritium. The only gamma-emitting radionuclides detected were cesium 137 and potassium 40. Minimum detectable concentrations (for a 3.5 kg sample) and estimated analytical errors for these samples are as follows:

Radionuclide	Minimum detectable concentration	Estimated error
Cesium 137.....	4 pCi/kg	± 4 pCi/kg or ± 10 percent, whichever is larger
Strontium 90.....	0.5 pCi/kg	± 0.5 pCi/kg or ± 7 percent, whichever is larger
Potassium 40.....	-	± 0.1 pCi/kg
Tritium.....	0.3 nCi/kg	± 0.3 nCi/kg or ± 5 percent, whichever is larger
Cesium 134.....	5 pCi/kg	± 5 pCi/kg or ± 10 percent, whichever is larger
Ruthenium 106.....	20 pCi/kg	± 20 pCi/kg or ± 10 percent, whichever is larger
Iodine 131.....	10-20 pCi/kg (depending on decay time)	± 10-20 pCi/kg or ± 10 percent, whichever is larger

Some of the produce samples from the individual home gardens were less than 3.5 kg and for these samples the minimum detectable concentration would be somewhat higher (about a factor of 2) than the listed values.

3.2 Radionuclide Concentrations and Intakes

3.2.1 Market basket sampling

Tables 3.1 and 3.2 present data on the concentrations and intakes of strontium 90 and cesium 137 in diets from Springville, N.Y. and Riceville-West Valley, N.Y. representing populations living in the vicinity of NFS. Only those food categories which could have been of local origin were sampled in Riceville-West Valley. The remaining food

Table 3.1 Radionuclides in Springville, N.Y. diets, September 1970

Diet category	Concentration[a]				Intake		
	^{90}Sr (pCi/kg)	^{137}Cs (pCi/kg)	K (g/kg)	Ca (g/kg)	Total (kg/yr)	^{90}Sr (pCi/yr)	^{137}Cs (pCi/yr)
Dairy products.....	9.4	11	1.6	1.20	200	1880	2200
Fresh vegetables.....	10.3	ND	3.0	0.50	48	494	0
Canned vegetables.....	4.6	5	1.3	0.26	22	101	110
Root vegetables.....	10.2	ND	2.3	0.30	10	102	0
Potatoes.....	3.3	8	3.6	0.10	38	125	304
Dry beans.....	11.2	14	14.2	0.84	3	34	42
Fresh fruit.....	1.8	ND	2.0	0.20	59	106	0
Canned fruit.....	1.2	ND	0.9	0.04	11	13	0
Fruit juices.....	3.5	8	1.7	0.07	28	98	224
Bakery products.....	8.0	31	1.9	1.70	44	352	1364
Flour.....	8.2	27	1.4	0.21	34	279	918
Whole grain products..	17.2	50	3.8	1.50	11	189	550
Macaroni.....	4.7	23	1.9	0.16	3	14	69
Rice.....	2.6	10	0.8	0.30	3	8	30
Meat.....	0.6	19	2.9	0.06	79	47	1501
Poultry.....	ND	7	2.4	0.30	20	0	140
Eggs.....	1.2	6	1.4	0.40	15	18	90
Fresh fish.....	0.5	9	3.6	0.57	8	0	72
Shell fish.....	1.5	7	NA	0.06	1	2	7
Yearly intake.....	.....	.....	.....	.....	.....	3862	7621

[a]Wet weight.
ND, nondetectable.
NA, no analysis.

Table 3.2 Radionuclides in selected diet categories from Riceville, N.Y. and West Valley, N.Y., September 1970

Diet category	Concentration[a]				Intake		
	^{90}Sr (pCi/kg)	^{137}Cs (pCi/kg)	K (g/kg)	Ca (g/kg)	Total (kg/yr)	^{90}Sr (pCi/yr)	^{137}CS (pCi/yr)
Dairy products.....	10.6	12	1.6	1.20	200	2120	2400
Fresh vegetables.....	5.4	ND	2.3	0.34	48	259	0
Root vegetables.....	8.3	6	2.1	0.30	10	83	60
Potatoes.....	3.7	6	3.8	0.08	38	141	228
Fresh fruit.....	4.6	5	2.0	0.19	59	271	295
Bakery products.....	8.6	30	1.9	1.50	44	378	1320
Meat.....	1.7	20	2.8	0.17	79	134	1580
Poultry.....	2.1	7	2.1	NA	20	42	140
Eggs.....	1.7	6	1.3	0.34	15	26	90
Yearly intake[b].....	.....	.....	.....	.....	.....	4192	8135

[a]Wet weight.
[b]Assumes concentrations in other food items similar to Springville samples.
ND, nondetectable.
NA, no analysis.

categories were assumed to be similar to those purchased in the Springville supermarkets. Tables 3.3 and 3.4 present data on the concentrations and intakes of strontium 90 and cesium 137 in diets from Winchester, Mass., New York, N.Y., and Chicago, Ill., which serve as control populations for this study.

3.2.2 Local produce sampling

Table 3.5 presents the concentrations of strontium 90 and cesium 137 in produce from home gardens located around the perimater of the NFS plant. The samples collected were those food items available from the garden in sufficient quantity for analysis at the time of the sampling. These samples do not represent all food items grown by the homeowner during the season. Tables 3.6 and 3.7 present data on samples from produce farms in Chaffee, N.Y. and Winchester, Mass., which serve as control sampling locations. The same food items were sampled at these control locations as were collected from the individual home gardens.

3.2.3 Tritium in food composites

Table 3.8 presents the concentrations of tritium in composite samples of total diet and produce from the various sampling locations.

Table 3.3 Radionuclides in Winchester, Mass. diets, September 1970

Diet category	Concentration[a]				Intake		
	^{90}Sr (pCi/kg)	^{137}Cs (pCi/kg)	K (g/kg)	Ca (g/kg)	Total (kg/yr)	^{90}Sr (pCi/yr)	^{137}Cs (pCi/yr)
Dairy products.....	8.5	24	1.6	1.20	200	1700	4800
Fresh vegetables.....	19.7	6	2.7	0.40	48	946	288
Canned vegetables.....	8.6	ND	1.2	0.35	22	189	0
Root vegetables.....	7.6	5	2.2	0.25	10	76	50
Potatoes.....	5.1	6	4.3	0.04	38	193	228
Dry beans.....	16.9	13	14.3	0.81	3	51	39
Fresh fruit.....	4.5	4	2.1	0.20	59	13	195
Canned fruit.....	1.4	5	0.9	0.04	11	15	55
Fruit juices.....	3.4	8	1.7	0.08	28	95	224
Bakery products.....	13.4	33	1.9	1.70	44	590	1452
Flour.....	6.4	23	1.0	0.14	34	218	782
Whole grain products..	29.8	52	3.6	1.40	11	328	572
Macaroni.....	4.4	24	2.0	0.16	3	13	72
Rice.....	2.3	8	0.8	0.14	3	7	24
Meat.....	0.6	14	2.9	0.16	79	47	1106
Poultry.....	1.1	7	2.1	0.22	20	22	140
Eggs.....	2.2	4	1.2	0.50	15	33	69
Fresh fish.....	ND	13	3.1	0.19	8	0	140
Shell fish.....	ND	4	1.0	0.18	1	0	4
Yearly intake.....	.....	.....	.....	.....	.....	4536	10,195

[a]Wet weight.
ND, nondetectable.

Table 3.4 Radionuclides in diets[a] from New York, N.Y. and Chicago, Ill.

Diet category	Concentration[b]			Intake		
	^{90}Sr (pCi/kg)	^{137}Cs (pCi/kg)	K (g/kg)	Total (kg/yr)	^{90}Sr (pCi/yr)	^{137}Cs (pCi/yr)
Dairy products	9.0	11	1.5	200	1800	2200
Fresh vegetables	10.2	6	2.3	48	490	288
Canned vegetables	12.7	ND	0.9	22	279	0
Root vegetables	4.3	8	3.3	10	43	176
Potatoes	4.5	15	4.5	38	171	570
Dry beans	16.2	15	11.7	3	49	45
Fresh fruit	2.2	6	1.9	59	130	354
Canned fruit	1.4	ND	0.7	11	15	0
Fruit juices	3.6	12	1.3	28	101	336
Bakery products	6.2	35	1.5	44	273	1540
Flour	6.6	30	1.1	34	224	1020
Whole grain products	15.1	35	2.3	14	166	385
Macaroni	4.7	35	2.0	3	14	105
Rice	2.1	NA	NA	3	6	0
Meat	1.1	14	3.3	79	87	1106
Poultry	0.8	ND	2.2	20	16	0
Eggs	2.3	ND	1.3	15	35	0
Fresh fish	0.3	77	3.3	8	2	616
Shell fish	1.4	NA	NA	1	1	0
Yearly intake	.....	.....	.....	.....	3902	8741

[a]Data from reference 11; diet samples for strontium 90 intake were collected in New York, N.Y., August 1970, and diet samples for cesium 137 were collected in Chicago, Ill., October 1970.

[b]Wet weight.

ND, nondetectable.

NA, no analysis.

Table 3.5. Radionuclides in garden produce from farms located around the perimeter of Nuclear Fuel Services, September 1970

Item	Concentration (pCi/kg)		Concentration (g/kg)	
	Strontium 90	Cesium 137	Potassium[a]	Calcium
Location 1:				
Beets----------	24	ND	3.4	0.11
Carrots----------	22	16	2.4	0.34
Cucumbers--------	3	ND	1.5	NA
Pumpkin----------	6	ND	3.5	NA
Tomatoes	1	ND	2.8	NA
Location 2:				
Apples----------	3	10	1.6	0.11
Cabbage----------	19	ND	2.3	0.62
Cucumbers--------	5	ND	1.4	NA
Onions----------	6	ND	2.0	0.10
Pears----------	16	14	1.9	0.16
Potatoes---------	4	ND	3.7	0.06
Tomatoes---------	5	ND	2.2	0.09
Location 3:				
Beets----------	28	ND	5.6	0.20
Cabbage----------	9	ND	2.3	0.36
Corn----------	ND	ND	2.3	0.01
Cucumbers--------	4	ND	1.7	0.16
Melons----------	17	32	5.9	0.20
Onions----------	14	ND	1.3	0.20
Potatoes---------	3	8	4.4	0.08
Squash----------	4	ND	3.1	0.13
Tomatoes---------	4	12	2.7	0.09
Watermelon-------	5	18	2.4	0.09
Location 4:				
Cabbage----------	21	ND	2.7	0.53
Onions----------	16	ND	1.2	NA
Potatoes---------	5	ND	4.7	0.03
Squash----------	15	ND	4.1	0.49
Tomatoes---------	8	ND	2.7	0.08

See footnotes at end of table.

Table 3.5. Radionuclides in garden produce from farms located around the perimeter of Nuclear Fuel Services, September 1970—continued

Item	Concentration (pCi/kg)		Concentration (g/kg)	
	Strontium 90	Cesium 137	Potassium[a]	Calcium
Location 5:				
Apples----------	ND	22	1.2	NA
Beets----------	16	ND	3.2	0.22
Carrots----------	35	ND	6.1	0.04
Corn----------	ND	ND	4.6	NA
Peppers----------	ND	ND	3.2	0.20
Tomatoes---------	4	ND	2.0	NA
Squash----------	9	ND	2.1	NA
Location 6:				
Apples----------	4	29	2.1	0.04
Cabbage----------	67	ND	2.0	0.34
Onions----------	140	ND	1.7	0.35
Potatoes---------	4	ND	4.8	0.06
Rutabagas--------	160	ND	2.5	0.36
Squash----------	63	ND	4.4	0.14
Tomatoes---------	19	ND	2.4	NA
Location 7:				
Cabbage----------	48	4	1.7	0.36
Turnips----------	48	ND	3.4	0.31
Peppers----------	2	ND	3.7	NA
Squash----------	16	ND	3.4	NA
Tomatoes---------	5	ND	2.3	NA

[a]Determined from potassium 40.
ND, nondetectable.
NA, no analysis.

Table 3.6 Radionuclides in produce from farm stands in Chaffee, N.Y., September 1970

Item	Concentration[a]			
	^{90}Sr (pCi/kg)	^{137}Cs (pCi/kg)	K (g/kg)	Ca (g/kg)
Apples	10.2	5	0.7	0.05
Cabbage	26.4	5	1.5	0.34
Carrots	16.5	ND	2.4	0.62
Corn	0.9	5	3.2	0.02
Cucumbers	14.0	ND	1.5	NA
Onions	3.7	ND	1.4	0.12
Watermelons	7.6	5	1.1	0.08
Peppers	3.1	ND	2.6	NA
Potatoes	7.3	8	4.1	0.05
Squash	7.6	ND	3.5	0.25
Tomatoes	12.0	ND	2.8	0.27
Turnips	20.0	9	2.3	0.42

[a]Wet weight.
ND, nondetectable.
NA, no analysis.

Table 3.7 Radionuclides in produce from farm stands in Winchester, Mass., September 1970

Item	Concentration[a]			
	^{90}Sr (pCi/kg)	^{137}Cs (pCi/kg)	K (g/kg)	Ca (g/kg)
Apples	5.0	9	1.0	0.04
Beets	28.3	6	3.9	0.40
Cabbage	24.1	ND	2.1	0.66
Carrots	21.7	8	3.4	0.39
Corn	0.8	8	2.9	0.03
Cucumbers	7.0	ND	1.9	0.08
Eggs	2.2	4	1.2	0.50
Onions	5.1	ND	1.5	0.20
Melons	1.9	ND	5.5	0.10
Pears	0.8	ND	1.3	0.08
Peppers	NA	ND	2.6	0.21
Potatoes	3.7	5	4.0	0.07
Squash	7.4	ND	2.7	0.13
Tomatoes	3.3	ND	2.6	0.17
Turnips	58.7	ND	2.5	0.42

[a]Wet weight.
ND, nondetectable.
NA, no analysis.

Table 3.8 Tritium in total diets and farm produce composites, September 1970

Location	Type of sample	Tritium (nCi/kg)
Springville, N.Y.....	Total diet	0.5
Riceville, N.Y.....	Total diet	0.5
Winchester, Mass.....	Total diet	0.6
Chaffee, N.Y.....	Produce composite	0.5
Winchester, Mass.....	Produce composite	0.6
Perimeter location 1....	Produce composite	1.1
Perimeter location 2....	Produce composite	0.7
Perimeter location 3....	Produce composite	0.4
Perimeter location 5....	Produce composite	0.6
Perimeter location 6....	Produce composite	0.6
Perimeter location 7....	Produce composite	0.6
Perimeter location 1....	Cucumbers	1.0
Perimeter location 1....	Tomatoes	1.9
Perimeter location 1....	Carrots	0.6

The total diet samples represent all of the diet categories of the "market basket" composited proportionally to the intake. The produce composites represent equal quantities of each of the food items collected at that location.

3.3 Results and Discussion

3.3.1 Market basket sampling

Table 3.9 presents a summary of the yearly intake of strontium 90, cesium 137, and tritium for the various locations included in the market basket survey. The supermarket basket samplings for Springville, N.Y. and Winchester, Mass. were adjusted in order to account for the intake of locally grown produce (not from NFS perimeter).

Strontium 90 intakes ranged from 3900 to 4500 pCi/yr, cesium 137 intakes from 7600 to 10,000 pCi/yr, and tritium intakes from 320 to 380 nCi/yr.

The data in table 3.9 indicate that radionuclide intakes for the populations of Springville, Riceville, and West Valley, N.Y. were similar to the intakes for the control populations and that the operations of the NFS plant had not resulted in any measurable increase in radionuclide intakes for the general population living in the vicinity of the plant.

Table 3.9 Estimated dietary intakes of strontium 90, cesium 137, and tritium from market basket sampling

Location	Intake (μCi/yr)		
	Strontium 90	Cesium 137	Tritium
Springville, N.Y.[a]...	3.9×10^{-3}	7.6×10^{-3}	3.2×10^{-1}
Springville, N.Y.[b]...	4.5×10^{-3}	8.0×10^{-3}	3.2×10^{-1}
Riceville, N.Y.[a].....	4.2×10^{-3}	8.1×10^{-3}	3.2×10^{-1}
Winchester, Mass.[a]...	4.5×10^{-3}	1.0×10^{-2}	3.8×10^{-1}
Winchester, Mass.[b]...	4.1×10^{-3}	9.9×10^{-3}	3.8×10^{-1}
New York, N.Y.[a].....	3.9×10^{-3}	NS	NS
Chicago, Ill.[a].....	NS	8.7×10^{-3}	NS

[a]Supermarket food items.
[b]Local farm stand produce (not from NFS perimeter) substituted for supermarket produce. Average concentrations in fresh fruit, fresh vegetables, root vegetables, and potatoes were used.
NS, no sample.

3.3.2 Local produce

A summary of mean concentrations of radionuclides in root vegetables, fresh vegetables, fresh fruit, potatoes and all items for each of the individual gardens from around the NFS perimeter, and a matching sample of similar food items for the control locations are presented in table 3.10. The following observations may be made from an inspection of these data:

(a) the cesium 137 concentrations in samples from the individual gardens do not differ from the control samples,
(b) the strontium 90 concentrations in the samples from individual gardens at locations 1 to 5 and 7 do not appear to be significantly different from those at the control locations,
(c) the strontium 90 concentrations in samples from location 6 are significantly higher than the samples from the other individual gardens as well as the controls, and
(d) the tritium concentration in the composite from location 1 was about twice the concentrations measured in the other composite samples. The analysis of several individual food items from location 1 also indicated higher tritium concentrations than the other locations. For additional information on tritium in the environment around NFS see reference (12).

Table 3.10 Comparison of radionuclide concentrations in produce from farms around NFS with matching control samples

Location	Mean concentration (pCi/kg wet weight)									
	Root vegetables		Fresh vegetables		Fruit		Potatoes		All items	
	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs
1.....	23	8	3	0	NS	NS	NS	NS	11	3
Control[a]....	24	5	9	1	--	--	--	--	15	2
2.....	6	0	10	0	10	12	4	0	8	3
Control.....	5	0	14	3	4	5	6	7	9	3
3.....	21	0	3	3	11	25	3	8	9	7
Control.....	16	3	6	2	5	3	6	7	10	3
4.....	16	0	15	0	NS	NS	5	0	13	0
Control.....	5	0	13	2	--	--	6	7	10	2
5.....	26	0	3	0	0	22	3	0	9	3
Control.....	24	7	5	5	8	7	6	7	10	5
6.....	150	0	50	0	4	29	4	0	65	4
Control.....	22	4	11	2	8	5	6	7	14	3
7.....	48	0	18	1	NS	NS	NS	NS	24	1
Control.....	39	7	11	2	--	--	--	--	17	3

[a]Matching control samples from Chaffee, N.Y. and Winchester, Mass.
NS, no sample.

It cannot be concluded from this information that the high concentrations of strontium 90 in samples from location 6 were caused by NFS plant operations. None of the other plant perimeter locations show strontium 90 concentrations in samples significantly higher than the controls, and no other radionuclides (such as ruthenium 106 and cesium 134) which are characteristic of the NFS waste were present.

Table 3.11 presents a summary of the yearly intakes of strontium 90, cesium 137, and tritium from the individual homes around the NFS plant perimeter. In calculating these intakes, the concentrations of radionuclides in homegrown food items were substituted for similar food categories in the supermarket basket survey for Springville; the remaining items were considered to be similar to the Springville supermarket basket.

The strontium 90 intakes for these families ranged from 3600 to 7300 pCi/yr, the cesium 137 intakes ranged from 7300 to 9200 pCi/yr, and the tritium intakes from 310 to 390 nCi/yr.

The data in table 3.11 indicates that for the households from which produce samples were obtained, the radionuclide intakes were similar to the intakes for the populations of other areas included in the market basket survey with the exception of the strontium 90 intakes for

Table 3.11 Estimated dietary intakes of strontium 90, cesium 137, and tritium for families living around NFS plant perimeter

Location	Intake (μCi/yr)		
	Strontium 90	Cesium 137	Tritium
1.....	3.9×10^{-3}	7.7×10^{-3}	3.9×10^{-1}
2.....	4.3×10^{-3}	8.1×10^{-3}	3.1×10^{-1}
3.....	4.2×10^{-3}	9.2×10^{-3}	3.4×10^{-1}
4.....	4.2×10^{-3}	7.3×10^{-3}	NA
5.....	3.6×10^{-3}	8.6×10^{-3}	3.3×10^{-1}
6.....	7.3×10^{-3}	9.0×10^{-3}	3.3×10^{-1}
7.....	4.6×10^{-3}	7.7×10^{-3}	3.3×10^{-1}

[a]Homegrown food items were substituted for supermarket food items in calculating intakes. Average concentrations of radionuclides in fresh fruit, fresh vegetables, root vegetables and potatoes were used.

NA, no analysis.

location 6. For location 6, the strontium 90 intake was estimated to be twice the normal intake. Further study would be necessary to clarify this phenomenon.

3.4 Addendum

As a followup to the food sampling described in this report, soil samples were collected during the summer of 1971 at the sample locations around the plant which were used for sampling produce. The principal objective of this sampling was to determine if the radionuclide deposition at location 6 was significantly higher than at the other locations and if so was it due to NFS operations. It was not possible to resample homegrown food from location 6 because the family did not have a garden during 1971 simply because it involved too much work.

Table 3.12 presents the deposition data obtained from this sampling. The sample collection procedure used was similar to that recommended by the AEC Health and Safety Laboratory except that these samples were collected at a depth of 0 to 5 cm only (10). It should be noted that the soil samples were not collected from the garden areas but from undisturbed areas in the same location.

Table 3.12 Radionuclides in soil collected around NFS plant perimeter

Location	Deposition[a] (mCi/km^2)			
	^{137}Cs	^{134}Cs	^{106}Ru	^{90}Sr
1.....	55	<0.2	18	29
2.....	48	<0.2	18	24
3.....	58	<0.2	16	17
5.....	43	<0.2	49	19
6.....	34	<0.2	15	33
7.....	51	<0.2	15	23
Control[b].....	54	<0.2	18	27

[a]Sample collected at depth of 0-5 cm only.
[b]Location ~32 km from plant.

The data from table 3.12 does not indicate any deposition in these areas resulting from the NFS plant operation that can be readily distinguished from fallout. The absence of any detectable cesium 134 tends to substantiate the conclusion that the plant's contribution to the radionuclide deposition in soil is relatively small.

The strontium 90 deposition at location 6 cannot explain the high concentrations of this radionuclide in food items grown in this area. Many of the food items grown at location 6 were 5 to 10 times higher in strontium 90 than similar food items grown at the other locations. Since the strontium 90 concentration in soil alone cannot be used to explain these concentrations in food, then other factors such as soil conditions may be influencing the uptake of strontium.

SUMMARY

Studies were carried out to determine the radiation exposure to the population living in the vicinity of NFS resulting from the ingestion of radionuclides which had been discharged from the plant. Measurements of the radionuclide concentrations in venison, fish, total diets, and home-grown garden produce showed that only the fish and venison contained measurable quantities of radionuclides which could be directly attributed to the operation of the NFS plant.

Surveys carried out to determine the intakes of venison and fish by the population living in the vicinity of NFS showed that the maximum intakes by an individual during 1971 were 45 kg of venison and 5 kg of fish flesh. Total population intakes were 5×10^4 kg of venison from deer kills within a 32-km radius of the plant and 280 kg of fish flesh from fishing along a 24-km length of the Cattaraugus Creek nearest the plant.

From the results of this study, the following estimates can be made concerning the dose commitments to the population fishing and hunting in the vicinity of NFS resulting from waste discharges from the plant:

(1) Whole-body doses to population fishing the Cattaraugus Creek during 1971:
   Integrated population dose—0.06 man-rem (0.04 man-rem external, 0.02 man-rem from ingestion)
   Maximum individual dose—1.4 mrem (1 mrem external, 0.4 mrem from ingestion)

(2) Dose to bone from ingestion of strontium 90 for population fishing the Cattaraugus Creek during 1971:
   Integrated population dose—0.3 man-rem
   Maximum individual dose—7 mrem

(3) Whole-body doses to population from ingestion of venison from deer kill in 1970:
   Integrated population dose—0.1 man-rem
   Maximum individual dose—14 mrem

(4) Dose to bone from ingestion of strontium 90 in venison resulting from the NFS discharges could not be determined from the available data.

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Appendix A.1

CATTARAUGUS CREEK SURVEY _____

Location: _____ Date: _____ Time: _____

Surveyed previously: Yes No If yes, when? _____

Name: _____

Address: _____ City: _____

Do you: eat what you catch within household Place back in creek Take and give to others, or use for pets, bait, etc.

If eaten: Number of people in household who eat fish: _____
Number of people in household who eat fish that are:
a) under 6 years old _____
b) 6 to 12 years old _____
c) over 12 years old _____

Do the bones get consumed? Yes No Remarks: _____

Frequency of fishing Cattaraugus _____ trips per _____
How long per trip _____
Period of year active fishing Cattaraugus _____

How many persons in household fish the Cattaraugus? _____
How often? _____ Remarks: _____

Frequency of eating fish taken from Cattaraugus: _____ meals per _____

Species taken from Cattaraugus		Species eaten from Cattaraugus	
Trout	_____	Trout	_____
Bass	_____	Bass	_____
Salmon	_____	Salmon	_____
Sunfish	_____	Sunfish	_____
Bullheads	_____	Bullheads	_____
Carp-Suckers	_____	Carp-Suckers	_____
Perch-Walleye	_____	Perch-Walleye	_____
Sheepshead	_____	Sheepshead	_____
Other	_____	Other	_____

CREEL SURVEY:
How long at this location? _____ How much longer _____

Trout		Bass		Salmon		Sunfish		Bull-heads		Suckers		Perch		Sheeps-head		Other	
Oz.	In.	Oz.	In.	Oz.	In.	Oz.	In.	Oz.	In.	Oz.	In.	Oz.	In.	Oz.	In.	Oz.	In.

Appendix A.2

CATTARAUGUS CREEK SURVEY
Daily Log Sheet

Surveyor: _____ Date: _____

Time	Located	People in area	People fishing	People interviewed	Remarks

Appendix B.1

York State Department of Environmental Conservation
, N. Y. 12201

Henry L. Diamond,
Commissioner

March 31, 1971

Dear Sir:

Our records indicate your success in taking a deer during the 1970 hunting season. We are analyzing deer for certain environmental contaminants such as pesticides, heavy metals (such as mercury), radioactivity and arsenic. Your cooperation will enable us to determine whether the levels found could be of any possible significance in man's diet.

Please help us to better evaluate this environmental pathway by filling in the questionnaire and returning it to us in the stamped, self-addressed envelope. Thank you.

Sincerely,

A. G. Hall
Director, Division of
Fish and Wildlife

Enclosures

Appendix B.2

DEER USE QUESTIONNAIRE

1. NAME: _____

2. ADDRESS: _____ CITY: _____

3. TOWNSHIP IN WHICH DEER WAS TAKEN: _____

4. DRESSED WEIGHT OF DEER: _____ POUNDS

5. EATABLE WEIGHT OF VENISON OBTAINED: _____ POUNDS

6. NUMBER OF PERSONS IN HOUSEHOLD THAT EAT VENISON THAT ARE;

   Insert Numbers On Lines:
   a) Under age 6 _____
   b) 6 to 12 years old _____
   c) Over 12 years old _____

7. DID YOU:

   Circle one:
   a) Consume total deer within household
   b) Give part of deer away; if so, gave away _____ pounds, or circle portion given away: 1/8, 1/4, 1/3, 1/2, 2/3, 3/4
   c) Give all of deer away

8. DO YOU CONSUME THE HEART: Please circle: Yes or No

9. DO YOU CONSUME THE LIVER: Please circle: Yes or No

10. DID YOU RECEIVE VENISON FROM ANOTHER SOURCE: (a friend, a road kill, etc.)
    Please circle: Yes or No
    If Yes, how much? _____ pounds, or what portion? 1/8, 1/4, 1/3, 1/2, 2/3, 3/4, or all?

11. DID YOU TAKE MORE THAN ONE DEER:
    Please circle: Yes or No
    If Yes, dressed weight _____ pounds; eatable weight _____ pounds
    All eaten within household: Yes or No; or portion given away: 1/4, 1/2, 3/4, or all?

12. DO YOU TAKE A DEER:

    Circle one:
    a) Each year
    b) Every other year
    c) One year out of three
    d) Less frequently than every three years

PLEASE USE OTHER SIDE FOR ANY COMMENTS OR ADDITIONAL INFORMATION YOU MAY DESIRE TO FURNISH

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-520/3-74-001	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Studies of Ingestion Dose Pathways from the Nuclear Fuel Services Fuel Reprocessing Plant		5. REPORT DATE December 1974; Issuing date 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Paul J. Magno, Richard Kramkowski, Thomas Reavey, and Robert Wozniak		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS ENVIRONMENTAL PROTECTION AGENCY Office of Radiation Programs Washington, D.C. 20460		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Studies were carried out to evaluate ingestion doses to individuals and the local population resulting from the operation of the Nuclear Fuel Services (NFS) reprocessing plant in West Valley, N.Y. These studies involved evaluations of radionuclide intakes from ingestion of fish, deer, and locally grown food items and included surveys of fishing and deer hunting in the vicinity of the plant.

The maximum dose commitment to an individual from the fish pathway during 1974 was estimated to have been 1.4 millirem whole body and 7 millirem bone. The maximum whole-body dose commitment to an individual from ingestion of venison from deer kills in 1970 was estimated to have been 14 millirem. Dose estimates for the local population from the fish and deer pathways indicated that the integrated whole-body population dose commitments from each of these pathways was about 0.1 man-rem per year. Measurements of radionuclide concentrations in locally grown food items indicated that the operation of the NFS plant had not resulted in any measureable increase in the radionuclide intakes of the population living in the vicinity of the plant from the pathway.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Environment; Nuclear Fuel Services; population dose; radiation; radionuclide concentrations.		

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