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Environmental Measurements Laboratory

A COMPENDIUM OF THE ENVIRONMENTAL MEASUREMENTS LABORATORY'S
RESEARCH PROJECTS RELATED TO THE CHERNOBYL NUCLEAR ACCIDENT

October 1, 1986

DEPARTMENT OF ENERGY
NEW YORK, N. Y. 10014

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**A COMPENDIUM OF THE ENVIRONMENTAL MEASUREMENTS LABORATORY'S
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Compiled and Edited by:

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U. S. Department of Energy
New York, NY 10014

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FOREWARD

Following the accident at the Chernobyl nuclear reactor power station in the U.S.S.R. on April 26, 1986, and the subsequent detection of related fission products in much of Europe within a few days, the Environmental Measurements Laboratory (EML) initiated a number of research projects that are appropriate to the Laboratory's mission, interests, expertise and resources. These projects can be categorized as follows:

- * Our global fallout programs are uniquely suited to investigate releases of the Chernobyl type, that is, widespread, atmospheric injections of radioactive materials. Hence, selected sites in both the Deposition and Surface Air networks were alerted and their sampling protocols adjusted to accomodate the anticipated arrival times and activity concentrations of the Chernobyl debris.
- * A number of cooperative programs involving field work, sampling, analysis and data interpretation were set up with institutions and scientists in other countries. Interactive research programs of this nature, have in the past, proven to be very instructional, as well as cost effective, and have often resulted in subsequent long term scientific cooperative ventures of mutual benefit.
- * EML's Regional Baseline Station at Chester, NJ, as well as the roof of the Laboratory in New York City, provided bases for sampling and measurements to study the radionuclide concentrations, radiation levels, physical characteristics and potential biological implications of the Chernobyl fallout on the northeastern United States.
- * The resulting fallout from the Chernobyl accident provided an 'experiment of opportunity' in that it enabled us to study fresh fission product deposition using collection systems resurrected from the 1950's and 1960's for comparison with current state-of-the-art methodology. The information gained in these observations will be valuable in the Laboratory's re-assessment of the doses to United States populations from early nuclear atmospheric weapons conducted at the Nevada Test Site.
- * The 13 reports of this volume reflect an intensive effort by EML's staff and our cooperating colleagues, to carry out and promptly report the initial basic data and preliminary results of our research efforts following the Chernobyl event. We anticipate subsequent publications with more comprehensive analyses and interpretation, as the data are refined and additional procedures requiring lengthy radiochemistry and low-level counting are completed.

Note Added in Press

The need for rapid radioassay of the large number of environmental samples collected after the Chernobyl accident required the use of all the gamma ray spectroscopy systems at EML. An NBS ^{134}Cs standard was not available at that time, and the ^{134}Cs detection efficiency of each system was estimated from the gamma branching ratios of ^{134}Cs and an empirically determined relationship between photon energy and detector efficiency.

Just prior to publication, these detector efficiencies were checked with a ^{134}Cs standard from the National Bureau of Standards. In most but not all systems the estimated ^{134}Cs efficiency proved to be high by about 16%. Time would not allow corrections to be made before publication of these results, but many of the ^{134}Cs data in this report should be increased by 16%.

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THE CHARACTERIZATION OF RADIONUCLIDES IN NORTH AMERICAN AND HAWAIIAN SURFACE AIR AND DEPOSITION FOLLOWING THE CHERNOBYL ACCIDENT

Richard J. Larsen, Colin G. Sanderson, William Rivera
and Mildred Zamichieli

INTRODUCTION

Concentrations of gamma-ray emitting radionuclides in the surface air are presented for nine sites in North America and Hawaii following the Chernobyl accident. Activity ratios of these radionuclides have also been tabulated. The wet and dry deposition of ^{131}I , ^{134}Cs and ^{137}Cs are presented for four sites. The data suggest that a portion of the radionuclides that were released into the atmosphere following the explosion and fire at the Chernobyl-4 nuclear reactor were transported by the Northern Hemispheric polar front westerlies at altitudes up to several km. Sections of this cloud were randomly mixed with the surface air when the meteorological conditions for strong vertical mixing were favorable. It appears that from May 9 to May 10 enhanced vertical mixing within the contiguous United States occurred, resulting in the sudden simultaneous appearance of particulate ^{131}I and ^{137}Cs in surface air at both the eastern and western sites. The magnitude of the surface air concentrations of particulate ^{131}I and ^{137}Cs observed during this first major episode was similar at all of these sites. Elevated surface air concentrations of particulate ^{131}I and ^{137}Cs were generally associated with elevated ^7Be values. The mean activity ratio of $^{137}\text{Cs}/^{134}\text{Cs}$ (^{134}Cs has been decay corrected to April 26) for all sites was 1.9, with minor spatial and temporal variation. The amount of ^{131}I , ^{134}Cs and ^{137}Cs deposited and the mechanism for deposition varied with the rainfall patterns and the location and concentration of the radioactive debris in the atmosphere. The northwest appears to have incurred the highest deposits in the United States of ^{131}I , ^{134}Cs and ^{137}Cs due to the simultaneous occurrence of elevated air concentrations of the debris and rainfall. Deposition velocities of ^{131}I , ^{134}Cs and ^{137}Cs are similar to those reported for sulfate.

BACKGROUND

The Environmental Measurements Laboratory has conducted the Surface Air Sampling Program (SASP) for over two decades. The primary objective of this program is to study the temporal and spatial distribution of specific natural and man-made radioisotopes in the surface air. The data and findings of this program are routinely published (Feely, 1985).

Several operational SASP sites in North America and Hawaii were selected to assess the impact of the Chernobyl nuclear accident. Sampling at these sites was altered from the routine SASP procedures to obtain a more detailed temporal resolution of fission products especially those having short half lives.

Several objectives were pursued using the altered SASP procedures:

- To determine the magnitude of the effect of the Chernobyl accident on North America.

- To determine the detailed temporal and spatial resolution of the debris as it was transported in the atmosphere.
- To investigate the mechanisms of transport from a surface release thousands of miles away, radionuclide fractionation and removal processes in the atmosphere.
- To contribute the data collected in this program to a larger data base that will be necessary to reconstruct conditions and emissions at the release point (the Chernobyl nuclear reactor) and to estimate the radiation exposure to the global population.

SAMPLING SITES AND COLLECTION PROCEDURES

The sites selected for this intensive study are listed in Table 1 and are shown in Figure 1. Table 1 lists the sites with their geographic coordinates and elevations. Table 2 lists the types and numbers of samples collected and analyzed at each site.

Hi-volume air samples were collected on a daily basis, whenever possible, using Microsorban filter material. All sites except the University of Miami's Sea-Air Exchange Program (SEAREX) site located in Key Biscayne, FL collected air filter samples using a 1 horsepower Brook Crompton Parkinson Limited motor and Roots compressor system (SASP system). At the Key Biscayne site and for a duplicate sample collected at the New York City site, a 0.52 horsepower Fuji ring compressor system (SEAREX system) was used to collect air samples. These air mover systems were calibrated for flow using either a Hastings Laminar flow element or a variable orifice meter calibrated against an American Meter Company dry meter. The SASP system moves ~ 2000 m³ of air per day through a 20 cm diameter filter, while the SEAREX system moves ~ 1400 m³ of air per day through a 20 cm by 25 cm rectangular filter. Daily readings of the pressure drop across the filter or across an orifice plate, and daily temperature measurements submitted to EML along with the filters permit the calculation of flow through each individual filter sample.

The SEAREX air sampler used at the Key Biscayne site is coupled with a wind controller and only operates above a specified wind speed and wind direction. The directional sampling sector is from the Northeast to the Southwest, selectively sampling the trade winds off the North Atlantic Ocean. The SEAREX system used to collect duplicate samples at New York City, remained on continuously. The Miami, FL site was the only site where air filter samples were collected on a weekly basis. Although daily sampling was stopped at all of the sites in late May, weekly filters from each site will continue to be analyzed for ¹³⁷Cs until it is no longer detectable.

SAMPLE PREPARATION AND ANALYSIS

Sample preparation and gamma-ray spectrometry systems used for analysis were selected on the basis of the type and amount of sample available. During this investigation most air filter samples were placed in a 45 cm³ plastic planchet for analysis. The daily air filter collected at EML from May 15 to May 20 using a SASP system was also analyzed in a 45 cm³ plastic planchet. The duplicate samples collected at EML using a SASP system were cut in half and compressed into a 1 to 2 cm³ cylinder. The other samples collected at EML using the SEAREX system had a 31.1% section of the total exposed filter cut and compressed into a similar cylindrical form.

Daily bulk deposition samples were collected at all but the two Florida sites. Samples were collected using plastic bags inserted into 13.2 L buckets having a diameter of 28.5 cm. The plastic bags were collected and replaced on a daily basis, whenever possible. Wet samples were transferred to plastic containers for shipment to EML. Aliquots of the wet samples were placed in 90 cm³ aluminum cans for gamma-ray spectrometry. If the water sample was < 90 cm³ it was diluted to 90 cm³ with deionized water before being transferred to the aluminum cans for analysis. Dry fallout samples collected in the plastic liners were composited and counted in the aluminum cans.

Gamma-ray spectrometry at EML was performed with seven high resolution germanium detectors in three different configurations. These consisted of two high purity germanium (HPGe) detectors with 1.5 cm diameter sample wells, two n-type low energy coaxials and three Ge(Li) or HPGe p-type coaxials. The efficiencies of these detectors, relative to the 1.33 MeV ⁶⁰Co gamma-ray efficiency obtained with a 3'' x 3'' NaI(Tl) detector at a distance of 25 cm (a standard industry specification), range from 15% to 35%. The plastic planchets and the aluminum cans were counted at the end cap of the coaxial detectors. The compressed cylinders were counted inside the well detectors. Concentrations of the gamma-ray emitting nuclides are determined by computer resolution of the spectral data. Several air filter samples were analyzed by Dr. Paul Linsalata, New York University, Institute of Environmental Medicine and by Dr. Dinkar Kharkar, TMA Thermo Analytical Inc. These samples were analyzed in plastic planchets with germanium gamma-ray detectors using a computer to resolve the resulting spectral data.

QUALITY ASSURANCE

Duplicate samples were collected daily at the New York City site and counted on a daily basis. The variation in the results between these duplicate samples appears small. Detailed statistical tests, such as the t-test or the Wilcoxon's signed ranked test (Langley, 1971), will be performed on these data sets in the near future to determine the significance of the variation in the concentrations measured. An initial t-test (Brownlee, 1965) indicated no significant difference ($P > 0.05$) between the particulate surface air concentrations of ¹³⁷Cs measured on the roof of EML using two air samplers. A second set of duplicate samples was collected at the New York City site and counted in a planchet. Since most of the samples collected in this experiment were counted in planchets, it is desirable to compare the duplicate concentrations obtained using the 1 to 2 cm³ cylinder geometry, which is more sensitive, with the planchet. The variation observed appears small and detailed statistical tests will be performed to determine the significance of the variation. The counters were routinely checked for background to assure that contamination did not occur. Reference samples are routinely analyzed in the SASP program and the SASP quality assurance plan is described along with the results in previous EML publications (Feely, 1985).

RESULTS

The results of analysis of radionuclides in the surface air samples by gamma-ray spectrometry for each site are reported in Tables 3 to 50. All of the radionuclide results are reported in fCi and mBq (see Table of Conversion Factors, page No. 13) per standard m³ of air. The standard volume used in this report is defined by the sea-level condition of the International Civil Aviation Organization (ICAO) Standard Atmosphere: a temperature of 15°C and a pressure of 1 atmosphere. The concentrations as reported are corrected for

radioactive decay to the midpoint of the collection interval. The half-life values used in this report are listed in the Table of Radionuclides (page No. 14). The collection period is reported in local time for each site. There are four tables of radionuclide concentrations in surface air per site. The first table reports the surface air concentrations of ^7Be , ^{131}I , ^{134}Cs , ^{137}Cs , ^{103}Ru and ^{106}Ru in conventional units, while the second table reports these same radionuclides in SI units. The third table reports surface air concentrations of ^{140}Ba , ^{140}La , ^{95}Zr , ^{99}Mo , ^{141}Ce , and ^{144}Ce in conventional units, while the fourth table reports these radionuclides in SI units. Counting errors which occasionally appear as 0.00 signify an error of <0.005 .

At Barrow, AK daily samples collected from April 30 through May 4 were screened for the presence of fission products using a high resolution germanium diode system. Since no fission product peaks were observed these samples were not given extensive count times and the results for ^7Be are presently unavailable.

At Moosonee, Ontario the daily sample collected from May 1 to May 2 was screened and no activity from fission products were observed. A ^7Be value is presently unavailable. The surface air concentrations of ^{140}Ba , ^{140}La , ^{95}Zr , ^{99}Mo , ^{141}Ce and ^{144}Ce after May 20 are not reported. These samples were analyzed outside of EML and our interest for these samples was primarily in ^7Be , ^{131}I , ^{134}Cs , ^{137}Cs and ^{103}Ru , ^{106}Ru .

At Rexburg, ID and at Beaverton, OR the surface air concentrations are not reported in the Barium-Lanthanum tables after May 22 for the same reasons as described above for Moosonee.

Four sets of data have been reported for the New York City site on the roof of EML. These sets represent duplicate analysis with samples counted in both the 1 to 2 cm³ cylinder geometry and in planchets. A final set was calculated using the weighted means statistical technique as described in EML-300 (1983). This last set has been used primarily for graphics and activity ratio calculations.

The surface air concentrations reported for Key Biscayne, also include the number of hours of running time during each sampling interval.

The daily samples collected at Mauna Loa, HI from May 5 to May 8 and from May 19 to May 21 were screened for the presence of fission product peaks. Since no activity in these regions was observed these samples were not counted.

Tables 51 to 58 present the activity ratios of $^{131}\text{I}^*/^{137}\text{Cs}$, ^{131}I , ^{137}Cs , $^{137}\text{Cs}/^{134}\text{Cs}^*$ and $^{103}\text{Ru}^*/^{137}\text{Cs}$ at each of the sites sampled. (The asterisk following some of these radionuclides symbolize that the radionuclides were decay corrected to April 26 prior to the calculation of the activity ratio.)

Figures 2 to 9 show the temporal trends of ^7Be , ^{131}I and ^{137}Cs concentrations in the surface air samples along with the daily precipitation for the month of May at each site. The scales used are not constant and vary with the magnitude of concentrations observed at each site. A compromise between scale size and graph compression had to be obtained, therefore, the bar graph occasionally extends beyond the scale maximum. This extension is symbolized by using a jagged edge for the horizontal bar line. The surface air concentrations are plotted in both conventional and SI units. The bar graphs were started at the first sample for each site having a counting error $< 100\%$ at two standard deviations. The precipitation data presented for Barrow, Beaverton and Rexburg were calculated from the total volume of precipitation collected in the daily bulk samples. Precipitation data for New York City, Chester, Moosonee, Miami and Mauna Loa were obtained using weighing bucket rain gauges.

Figures 10 to 12 show the spatial and temporal distributions of ^7Be , ^{131}I and ^{137}Cs in the surface air at eight sites sampled during the month of May. The scales have been fixed so that the relative surface air concentrations between the sites can be visualized. Again a compromise between scale size and graph compression was made. When values are greater than the scale the horizontal bar line has a jagged edge. The surface air concentrations in these figures are presented both in conventional units and SI units. The bar graphs were started at the first sample for each site having a counting error $< 100\%$ at two standard deviations. Figure 13 shows the temporal and spatial variation of the $^{131}\text{I}^*/^{137}\text{Cs}$ activity ratio for all sites during the month of May. The ratio range is from 0 to 30.

Tables 59 to 66 present the bulk deposition data at Beaverton, OR, Rexburg, ID, Chester, NJ and New York City, NY in both conventional and SI units. Generally, the samples were collected on a daily basis, however, exposure periods were longer at Chester. At both Chester, and New York City, the estimated precipitation, based on the sample volume collected, was equal to the recorded precipitation using weighing buckets. This agreement was probably due to the short exposure intervals, which limited evaporation from the collector. Estimates for the total wet deposition were obtained by summing the data of all samples containing precipitation. 'Less than' values were treated as absolute numbers having errors of 100% at two standard deviations. These numbers were used in the calculations of wet, dry and total deposition. The ratios of $^{131}\text{I}/^{137}\text{Cs}$ deposited during a given collection period along with the corresponding ratio of $^{131}\text{I}/^{137}\text{Cs}$ in the surface air are also presented in these tables. Finally, the relative contribution between wet and dry deposition is estimated for each radionuclide at each site.

Estimates of the deposition velocity for ^{131}I , ^{134}Cs and ^{137}Cs are presented in Table 67. The table presents the site, collection period, surface air concentration and deposition rates from which the deposition velocities were calculated. The deposition velocities are reported in the standard unit of cm/sec.

DISCUSSION

The first reported measurements of radioactivity in the atmosphere, east of the U.S.S.R., were made in Japan. Aoyama (1986) reported an abrupt increase in the radioactivity of the surface air and water at Honshu Island on May 3, a week after the accidental release. Aoyama suggested that the radioactive material was transported to Japan by the Northern Hemispheric westerlies at a speed of $\sim 1,000$ km/day. The mean zonal wind speed in the Northern Hemispheric springtime at 45° latitude and altitudes of 4 to 5 km will range from ~ 850 to ~ 1300 km/day (Eliassen, 1977). Low levels of radioactivity, primarily ^{131}I and ^{137}Cs , were first measured at Rexburg, and Beaverton, OR in surface air and rainfall samples collected on May 5th. This time of arrival in the northwestern United States suggests that the radioactive cloud was transported in the polar front westerlies at wind speeds of ~ 1500 km/day. Using the mean zonal wind speeds calculated by Eliassen, the radioactive cloud may have been transported at altitudes ranging from 4 to 7 km at 45°N latitude.

From Figures 11 and 12 it can be observed that a sudden simultaneous arrival of elevated ^{131}I and ^{137}Cs on May 9 to May 10 at both the western and eastern contiguous United States sites occurred. The magnitude of the surface air concentrations of ^{131}I and ^{137}Cs at these sites were similar. This pattern suggests large scale vertical and horizontal mixing over the contiguous United States. If the radioactive cloud was being transported easterly

in the surface air, this cloud of elevated concentrations of radionuclides would have been detected at the western United States sites several days before its arrival at the eastern United States.

The simultaneous arrival of elevated radioactivity in the contiguous United States supports the scenario that the radioactive cloud was transported via the polar front westerlies at ~1500 km/day at altitudes ranging from 4 to 7 km. This transport mechanism would position the radioactive cloud over the entire United States on May 9 if it is assumed that the radioactive material was released into the atmosphere at Chernobyl during the initial explosion and injected into the atmosphere up to 7 km in altitude. This transport mechanism also agrees with the observations by Thomas (1986) of the increase in the surface air activities of long-lived radionuclides, such as ^{137}Cs , in Paris between May 10 and May 19. Thomas suggested that this pattern resulted from the second passage of the radioactive cloud over Paris after circumnavigation of the earth.

Several other patterns in the temporal and spatial distribution of radionuclides in the surface air support this transport scenario. Elevated surface air concentrations of ^{131}I and ^{137}Cs coincide with elevated surface air concentrations of ^7Be at all sites sampled in our study throughout May. ^7Be is a natural radionuclide produced by cosmic rays in the stratosphere and upper troposphere. The presence of elevated concentrations of ^7Be in the surface air indicate vertical mixing with the upper troposphere. It is interesting to note that Thomas (1986) reported that the concentrations of cosmogenic ^7Be in Paris remained constant throughout their observations.

With the absence of detailed information on the release of radioactivity from the Chernobyl site, we have assumed two possible scenarios. The first assumes that a large portion of the radioactive materials were released and injected to elevated altitudes during the initial fire and explosion. The second assumes that the radioactive debris was released and injected into the upper troposphere continuously at varying rates for several days following the initial explosion and fire. Stante (1986) reported that fission products were released at the Chernobyl site until May 13. Various aspects of our data support each possible scenario.

In Figures 11 and 12, it can be observed that Rexburg, ID, located at an altitude of 1.5 km in the lee waves of the Salmon River Mountain range, which may continually enhance vertical mixing, had particulate ^{131}I and ^{137}Cs surface air concentrations that were generally two times higher than the surface air concentrations observed at all of the other sites. Surface air concentrations of ^{131}I at Rexburg $> 250 \text{ fCi/m}^3$ and ^{137}Cs levels $> 100 \text{ fCi/m}^3$ lasted for about nine consecutive days. Since ^{131}I has a half-life of 8.04 days, a continuous source of ^{131}I was being transported to Rexburg. The major elevated concentrations of ^{131}I and ^{137}Cs in the surface air observed by Aoyama (1986) also lasted for ~10 days. The ^{137}Cs levels in the surface air in Paris due to global transport of the radioactive cloud also lasted for ~10 days (Thomas, 1986).

In the study of the circumglobal transport of the El Chichon volcanic dust cloud, Robock (1983) observed the longitudinal stretching of the dust cloud, which may be due to vertical wind shear creating different transport velocities at different altitudes. A similar effect may have been operating during the transport of the radioactive cloud from Chernobyl. After the initial explosion, a gradient in concentration and composition of radionuclides with altitude may have existed. The zonal transport of a section of this cloud along with the longitudinal stretching may explain the extended episode of elevated concentrations observed in Japan, Idaho and Paris. A continuous release of radioactivity from Chernobyl over a period of several days along with longitudinal stretching may also explain this extended episode.

The radioactive cloud observed in Europe in late April and early May, (Devell, 1986; Fry, 1986), may have resulted from the transport of radioactive materials released into the lower atmosphere. Some of the properties of this cloud may differ from the upper atmospheric debris that was transported to the east.

One episode of ^{131}I and ^{137}Cs was observed in the surface air at Chester and New York City. The data suggest that this episode, which occurred on May 9 and 10th resulted from the enhanced vertical and horizontal mixing. The surface air concentrations of particulate ^{131}I and ^{137}Cs at these sites gradually decreased over the next seven days until May 16th after which the concentrations of ^{131}I and ^{137}Cs generally remained $< 25 \text{ fCi/m}^3$. This apparent half-time of 3 days for airborne radioactivity was also observed by Aoyama (1986). Generally, the atmospheric life time will vary with the sources and sinks at a given location and time. Surface air concentrations of $^{131}\text{I} > 450 \text{ fCi/m}^3$ and of $^{137}\text{Cs} > 140 \text{ fCi/m}^3$ were still being measured in the Rexburg, ID samples during mid-May. It would appear that the meteorological conditions that resulted in large scale vertical and horizontal mixing on May 9 and 10th did not reoccur during the remainder of May. The radioactivity measured in the surface air at Rexburg, ID during mid-May apparently was not transported to surface air in the northeastern United States.

The temporal distribution of particulate ^{131}I and ^{137}Cs in the surface air at Moosonee, Ontario, Canada shows several unique characteristics. The sudden elevated concentrations of ^{131}I and ^{137}Cs observed at all of the contiguous United States sites on May 9th and 10th was not observed at Moosonee, Ontario. The site exhibits two distinct episodes of elevated particulate ^{131}I and ^{137}Cs in the surface air during May. The first episode centered around May 13, while the second centered around May 23. These episodes seem offset from those observed at Beaverton, and Rexburg, by about 4 days. The magnitudes of the concentrations of ^{137}Cs are slightly less than the concentrations observed at Rexburg, ID and Beaverton, OR.

During the late winter and early spring, mid-latitude continental air is transported horizontally poleward (Barrie, 1986). This transport process results in elevated air concentrations of crustal materials and man-made pollutants such as sulfate in the Arctic region. A pronounced seasonal cycle of ^{210}Pb and ^7Be , with elevated surface air concentrations from late winter to mid-May, resulting from poleward transport of mid-latitude continental air was observed by Larsen and Feely (1986) at Barrow, AK. Meteorological flow fields favor northern Eurasia as the main source of visibility reducing haze (Barrie, 1986). These findings about transport to the Arctic may partially explain the temporal trends of radioactivity from Chernobyl in the surface air observed at Barrow, AK. Two elevated peaks of ^{131}I were observed on May 18 and May 22. These samples were unique due to the absence of elevated ^{137}Cs concentrations. It is possible that a portion of the initial cloud, enriched in ^{131}I , was transported into the Arctic from Eurasia. A thorough explanation of this pattern may provide interesting information related to the release of radioactivity from Chernobyl, the gas and particulate states of ^{131}I and its transport to the polar region.

The air concentrations at Mauna Loa Observatory, HI for ^{131}I and ^{137}Cs were generally an order of magnitude lower than those observed at our other sites. Detectable ^{131}I was observed from May 9 to May 12 and again from May 16 to May 19. After May 22 both ^{131}I and ^{137}Cs were continually measured in the surface air filters. The periods from May 9 to May 12 and May 16 to May 19 correspond with the two largest ^{131}I peaks observed at Rexburg. It is possible that the observatory was initially on the southern edge of the cloud of radioactivity in the free troposphere. The highest levels of ^{131}I and

^{137}Cs were observed at the end of May. It is possible that during the continual circumnavigation of the earth, the cloud extended latitudinally due to turbulent diffusion resulting in measurable air concentrations of ^{131}I and ^{137}Cs at Mauna Loa. The highest levels of ^{131}I and ^{137}Cs at Mauna Loa were observed on May 29. This sample also had the highest concentration of ^7Be observed during the month of May.

The temporal and spatial variation of the ratio $^{131}\text{I}/^{137}\text{Cs}$, decay corrected to April 26, in the surface air was quite large at all of the sites. The analysis of trends in this activity ratio are complicated by the gaseous and particulate states of ^{131}I . The ratio is only based on particulate ^{131}I . One noticeable feature about the spatial distribution of this ratio was its relatively high values at Barrow, Rexburg, and Mauna Loa.

The activity ratio of $^{137}\text{Cs}/^{134}\text{Cs}$ in surface air filter samples showed no temporal or spatial variations. The mean ratio of 1.9 is similar to that determined by other investigators (Thomas, 1986; Aoyama, 1986; Devell, 1986).

The fallout mechanisms and patterns of radioactivity resulting from Chernobyl in the United States varied with the rainfall pattern and the location and concentration of the debris in the atmosphere. Hohenemser (1986) also found extreme geographical variability depending on rainfall and cloud passage in the vicinity of Konstanz, Germany.

At the two northeastern sites selected for fallout measurements in this study, Chester and New York City, dry deposition contributed more than 50% of the total deposit of ^{131}I and ^{137}Cs from the initial arrival time of these radionuclides through May 19. Heavy rainfall on May 20 through May 22 lowered the surface air concentrations of these radionuclides and washed out a significant quantity of ^{131}I and ^{137}Cs from the atmosphere. The large errors or "less than" values obtained for these samples reflect their low concentration. The large volume of sample collected was not concentrated by evaporation in order to minimize ^{131}I losses. This rainstorm altered the relative contributions of wet and dry deposition to the total deposit. In the northwestern sites sampled, Beaverton and Rexburg, daily rainfall occurred during the period of elevated surface air concentrations of radionuclides. This resulted in significantly greater deposition, primarily as a result of washout, than was observed in the northeastern United States.

The activity ratio of $^{131}\text{I}/^{137}\text{Cs}$ was consistently greater in deposition than the activity ratio observed in the corresponding surface air samples at all sites. This observation suggests that a portion of the gaseous ^{131}I in the atmosphere was deposited. Since the activity ratio obtained for air samples is based on particulate ^{131}I only, the added contribution of gaseous ^{131}I to the total deposit would result in increased $^{131}\text{I}/^{137}\text{Cs}$ ratios in deposition.

The mean total deposit of ^{131}I at the northwestern sites from May 5 through May 22 was 15.2 mCi/km^2 , while that of ^{137}Cs was 2.41 mCi/km^2 . In the northeastern sites the total deposit of ^{131}I from May 5 through May 23 was 3.7 mCi/km^2 , while that of ^{137}Cs was 1.5 mCi/km^2 . The total deposit of ^{131}I in the northwestern United States is about four times greater than the northeastern sites, while the deposit of ^{137}Cs is about 1.6 times greater.

The deposition velocities calculated for ^{131}I , ^{134}Cs and ^{137}Cs were similar to those reported by Feely (1985) for sulfate. In general, the deposition velocity calculated for ^{131}I were greater than the velocity obtained for ^{134}Cs and ^{137}Cs . This may result from the deposition of gaseous ^{131}I , which was not considered in the calculations.

Clearly, our understanding of the transport and deposition of radionuclides released from the Chernobyl-4 reactor accident will increase as more data become available. The interpretations and discussions in this report

have been made using the data available thus far and are presented primarily to formulate some thoughts on the transport and deposition of radionuclides resulting from this accident.

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REFERENCES

- Aoyama, M., K. Hirose, Y. Suzuki, H. Inoue and Y. Sugimura
'High Level Radioactive Nuclides in Japan in May'
Nature, 321, 819-820 (1986)
- Barrie, L.
'Arctic Air Pollution: An Overview of Current Knowledge'
Atmospheric Environment, 20, 643-663 (1986)
- Brownlee, K.
Statistical Theory and Methodology in Science and Engineering
John Wiley and Sons (1965)
- Devell, L., H. Tovedal, U. Bergstrom, A. Appelgren, J. Chyssler and
L. Andersson
'Initial Observations of Fallout from the Reactor Accident at Chernobyl'
Nature, 321, 192-193 (1986)
- Eliassen, A.
Meteorology
in: McGraw-Hill Encyclopedia of Science and Technology, Vol. 8 McGraw-Hill, NY
(1977)
- Feely, H., D. Bogen, S. Nagourney and C. Torquato
'Rates of Dry Deposition Determined Using Wet/Dry Collectors'
J. Geophys. Res., 90, 2161-2165 (1985)
- Feely, H., R. Larsen and C. Sanderson
'Annual Report of the Surface Air Sampling Program'
USDOE Report EML-440, March (1985)
- Fry, F., R. Clarke and M. O'Riordan
'Early Estimates of UK Radiation Doses from the Chernobyl Reactor'
Nature, 321, 193-195, (1986)
- Hohenemser, C., M. Deicher, H. Hofsass, G. Lindner, E. Recknagel and
J. Budnick
'Agriculture Impact of Chernobyl: a Warning'
Nature, 321, 817-817 (1986)
- Langley, R.
Practical Statistics Simply Explained
Dover Publications, Inc. (1971)
- Larsen, R. and H. Feely
'Seasonal Variation of Pb-210 and Be-7 at Mauna Loa Observatory and Barrow,
AK'
Geophysical Monitoring for Climatic Change No. 14, Summary Report 1985, NOAA,
to be published February (1987).

Marshall, E.

'Reactor Explodes Amid Soviet Silence'
Science, 232, 814-815 (1986)

Robock, A. and M. Matson

'Circumglobal Transport of the El Chichon Volcanic Dust Cloud'
Science, 221, 195-197 (1983)

Stanic, N.

'Soviet Representative to IAEA Sketches Chernobyl Accident'
Nucleonics Week, 8-9, May 29 (1986)

Thomas, A. and J. Martin

'First Assessment of Chernobyl Radioactive Plume over Paris'
Nature, 321, 817-819 (1986)

Volchok, H. and G. de Planque (Editors)

'EML Procedures Manual'
HASL-300, 26th Edition, p. A-06-06 (1983)

TABLE OF CONVERSION FACTORS

The following conversion table includes units of measurements used in the EML Fallout Program:

<u>Multiple</u>	<u>Prefix</u>	<u>Symbol</u>	<u>Fraction</u>	<u>Prefix</u>	<u>Symbol</u>
10 ¹⁸	exo	E	10 ⁻¹	deci	d
10 ¹⁵	peta	P	10 ⁻²	centi	c
10 ¹²	tera	T	10 ⁻³	milli	m
10 ⁹	giga	G	10 ⁻⁶	micro	u
10 ⁶	mega	M	10 ⁻⁹	nano	n
10 ³	kilo	k	10 ⁻¹²	pico	p
10 ³	hecto	h	10 ⁻¹⁵	femto	f
10	deka	da	10 ⁻¹⁸	atto	a

Units

Ci	curie
Bq	becquerel
dpm	disintegrations per minute

Conversion Table

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>	<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
MCi	37.0	PBq	PBq	0.027	MCi
kCi	0.037	PBq	PBq	27.027	kCi
kCi	37.0	TBq	TBq	0.027	kCi
dpm	16.667	mBq	mBq	0.060	dpm
mCi/km ²	37.0	Bq/m ²	Bq/m ²	0.027	mCi/km ²
pCi/L	37.0	mBq/L	mBq/L	0.027	pCi/L
fCi/m ³	0.037	mBq/m ³	mBq/m ³	27.027	fCi/m ³

Area of the Earth

	<u>Area</u>		<u>Latitude Band</u>	<u>Area</u>	
	<u>mi²</u>	<u>km²</u>		<u>mi²</u>	<u>km²</u>
Land	57.467 x 10 ⁶	148.892 x 10 ⁶	0-10	17.016 x 10 ⁶	44.084 x 10 ⁶
			10-20	16.512 x 10 ⁶	42.778 x 10 ⁶
			20-30	15.516 x 10 ⁶	40.198 x 10 ⁶
			30-40	14.052 x 10 ⁶	36.405 x 10 ⁶
Ocean and Seas	139.369 x 10 ⁶	148.892 x 10 ⁶	40-50	12.158 x 10 ⁶	31.497 x 10 ⁶
			50-60	9.884 x 10 ⁶	25.607 x 10 ⁶
			60-70	7.297 x 10 ⁶	18.905 x 10 ⁶
			70-80	1.508 x 10 ⁶	11.594 x 10 ⁶
Total	196.836 x 10 ⁶	509.951 x 10 ⁶	80-90	1.508 x 10 ⁶	3.908 x 10 ⁶

TABLE OF RADIONUCLIDES

Isabel M. Fisenne (EML)

The following table is a revised listing of radionuclides of interest in the EML environmental program. The half-life values are currently used at EML and are subject to change as new data become available. The reference for this tabulation is:

Table of Isotopes, 7th edition
C.M. Lederer and V.S. Shirley, editors
John Wiley and Sons, Inc., New York (1978)

RADIOACTIVE		HALF-LIFE		RADIOACTIVE		HALF-LIFE	
NUCLIDES	DAUGHTER	DAYS	OTHER UNITS	NUCLIDE	DAUGHTER	DAYS	OTHER UNITS
Fission Products				Reactor Corrosion and Activation Products			
85 36Kr		3908.5	10.701y	16 7N			7.13s
89 38Sr		50.55		24 11Na		0.626	15.03h
90 38Sr	90 39Y	1.05 x 10 ⁴	28.82y	51 24Cr		27.701	
		2.67	64.06h	54 25Mn		312.20	0.855y
91 39Y		58.51		56 25Mn			2.578h
95 40Zr	95 41Nb	63.98		55 26Fe		980.7	2.685y
		34.97		59 26Fe		44.56	
103 44Ru	103m 45Rh	39.35		57 27Co		271.65	0.744
				58 27Co		70.78	
106 44Ru	106 45Rh	366.5	1.003y	60 27Co		1925.6	5.272y
				29.80s	63 28Ni		3.66 x 10 ⁴
115m 48Cd		44.8		64 29Cu		0.529	12.699h
125 51Sb	125m 52Te	989.83	2.71y	65 30Zn		244.0	0.668y
			58.		102m 45Rh		206.
129 53I		5.73 x 10 ⁹	1.57 x 10 ⁷ y	102 45Rh		1059.2	2.9y
131 53I		8.04		109 48Cd	109m 47Ag	453.	1.254y
133 54Xe		5.245				39.8s	
134 55Cs		753.15	2.062y	113m 48Cd		5332.7	14.6y
136 55Cs		13.0		124 51Sb		60.2	
137 55Cs	137m 56Ba	1.10 x 10 ⁴	30.174y				
				2.55m			
140 56Ba	140 57La	12.789					
			1.678	40.27h			
141 58Ce		32.55					
144 58Ce	144 59Pr	284.5	0.779y				
				17.30m			
143 59Pr		13.59					
147 60Nd	147 61Pm	10.98					
			958.05	2.623y			

TABLE OF RADIONUCLIDES (Cont'd)

NUCLIDES	RADIOACTIVE DAUGHTER	HALF-LIFE		NUCLIDE	RADIOACTIVE DAUGHTER	HALF-LIFE	
		DAYS	OTHER UNITS			DAYS	OTHER UNITS
<u>Cosmogenic</u>				<u>Other Radionuclides</u>			
³ ₁ H		4509.4	12.346y	²⁰⁸ ₈₄ Po		1058.5	2.898y
⁷ ₄ Be		53.29		²⁰⁹ ₈₄ Po	↙	3.73 x 10 ⁴	102y
¹⁴ ₆ C		2.09 x 10 ⁶	5730y		²⁰⁵ ₈₂ Pb	5.11 x 10 ⁹	1.4 x 10 ⁷ y
²² ₁₁ Na		950.4	2.602y	²²⁹ ₉₀ Th	↙	2.68 x 10 ⁶	7340y
<u>Terrestrial</u>					²²⁵ ₈₈ Ra	14.8	
⁴⁰ ₁₉ K		4.66 x 10 ¹¹	1.277 x 10 ⁹ y		²²⁵ ₈₉ Ac	10.	
²³⁸ ₉₂ U	↙	1.63 x 10 ¹²	4.468 x 10 ⁹ y		²²¹ ₈₇ Fr		4.8m
	²³⁴ ₉₀ Th	24.101			²¹⁷ ₈₅ At		3.23 x 10 ⁻³ s
	^{234m} ₉₁ Pa		1.175m		²¹³ ₈₃ Bi		45.59m
	²³⁴ ₉₂ U	8.93 x 10 ⁷	2.446 x 10 ⁵ y		²¹³ ₈₄ Po		4.2 x 10 ⁻⁶
	²³⁰ ₉₀ Th	2.92 x 10 ⁷	8.0 x 10 ⁴ y	²³² ₉₂ U	↙	0.136	3.253h
	²²⁶ ₈₈ Ra	5.84 x 10 ⁵	1599y		²²⁸ ₉₀ Th	2.63 x 10 ⁴	71.9y
	²²² ₈₆ Rn	3.824		²³⁶ ₉₄ Pu	↙	698.7	1.913y
	²¹⁸ ₈₄ Po		3.05m		²³² ₉₂ U	1041.3	2.851y
	²¹⁴ ₈₂ Pb		26.8m	²³⁸ ₉₄ Pu	↙	2.63 x 10 ⁴	71.9y
	²¹⁴ ₈₃ Bi		19.7m		²³⁴ ₉₂ U	3.20 x 10 ⁴	87.71y
	²¹⁴ ₈₄ Po		1.64 x 10 ⁻⁴ s	²³⁹ ₉₄ Pu	↙	8.93 x 10 ⁷	2.446 x 10 ⁵ y
	²¹⁰ ₈₂ Pb	8130.5	22.26y		²³⁵ ₉₂ U	8.81 x 10 ⁶	2.413 x 10 ⁴ y
	²¹⁰ ₈₃ Bi	6.013		²⁴⁰ ₉₄ Pu	↙	2.57 x 10 ¹¹	7.038 x 10 ⁸ y
	²¹⁰ ₈₄ Po	138.376			²³⁶ ₉₂ U	2.40 x 10 ⁶	6570y
²³² ₉₀ Th	↙	5.15 x 10 ¹²	1.41 x 10 ¹⁰ y	²⁴¹ ₉₄ Pu	↙	8.55 x 10 ⁹	2.341 x 10 ⁷ y
	²²⁸ ₈₈ Ra	2107.5	5.77y		²⁴¹ ₉₅ Am	5243.	14.355y
	²²⁸ ₈₉ Ac	0.255	6.13h	²⁴² ₉₄ Pu	↙	1.58 x 10 ⁴	432.0y
	²²⁸ ₉₀ Th	698.7	1.913y		²³⁸ ₉₂ U	1.37 x 10 ⁸	3.763 x 10 ⁵ y
	²²⁴ ₈₈ Ra	3.665		²⁴³ ₉₅ Am	↙	1.63 x 10 ¹²	4.468 x 10 ⁹ y
	²²⁰ ₈₆ Rn		55.61s		²³⁹ ₉₃ Np	2.69 x 10 ⁶	7370y
	²¹⁶ ₈₄ Po		0.145s		²³⁹ ₉₄ Pu	2.346	
	²¹² ₈₂ Pb	0.444	10.643h	²⁴² ₉₆ Cm	↙	8.81 x 10 ⁶	2.413 x 10 ⁴ y
	²¹² ₈₃ Bi	0.0421	60.60m		²³⁸ ₉₄ Pu	162.76	0.446
	²¹² ₈₄ Po		2.96 x 10 ⁻⁷ s	²⁴³ ₉₆ Cm	↙	3.20 x 10 ⁴	87.81y
²¹² ₈₄ Po	↙		3.053m		²³⁹ ₉₄ Pu	1.04 x 10 ⁴	28.5y
	²⁰⁸ ₈₁ Tl			²⁴⁴ ₉₆ Cm	↙	8.81 x 10 ⁶	2.413 x 10 ⁴ y
					²⁴⁰ ₉₄ Pu	6.61 x 10 ³	18.099y
						2.40 x 10 ⁶	6570y

TABLE 1
Site Locations

Location	Latitude	Longitude	Altitude (M)
Barrow, Alaska	N 71:10	W 156:30	4
Moosonee, Canada	N 51:16	W 80:30	10
Beaverton, Oregon	N 45:32	W 122:53	64
Rexburg, Idaho	N 43:48	W 111:50	1502
Chester, New Jersey	N 40:48	W 74:40	268
New York, New York	N 40:44	W 74:00	56
Key Biscayne, Florida	N 25:49	W 80:17	20
Miami, Florida	N 25:49	W 80:17	7
Mauna Loa, Hawaii	N 19:28	W 155:36	3401

TABLE 2
Samples Collected and Analyzed

Location	Air Filters	Bulk Wet	Bulk Dry
Barrow, Alaska	25 (25)	5 (0)	11 (0)
Moosonee, Canada	27 (27)	2 (0)	14 (0)
Beaverton, Oregon	24 (24)	12 (12)	11 (5)
Rexburg, Idaho	24 (24)	9 (9)	8 (7)
Chester, New Jersey	19 (19)	6 (6)	2 (2)
New York, New York	71 (71)	6 (6)	20 (4)
Key Biscayne, Florida	11 (11)	0	0
Miami, Florida	4 (4)	0	0
Mauna Loa, Hawaii	21 (21)	4 (0)	12 (0)

() Represent analyzed samples

TABLE 3
Surface Air Concentrations at Barrow, Alaska *

		(FemtoCurie/Cubic Meter)					
Collection Period		8e-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/05 1615L - 5/06 1235L		34.6+/-10.9	< 19.0	< 1.5	< 1.9	< 2.8	< 16.7
5/06 1235L - 5/07 1445L		57.9+/-8.0	23.2+/-10.5	< 0.8	< 1.1	< 1.9	< 8.2
5/07 1445L - 5/08 1445L		55.2+/-9.1	17.5+/-6.9	2.3+/-0.8	1.6+/-0.7		
5/08 1445L - 5/09 1440L		104.1+/-17.4	63.8+/-13.8	2.9+/-0.8	5.6+/-1.4	4.6+/-1.8	< 22.3
5/09 1440L - 5/11 1410L		94.2+/-0.1	46.2+/-2.5	18.0+/-1.4	27.6+/-1.5		
5/11 1410L - 5/12 1445L		52.4+/-9.5	32.6+/-2.2	18.6+/-1.3	25.4+/-1.3		
5/12 1445L - 5/13 1450L		38.1+/-11.7	42.9+/-2.4	9.5+/-0.7	19.4+/-1.2		
5/13 1450L - 5/14 1405L		61.7+/-7.5	23.6+/-1.6	11.0+/-0.9	14.2+/-0.9		
5/14 1405L - 5/15 1455L		< 29.8	42.7+/-3.1	< 1.8	< 2.3		
5/15 1455L - 5/16 1455L		37.5+/-4.9	34.5+/-1.2	4.0+/-0.3	8.2+/-0.5		
5/16 1455L - 5/17 1455L		29.8+/-7.9	36.7+/-1.6	2.6+/-0.6	6.6+/-0.8		
5/17 1455L - 5/18 1425L		50.3+/-12.0	178.6+/-5.9	4.2+/-1.1	6.3+/-1.3		
5/18 1425L - 5/19 1340L		40.4+/-5.7	89.3+/-5.7	3.6+/-0.8	7.0+/-0.8	2.8+/-0.6	< 6.7
5/19 1340L - 5/20 1445L		50.2+/-5.7	66.1+/-4.0	6.7+/-0.7	13.3+/-0.9	3.9+/-0.6	< 4.9
5/20 1445L - 5/21 1445L		57.6+/-6.7	57.5+/-4.0	8.1+/-0.8	15.5+/-1.0	5.6+/-0.7	< 5.3
5/21 1445L - 5/22 1505L		55.2+/-5.6	218.7+/-6.6	7.8+/-0.8	15.5+/-1.0	8.1+/-0.8	< 6.2
5/22 1505L - 5/23 1445L		46.3+/-5.0	54.7+/-3.0	6.0+/-0.8	13.2+/-0.8	8.3+/-0.7	< 4.9
5/23 1445L - 5/24 1445L		27.8+/-2.7	57.3+/-2.7	3.8+/-0.4	7.3+/-0.6	4.6+/-0.5	< 3.6
5/24 1445L - 5/25 1430L		33.8+/-3.3	39.8+/-2.0	4.3+/-0.4	8.8+/-0.5	4.9+/-0.4	< 2.5
5/25 1430L - 5/26 1440L		41.9+/-3.5	33.7+/-1.4	5.4+/-0.4	11.0+/-0.5	9.3+/-0.5	< 4.3
5/26 1440L - 5/27 1520L		47.3+/-2.7	25.6+/-1.0	8.2+/-0.4	16.8+/-0.5	15.3+/-0.5	< 3.0

* Air filter sample collected using a Brooks/Roots system (SASP pump)
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 4

Surface Air Concentrations at Barrow, Alaska *

(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/05 1615L - 5/06 1235L	1.28+/-0.40	< 0.70	< 0.06	< 0.07	< 0.10	< 0.62
5/06 1235L - 5/07 1445L	2.14+/-0.30	0.86+/-0.37	< 0.03	< 0.04	< 0.07	< 0.30
5/07 1445L - 5/08 1445L	2.04+/-0.34	0.65+/-0.26	0.09+/-0.03	0.06+/-0.03		
5/08 1445L - 5/09 1440L	3.85+/-0.64	2.36+/-0.48	0.11+/-0.03	0.21+/-0.05	0.17+/-0.07	< 0.83
5/09 1440L - 5/11 1410L	3.49+/-0.00	1.71+/-0.09	0.67+/-0.05	1.02+/-0.06		
5/11 1410L - 5/12 1445L	1.94+/-0.35	1.21+/-0.08	0.69+/-0.05	0.94+/-0.05		
5/12 1445L - 5/13 1450L	1.41+/-0.43	1.59+/-0.09	0.35+/-0.03	0.72+/-0.04		
5/13 1450L - 5/14 1405L	2.28+/-0.28	0.87+/-0.06	0.41+/-0.03	0.53+/-0.03		
5/14 1405L - 5/15 1455L	< 1.10	1.58+/-0.11	< 0.07	< 0.09		
5/15 1455L - 5/16 1455L	1.39+/-0.18	1.28+/-0.04	0.15+/-0.01	0.30+/-0.02		
5/16 1455L - 5/17 1455L	1.10+/-0.29	1.36+/-0.06	0.10+/-0.02	0.24+/-0.03		
5/17 1455L - 5/18 1425L	1.86+/-0.44	6.61+/-0.22	0.16+/-0.04	0.23+/-0.05		
5/18 1425L - 5/19 1340L	1.49+/-0.21	3.30+/-0.21	0.13+/-0.03	0.26+/-0.03	0.10+/-0.02	< 0.25
5/19 1340L - 5/20 1445L	1.86+/-0.21	2.45+/-0.15	0.25+/-0.03	0.49+/-0.03	0.14+/-0.02	< 0.18
5/20 1445L - 5/21 1445L	2.13+/-0.25	2.13+/-0.15	0.30+/-0.03	0.57+/-0.04	0.21+/-0.03	< 0.20
5/21 1445L - 5/22 1505L	2.04+/-0.21	8.09+/-0.24	0.29+/-0.03	0.57+/-0.04	0.30+/-0.03	< 0.23
5/22 1505L - 5/23 1445L	1.71+/-0.19	2.02+/-0.11	0.22+/-0.03	0.49+/-0.03	0.31+/-0.03	< 0.18
5/23 1445L - 5/24 1445L	1.03+/-0.10	2.12+/-0.10	0.14+/-0.01	0.27+/-0.02	0.17+/-0.02	< 0.13
5/24 1445L - 5/25 1430L	1.25+/-0.12	1.47+/-0.07	0.16+/-0.01	0.33+/-0.02	0.18+/-0.01	< 0.09
5/25 1430L - 5/26 1440L	1.55+/-0.13	1.25+/-0.05	0.20+/-0.01	0.41+/-0.02	0.34+/-0.02	< 0.16
5/26 1440L - 5/27 1520L	1.75+/-0.10	0.95+/-0.04	0.30+/-0.01	0.62+/-0.02	0.57+/-0.02	< 0.11

* Air filter sample collected using a Brooks/Roots system (SASP pump)

< Less than reported value

Errors reported represent two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 5
Surface Air Concentrations at Barrow, Alaska *
(Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/05 1615L - 5/06 1235L	< 25.6	< 14.4	< 4.0		< 2.3	< 5.6
5/06 1235L - 5/07 1445L	< 28.0	< 12.3	< 2.9		< 2.7	< 5.3
5/07 1445L - 5/08 1445L	< 24.3	< 7.9	< 2.6		< 1.3	< 4.4
5/08 1445L - 5/09 1440L	< 30.7	< 15.1	< 4.4		< 3.5	< 11.3
5/09 1440L - 5/11 1410L	8.8+/-3.5	< 8.8	2.6+/-0.8	< 5.8	< 1.2	< 3.3
5/11 1410L - 5/12 1445L	12.4+/-5.1	< 7.7	< 1.7	< 11.9	< 1.6	< 5.8
5/12 1445L - 5/13 1450L	< 8.6	< 8.6	< 2.5	< 8.5	< 1.4	< 5.6
5/13 1450L - 5/14 1405L	< 5.9	< 6.2	< 2.0	< 5.0	< 0.8	< 3.1
5/14 1405L - 5/15 1455L	< 9.7	< 8.1	< 2.9	< 5.8	< 1.4	< 5.0
5/15 1455L - 5/16 1455L	< 4.9	< 3.6	< 0.8	< 2.7	< 0.8	< 2.3
5/16 1455L - 5/17 1455L	< 5.3	< 5.6	< 1.9	< 3.5	< 1.6	< 5.4
5/17 1455L - 5/18 1425L	< 9.1	< 6.5	< 3.6	< 13.4	< 3.0	< 10.2
5/18 1425L - 5/19 1340L	< 7.5	< 6.5	< 2.1	< 94.2	< 0.9	< 2.8
5/19 1340L - 5/20 1445L	< 5.7	< 5.7	< 1.1	< 70.8	< 0.9	< 2.1
5/20 1445L - 5/21 1445L	< 6.9	< 8.0	< 1.1	< 66.3	< 0.9	< 3.5
5/21 1445L - 5/22 1505L	< 7.1	< 7.8	< 1.0	< 52.5	< 1.2	< 3.5
5/22 1505L - 5/23 1445L	< 6.7	< 6.2	< 1.5	< 34.3	< 0.6	< 1.7
5/23 1445L - 5/24 1445L	< 4.2	< 3.8	< 1.6	< 23.0	< 0.6	< 1.6
5/24 1445L - 5/25 1430L	< 3.3	< 3.2	< 0.6	< 17.7	< 0.6	< 1.7
5/25 1430L - 5/26 1440L	< 3.0	< 2.9	< 1.0	< 9.3	< 0.5	< 1.2
5/26 1440L - 5/27 1520L	3.0+/-1.3	3.5+/-1.6	< 0.5	< 7.2	< 0.5	< 1.6

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 6
Surface Air Concentrations at Barrow, Alaska *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/05 1615L - 5/06 1235L	< 0.95	< 0.53	< 0.15		< 0.09	< 0.21
5/06 1235L - 5/07 1445L	< 1.04	< 0.46	< 0.11		< 0.10	< 0.20
5/07 1445L - 5/08 1445L	< 0.90	< 0.29	< 0.10		< 0.05	< 0.16
5/08 1445L - 5/09 1440L	< 1.14	< 0.56	< 0.16		< 0.13	< 0.42
5/09 1440L - 5/11 1410L	0.33+/-0.13	< 0.33	0.10+/-0.03	< 0.21	< 0.04	< 0.12
5/11 1410L - 5/12 1445L	0.46+/-0.19	< 0.28	< 0.06	< 0.44	< 0.06	< 0.21
5/12 1445L - 5/13 1450L	< 0.32	< 0.32	< 0.09	< 0.31	< 0.05	< 0.21
5/13 1450L - 5/14 1405L	< 0.22	< 0.23	< 0.07	< 0.19	< 0.03	< 0.11
5/14 1405L - 5/15 1455L	< 0.36	< 0.30	< 0.11	< 0.21	< 0.05	< 0.19
5/15 1455L - 5/16 1455L	< 0.18	< 0.13	< 0.03	< 0.10	< 0.03	< 0.09
5/16 1455L - 5/17 1455L	< 0.20	< 0.21	< 0.07	< 0.13	< 0.06	< 0.20
5/17 1455L - 5/18 1425L	< 0.34	< 0.24	< 0.13	< 0.50	< 0.11	< 0.38
5/18 1425L - 5/19 1340L	< 0.28	< 0.24	< 0.08	< 3.49	< 0.03	< 0.10
5/19 1340L - 5/20 1445L	< 0.21	< 0.21	< 0.04	< 2.62	< 0.03	< 0.08
5/20 1445L - 5/21 1445L	< 0.26	< 0.30	< 0.04	< 2.45	< 0.03	< 0.13
5/21 1445L - 5/22 1505L	< 0.26	< 0.29	< 0.04	< 1.94	< 0.04	< 0.13
5/22 1505L - 5/23 1445L	< 0.25	< 0.23	< 0.06	< 1.27	< 0.02	< 0.06
5/23 1445L - 5/24 1445L	< 0.16	< 0.14	< 0.06	< 0.85	< 0.02	< 0.06
5/24 1445L - 5/25 1430L	< 0.12	< 0.12	< 0.02	< 0.65	< 0.02	< 0.047
5/25 1430L - 5/26 1440L	< 0.11	< 0.11	< 0.04	< 0.34	< 0.02	< 0.04
5/26 1440L - 5/27 1520L	0.11+/-0.05	0.13+/-0.06	< 0.02	< 0.27	< 0.02	< 0.06

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 7
Surface Air Concentrations at Moosonee, Ontario Canada *
(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/02 1400L - 5/03 1400L	105.8+/-10.6	< 14.8	< 0.9	< 1.3		
5/03 1400L - 5/04 1400L	115.5+/-9.4	< 9.2	< 1.0	< 0.8		
5/04 1400L - 5/05 1400L	120.0+/-9.7	< 10.2	< 1.6	< 0.9		
5/05 1400L - 5/06 1400L	165.2+/-16.0	< 17.2	< 1.7	< 1.9		
5/06 1400L - 5/07 1400L	115.1+/-16.0	< 34.3	3.5+/-1.0	8.8+/-1.6		
5/07 1400L - 5/08 1400L	88.5+/-6.8	37.2+/-2.3	6.4+/-0.3	12.1+/-0.7		
5/08 1400L - 5/09 1400L	72.6+/-11.3	18.5+/-2.4	1.5+/-0.7	4.6+/-0.7		
5/09 1400L - 5/10 1400L	34.4+/-5.1	8.9+/-1.2	0.6+/-0.2	1.2+/-0.3		
5/10 1400L - 5/11 1400L	< 11.5	5.9+/-2.4	2.9+/-1.0	2.7+/-0.8		
5/11 1400L - 5/12 1400L	166.7+/-18.8	27.8+/-3.2	33.3+/-2.6	46.0+/-2.8		
5/12 1400L - 5/13 1400L	228.0+/-15.9	104.9+/-2.9	85.8+/-1.3	164.4+/-2.7		
5/13 1400L - 5/14 1400L	338.9+/-24.9	188.9+/-6.4	99.6+/-3.3	148.0+/-3.7		
5/14 1400L - 5/15 1400L	263.0+/-21.9	105.3+/-5.2	77.6+/-2.8	121.6+/-3.2		
5/15 1400L - 5/16 1400L	117.3+/-16.9	41.9+/-3.0	28.8+/-1.2	58.2+/-2.2		
5/16 1400L - 5/17 1400L	110.0+/-16.7	17.3+/-3.7	17.3+/-1.9	23.3+/-2.1		
5/17 1400L - 5/18 1400L	62.8+/-14.6	20.5+/-3.9	7.4+/-1.3	19.1+/-2.0		
5/18 1400L - 5/19 1400L	83.8+/-3.9	35.6+/-1.1	12.4+/-0.3	23.7+/-0.7		
5/19 1400L - 5/20 1400L	113.5+/-7.2	44.2+/-1.5	12.8+/-0.6	27.1+/-0.8		
5/20 1400L - 5/21 1400L	182.9+/-22.0	70.4+/-16.0	27.0+/-1.4	49.7+/-3.0	55.0+/-3.4	17.9+/-4.0
5/21 1400L - 5/22 1400L	284.8+/-48.0	98.3+/-30.0	60.5+/-6.2	115.1+/-7.2	141.7+/-9.0	54.9+/-18.0
5/22 1400L - 5/23 1400L	174.1+/-26.0	85.8+/-19.2	57.7+/-3.6	114.1+/-4.2	151.8+/-5.2	57.5+/-24.0
5/23 1400L - 5/24 1400L	245.3+/-46.0	81.9+/-28.0	65.1+/-6.4	133.2+/-7.6	152.4+/-9.2	79.6+/-48.0
5/24 1400L - 5/25 1400L	220.4+/-44.0	33.9+/-20.0	50.8+/-6.0	107.4+/-7.2	123.6+/-8.0	45.9+/-17.2
5/25 1400L - 5/26 1400L	213.5+/-46.0	57.2+/-24.0	44.4+/-5.4	87.6+/-6.2	119.9+/-7.8	29.9+/-17.6

* Air filter sample collected using a Brooks/Roots system (SASP pump)
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 7 (Cont'd)
Surface Air Concentrations at Moosonee, Ontario Canada *
(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/26 1400L - 5/27 1400L	249.4+/-24.0	51.5+/-11.6	42.3+/-3.2	84.5+/-3.8	107.0+/-4.2	41.0+/-10.2
5/27 1400L - 5/28 1400L	134.3+/-20.0	27.0+/-10.0	23.8+/-1.3	50.3+/-2.8	56.5+/-3.4	17.6+/-8.2
5/28 1400L - 5/29 1400L	161.5+/-35.0	20.6+/-10.1	17.0+/-2.6	34.7+/-2.2	52.4+/-1.8	

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 8
Surface Air Concentrations at Moosonee, Ontario Canada *
(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/02 1400L - 5/03 1400L	3.91+/-0.39	< 0.55	< 0.03	< 0.05		
5/03 1400L - 5/04 1400L	4.27+/-0.35	< 0.34	< 0.04	< 0.03		
5/04 1400L - 5/05 1400L	4.44+/-0.36	< 0.38	< 0.06	< 0.03		
5/05 1400L - 5/06 1400L	6.11+/-0.59	< 0.64	< 0.06	< 0.07		
5/06 1400L - 5/07 1400L	4.26+/-0.59	< 1.27	0.13+/-0.04	0.33+/-0.06		
5/07 1400L - 5/08 1400L	3.27+/-0.25	1.38+/-0.09	0.24+/-0.01	0.45+/-0.03		
5/08 1400L - 5/09 1400L	2.69+/-0.42	0.68+/-0.09	0.06+/-0.03	0.17+/-0.03		
5/09 1400L - 5/10 1400L	1.27+/-0.19	0.33+/-0.04	0.02+/-0.01	0.04+/-0.01		
5/10 1400L - 5/11 1400L	< 0.43	0.22+/-0.09	0.11+/-0.04	0.10+/-0.03		
5/11 1400L - 5/12 1400L	6.17+/-0.70	1.03+/-0.12	1.23+/-0.10	1.70+/-0.10		
5/12 1400L - 5/13 1400L	8.44+/-0.59	3.88+/-0.11	3.17+/-0.05	6.08+/-0.10		
5/13 1400L - 5/14 1400L	12.54+/-0.92	6.99+/-0.24	3.69+/-0.12	5.48+/-0.14		
5/14 1400L - 5/15 1400L	9.73+/-0.81	3.90+/-0.19	2.88+/-0.10	4.50+/-0.12		
5/15 1400L - 5/16 1400L	4.34+/-0.63	1.55+/-0.11	1.07+/-0.04	2.15+/-0.08		
5/16 1400L - 5/17 1400L	4.07+/-0.62	0.64+/-0.14	0.64+/-0.07	0.86+/-0.08		
5/17 1400L - 5/18 1400L	2.32+/-0.54	0.76+/-0.14	0.27+/-0.05	0.71+/-0.07		
5/18 1400L - 5/19 1400L	3.10+/-0.14	1.32+/-0.04	0.46+/-0.01	0.88+/-0.03		
5/19 1400L - 5/20 1400L	4.20+/-0.27	1.64+/-0.06	0.47+/-0.02	1.00+/-0.03		
5/20 1400L - 5/21 1400L	6.77+/-0.81	2.60+/-0.59	1.00+/-0.05	1.84+/-0.11	2.04+/-0.13	0.66+/-0.15
5/21 1400L - 5/22 1400L	10.54+/-1.78	3.64+/-1.11	2.24+/-0.23	4.26+/-0.27	5.24+/-0.33	2.03+/-0.67
5/22 1400L - 5/23 1400L	6.44+/-0.96	3.17+/-0.70	2.13+/-0.13	4.22+/-0.16	5.62+/-0.19	2.13+/-0.89
5/23 1400L - 5/24 1400L	9.08+/-1.70	3.03+/-1.04	2.41+/-0.24	4.93+/-0.28	5.64+/-0.34	2.95+/-1.78
5/24 1400L - 5/25 1400L	8.15+/-1.63	1.25+/-0.74	1.88+/-0.22	3.97+/-0.27	4.57+/-0.30	1.70+/-0.64
5/25 1400L - 5/26 1400L	7.90+/-1.70	2.12+/-0.89	1.64+/-0.20	3.24+/-0.23	4.44+/-0.29	1.11+/-0.65

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 8 (Cont'd)
Surface Air Concentrations at Moosonee, Ontario Canada *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/26 1400L - 5/27 1400L	9.23+/-0.89	1.91+/-0.41	1.57+/-0.12	3.13+/-0.14	3.96+/-0.16	1.52+/-0.38
5/27 1400L - 5/28 1400L	4.97+/-0.74	1.00+/-0.37	0.88+/-0.05	1.86+/-0.10	2.09+/-0.13	0.65+/-0.30
5/28 1400L - 5/29 1400L	5.98+/-1.30	0.76+/-0.37	0.63+/-0.10	1.28+/-0.08	1.94+/-0.07	

* Air filter sample collected using a Brooks/Roots system (SASP pump)
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 9

Surface Air Concentrations at Moosonee, Ontario Canada *

(Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/02 1400L - 5/03 1400L	< 27.1	< 9.6	< 2.0	< 3.8	< 2.7	< 8.1
5/03 1400L - 5/04 1400L	< 15.5	< 7.3	2.7+/-1.3	< 1.8	< 1.2	< 4.0
5/04 1400L - 5/05 1400L	< 15.0	< 8.1	< 1.7	< 1.7	< 1.3	< 2.0
5/05 1400L - 5/06 1400L	< 19.2	< 8.8	< 2.9	< 4.4	< 2.2	< 7.9
5/06 1400L - 5/07 1400L	< 33.0	< 19.6	< 5.8	< 2.6	< 3.1	< 6.7
5/07 1400L - 5/08 1400L	< 6.9	< 8.6	< 1.2	< 31.1	< 0.7	< 2.4
5/08 1400L - 5/09 1400L	< 7.8	< 10.4	< 3.1	< 25.4	< 1.8	< 4.9
5/09 1400L - 5/10 1400L	< 6.2	< 4.9	< 1.0	< 8.5	< 0.8	< 2.3
5/10 1400L - 5/11 1400L	< 9.0	< 4.1	4.7+/-0.2	< 14.1	< 1.5	< 5.2
5/11 1400L - 5/12 1400L	25.6+/-8.7	< 15.9	< 3.6	< 9.5	< 1.6	< 10.7
5/12 1400L - 5/13 1400L	38.4+/-6.5	24.1+/-2.0	< 2.1	< 10.1	< 2.1	< 5.9
5/13 1400L - 5/14 1400L	32.0+/-10.5	22.3+/-10.5	< 3.7	< 26.9	< 3.0	< 6.4
5/14 1400L - 5/15 1400L	33.6+/-10.0	23.3+/-6.8	< 3.6	< 28.8	3.2+/-1.2	< 9.1
5/15 1400L - 5/16 1400L	< 13.3	< 12.9	< 2.9	< 10.5	< 2.7	< 8.0
5/16 1400L - 5/17 1400L	10.4+/-5.1	< 15.5	< 3.2	< 16.0	< 1.9	8.9+/-4.1
5/17 1400L - 5/18 1400L	< 15.9	< 6.2	< 2.8	< 27.8	< 3.8	< 13.0
5/18 1400L - 5/19 1400L	4.2+/-2.1	< 3.7	< 0.6	< 6.8	< 0.4	< 1.6
5/19 1400L - 5/20 1400L	< 6.2	< 6.2	< 1.2	< 8.8	< 1.3	< 3.9

* Air filter sample collected using a Brooks/Roots system (SASP pump)

< Less than reported value

Errors reported represent two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 10
Surface Air Concentrations at Moosonee, Ontario Canada *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ca-144
5/02 1400L - 5/03 1400L	< 1.00	< 0.36	< 0.07	< 0.14	< 0.10	< 0.30
5/03 1400L - 5/04 1400L	< 0.57	< 0.27	0.10+/-0.05	< 0.07	< 0.04	< 0.15
5/04 1400L - 5/05 1400L	< 0.56	< 0.30	< 0.06	< 0.06	< 0.05	< 0.07
5/05 1400L - 5/06 1400L	< 0.71	< 0.33	< 0.11	< 0.16	< 0.08	< 0.29
5/06 1400L - 5/07 1400L	< 1.22	< 0.73	< 0.21	< 0.10	< 0.11	< 0.25
5/07 1400L - 5/08 1400L	< 0.26	< 0.32	< 0.04	< 1.15	< 0.03	< 0.09
5/08 1400L - 5/09 1400L	< 0.29	< 0.38	< 0.11	< 0.94	< 0.07	< 0.18
5/09 1400L - 5/10 1400L	< 0.23	< 0.18	< 0.04	< 0.31	< 0.03	< 0.09
5/10 1400L - 5/11 1400L	< 0.33	< 0.15	0.17+/-0.01	< 0.52	< 0.06	< 0.19
5/11 1400L - 5/12 1400L	0.95+/-0.32	< 0.59	< 0.13	< 0.35	< 0.06	< 0.40
5/12 1400L - 5/13 1400L	1.42+/-0.24	0.89+/-0.07	< 0.08	< 0.37	< 0.08	< 0.22
5/13 1400L - 5/14 1400L	1.18+/-0.39	0.83+/-0.37	< 0.14	< 1.00	< 0.11	< 0.24
5/14 1400L - 5/15 1400L	1.24+/-0.37	0.86+/-0.25	< 0.13	< 1.07	0.12+/-0.04	< 0.34
5/15 1400L - 5/16 1400L	< 0.49	< 0.48	< 0.11	< 0.39	< 0.10	< 0.30
5/16 1400L - 5/17 1400L	0.38+/-0.19	< 0.57	< 0.12	< 0.59	< 0.07	0.33+/-0.15
5/17 1400L - 5/18 1400L	< 0.59	< 0.23	< 0.10	< 1.03	< 0.14	< 0.48
5/18 1400L - 5/19 1400L	0.15+/-0.08	< 0.14	< 0.02	< 0.25	< 0.01	< 0.06
5/19 1400L - 5/20 1400L	< 0.23	< 0.23	< 0.04	< 0.33	< 0.05	< 0.14

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 11
Surface Air Concentrations at Beaverton, Oregon *
(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/02 1500L - 5/03 1230L	48.4+/-5.6	< 2.6	1.8+/-0.7	< 1.0		
5/03 1230L - 5/04 1330L	80.0+/-9.2	< 2.5	< 1.0	< 0.9		
5/04 1330L - 5/05 1030L	< 21.6	0.7+/-0.2	< 1.3	< 1.6		
5/05 1030L - 5/06 1120L	75.0+/-2.7	7.2+/-0.3	< 0.4	0.3+/-0.1		
5/06 1120L - 5/07 1110L	56.5+/-5.2	5.6+/-0.6	< 0.6	1.0+/-0.4		
5/07 1110L - 5/08 1020L	48.4+/-5.8	15.9+/-0.8	5.3+/-0.7	4.5+/-0.5		
5/08 1020L - 5/09 1400L	45.5+/-6.9	51.7+/-1.5	7.9+/-0.4	15.5+/-0.8		
5/09 1400L - 5/10 1400L	< 93.9	278.4+/-8.4	94.2+/-7.9	181.4+/-7.6		
5/10 1400L - 5/11 1730L	< 16.1	63.1+/-1.8	11.9+/-0.6	23.7+/-1.2		
5/11 1730L - 5/12 1000L	< 36.2	98.5+/-2.9	26.9+/-1.4	52.7+/-2.5		
5/12 1000L - 5/13 1045L	70.9+/-22.7	112.9+/-4.0	49.6+/-3.2	75.1+/-3.6		
5/13 1050L - 5/14 0911L	49.8+/-6.2	37.3+/-1.2	4.4+/-0.5	9.1+/-0.7		
5/14 0910L - 5/15 1100L	76.6+/-11.1	50.6+/-1.5	10.5+/-0.9	21.3+/-1.3		
5/15 1100L - 5/16 1000L	79.3+/-11.9	66.2+/-2.2	15.8+/-0.8	32.3+/-1.6		
5/16 1000L - 5/18 1100L	160.8+/-47.0	178.3+/-9.0	83.5+/-4.0	171.2+/-7.8		
5/18 1100L - 5/19 1330L	94.9+/-33.3	85.7+/-5.7	78.9+/-2.8	106.4+/-3.8		
5/19 1330L - 5/20 1545L	87.7+/-20.0	65.5+/-3.6	24.8+/-1.3	54.5+/-2.5		
5/20 1545L - 5/21 1400L	48.4+/-15.3	38.2+/-2.9	15.4+/-1.1	30.6+/-2.2		
5/21 1400L - 5/22 1400L	46.9+/-8.6	22.5+/-1.7	8.7+/-1.0	12.2+/-1.1		
5/22 1400L - 5/23 1000L	79.6+/-8.8	53.6+/-6.8	13.0+/-4.2	27.6+/-3.1	45.8+/-2.6	< 1.0
5/23 1000L - 5/24 1120L	169.9+/-4.1	98.3+/-3.6	31.8+/-2.8	60.0+/-1.6	103.8+/-1.2	32.0+/-15.4
5/24 1123L - 5/26 1200L	62.4+/-2.4	14.6+/-5.0	8.8+/-1.8	17.3+/-1.3	32.1+/-0.9	< 10.0
5/26 1200L - 5/27 1400L	27.3+/-12.6	< 4.5	< 1.8	< 4.9	8.8+/-6.1	< 1.0
5/27 1400L - 6/03 1400L	111.8+/-2.2	8.9+/-0.4	3.6+/-0.4	7.5+/-0.2	19.3+/-0.1	7.0+/-1.3

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 12
Surface Air Concentrations at Beaverton, Oregon *

Collection Period	Ba-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/02 1500L - 5/03 1230L	1.79+/-0.21	< 0.10	0.07+/-0.03	< 0.04		
5/03 1230L - 5/04 1330L	2.96+/-0.34	< 0.09	< 0.04	< 0.03		
5/04 1330L - 5/05 1030L	< 0.80	0.03+/-0.01	< 0.05	< 0.06		
5/05 1030L - 5/06 1120L	2.78+/-0.10	0.27+/-0.01	< 0.01	0.01+/-0.00		
5/06 1120L - 5/07 1110L	2.09+/-0.19	0.21+/-0.02	< 0.02	0.04+/-0.01		
5/07 1110L - 5/08 1020L	1.79+/-0.21	0.59+/-0.03	0.20+/-0.03	0.17+/-0.02		
5/08 1020L - 5/09 1400L	1.68+/-0.26	1.91+/-0.06	0.29+/-0.01	0.57+/-0.03		
5/09 1400L - 5/10 1400L	< 3.47	10.30+/-0.31	3.49+/-0.29	6.71+/-0.28		
5/10 1400L - 5/11 1730L	< 0.60	2.33+/-0.07	0.44+/-0.02	3.88+/-0.04		
5/11 1730L - 5/12 1000L	< 1.34	3.64+/-0.11	1.00+/-0.05	1.95+/-0.09		
5/12 1000L - 5/13 1045L	2.62+/-0.84	4.18+/-0.15	1.84+/-0.12	2.78+/-0.13		
5/13 1050L - 5/14 0911L	1.84+/-0.23	1.38+/-0.04	0.16+/-0.02	0.34+/-0.03		
5/14 0910L - 5/15 1100L	2.83+/-0.41	1.87+/-0.06	0.39+/-0.03	0.79+/-0.05		
5/15 1100L - 5/16 1000L	2.93+/-0.44	2.45+/-0.08	0.58+/-0.03	1.20+/-0.06		
5/16 1000L - 5/18 1100L	5.95+/-1.74	6.60+/-0.33	3.09+/-0.15	6.33+/-0.29		
5/18 1100L - 5/19 1330L	3.51+/-1.23	3.17+/-0.21	2.92+/-0.10	3.94+/-0.14		
5/19 1330L - 5/20 1545L	3.24+/-0.74	2.42+/-0.13	0.92+/-0.05	2.02+/-0.09		
5/20 1545L - 5/21 1400L	1.73+/-0.57	1.41+/-0.11	0.57+/-0.04	1.13+/-0.08		
5/21 1400L - 5/22 1400L	1.74+/-0.32	0.83+/-0.06	0.32+/-0.04	0.45+/-0.04		
5/22 1400L - 5/23 1000L	2.95+/-0.33	1.98+/-0.25	0.48+/-0.16	1.02+/-0.11	1.69+/-0.10	< 0.04
5/23 1000L - 5/24 1120L	6.29+/-0.15	3.64+/-0.13	1.18+/-0.10	2.22+/-0.06	3.84+/-0.04	1.18+/-0.57
5/24 1123L - 5/26 1200L	2.31+/-0.09	0.54+/-0.19	0.33+/-0.07	0.64+/-0.05	1.19+/-0.03	< 0.37
5/26 1200L - 5/27 1400L	1.01+/-0.47	< 0.17	< 0.07	< 0.18	0.33+/-0.23	< 0.04
5/27 1400L - 6/03 1400L	4.14+/-0.08	0.33+/-0.01	0.13+/-0.01	0.28+/-0.01	0.71+/-0.00	0.26+/-0.05

* Air filter sample collected using a Brooks/Roots system (SASP pump)
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 13
Surface Air Concentrations at Beaverton, Oregon *
(Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/02 1500L - 5/03 1230L	< 6.0	< 3.4	< 1.8	< 5.5	< 1.5	< 5.3
5/03 1230L - 5/04 1330L	< 7.7	< 7.1	< 2.5	< 7.0	< 1.1	< 3.9
5/04 1330L - 5/05 1030L	< 7.1	< 6.8	< 2.2	< 5.9	< 1.4	< 4.4
5/05 1030L - 5/06 1120L	< 2.1	< 1.1	0.4+/-0.2	< 0.2	< 0.3	< 1.1
5/06 1120L - 5/07 1110L	< 3.1	< 3.1	< 1.3	< 0.6	< 0.5	< 3.0
5/07 1110L - 5/08 1020L	< 4.3	< 1.9	< 1.5	1.5+/-0.5	< 0.6	< 2.6
5/08 1020L - 5/09 1400L	6.0+/-2.6	< 4.2	< 1.2	< 1.7	< 0.8	< 3.1
5/09 1400L - 5/10 1400L	32.2+/-10.4	< 19.8	< 5.6	< 6.4	< 3.7	< 19.3
5/10 1400L - 5/11 1730L	< 4.9	< 4.3	< 1.2	< 1.3	< 1.3	< 4.5
5/11 1730L - 5/12 1000L	< 10.8	< 9.1	< 3.3	< 3.2	< 2.2	< 11.5
5/12 1000L - 5/13 1045L	24.9+/-7.6	16.8+/-4.5	< 3.3	< 4.1	< 3.2	< 10.6
5/13 1050L - 5/14 0911L	< 5.0	< 3.9	< 1.2	< 1.1	< 1.0	< 2.4
5/14 0910L - 5/15 1100L	< 7.0	< 6.1	< 1.9	< 1.2	< 1.5	< 5.7
5/15 1100L - 5/16 1000L	< 7.3	< 7.6	< 3.2	< 3.0	< 2.1	< 7.6
5/16 1000L - 5/18 1100L	29.5+/-13.8	< 29.6	< 5.9	< 12.7	< 5.1	< 19.3
5/18 1100L - 5/19 1330L	25.9+/-11.9	< 22.3	< 5.9	< 10.6	< 4.5	< 12.3
5/19 1330L - 5/20 1545L	17.4+/-6.8	< 14.2	< 3.2	< 16.0	< 4.0	< 11.5
5/20 1545L - 5/21 1400L	< 11.2	< 8.7	< 24.8	< 6.3	< 2.2	< 5.1
5/21 1400L - 5/22 1400L	6.1+/-3.0	< 6.4	< 2.0	< 4.7	< 1.3	< 4.7

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 14
Surface Air Concentrations at Beaver ton, Oregon *

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/02 1500L - 5/03 1230L	< 0.22	< 0.13	< 0.07	< 0.20	< 0.06	< 0.20
5/03 1230L - 5/04 1330L	< 0.28	< 0.26	< 0.09	< 0.26	< 0.04	< 0.14
5/04 1330L - 5/05 1030L	< 0.26	< 0.25	< 0.08	< 0.22	< 0.05	< 0.16
5/05 1030L - 5/06 1120L	< 0.08	< 0.04	0.01+/-0.01	< 0.01	< 0.01	< 0.04
5/06 1120L - 5/07 1110L	< 0.11	< 0.11	< 0.05	< 0.02	< 0.02	< 0.11
5/07 1110L - 5/08 1020L	< 0.16	< 0.07	< 0.06	0.06+/-0.02	< 0.02	< 0.10
5/08 1020L - 5/09 1400L	0.22+/-0.10	< 0.16	< 0.04	< 0.06	< 0.03	< 0.11
5/09 1400L - 5/10 1400L	1.19+/-0.38	< 0.71	< 0.21	< 0.24	< 0.14	< 0.71
5/10 1400L - 5/11 1730L	< 0.18	< 0.16	< 0.04	< 0.05	< 0.05	< 0.17
5/11 1730L - 5/12 1000L	< 0.40	< 0.34	< 0.12	< 0.12	< 0.08	< 0.43
5/12 1000L - 5/13 1045L	0.92+/-0.28	0.62+/-0.17	< 0.12	< 0.15	< 0.12	< 0.39
5/13 1050L - 5/14 0911L	< 0.19	< 0.14	< 0.04	< 0.04	< 0.04	< 0.09
5/14 0910L - 5/15 1100L	< 0.26	< 0.23	< 0.07	< 0.04	< 0.06	< 0.21
5/15 1100L - 5/16 1000L	< 0.27	< 0.28	< 0.12	< 0.11	< 0.08	< 0.28
5/16 1000L - 5/18 1100L	1.09+/-0.51	< 1.10	< 0.22	< 0.47	< 0.19	< 0.71
5/18 1100L - 5/19 1330L	0.96+/-0.44	< 0.83	< 0.22	< 0.39	< 0.17	< 0.46
5/19 1330L - 5/20 1545L	0.64+/-0.25	< 0.53	< 0.12	< 0.59	< 0.15	< 0.43
5/20 1545L - 5/21 1400L	< 0.41	< 0.32	< 0.92	< 0.23	< 0.08	< 0.19
5/21 1400L - 5/22 1400L	0.23+/-0.11	< 0.24	< 0.07	< 0.17	< 0.05	< 0.17

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 15
Surface Air Concentrations at Rexburg, Idaho *
(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/01 1100L - 5/02 1115L	298.9+/-12.6	< 2.4	1.6+/-0.7	< 1.1		
5/02 1115L - 5/03 1300L	244.5+/-12.6	< 2.2	< 1.0	< 1.4		
5/03 1310L - 5/04 1245L	65.4+/-11.7	< 1.5	< 0.9	< 1.3		
5/04 1310L - 5/05 0905L	80.1+/-10.1	< 3.8	< 1.2	2.3+/-1.0		
5/05 0910L - 5/06 0805L	173.2+/-7.4	5.2+/-0.8	< 0.6	< 0.9		
5/06 0810L - 5/07 0855L	159.6+/-9.1	46.1+/-1.6	2.6+/-0.7	5.1+/-0.8		
5/07 0900L - 5/08 0815L	41.0+/-5.2	39.7+/-1.1	1.6+/-0.3	3.7+/-0.4		
5/08 0815L - 5/09 0840L	21.7+/-8.4	14.9+/-2.6	3.2+/-1.2	3.4+/-1.1		
5/09 1000L - 5/10 1030L	122.4+/-21.5	516.5+/-9.2	45.5+/-4.9	92.6+/-2.9		
5/10 1030L - 5/11 1115L	100.3+/-30.2	523.3+/-8.8	147.7+/-4.0	205.5+/-4.2		
5/11 1115L - 5/12 1530L	393.4+/-32.3	486.6+/-5.8	213.1+/-4.4	307.8+/-4.8		
5/12 1530L - 5/13 0925L	202.6+/-29.7	444.5+/-5.8	76.0+/-2.2	153.7+/-4.2		
5/13 0930L - 5/14 0805L	215.8+/-32.7	305.7+/-7.6	48.0+/-2.3	99.3+/-4.4		
5/14 0810L - 5/15 0815L	277.0+/-35.6	446.8+/-10.1	70.9+/-2.7	140.3+/-5.0		
5/15 0815L - 5/16 0815L	219.1+/-55.4	445.0+/-16.5	57.0+/-5.8	142.0+/-8.2		
5/16 0815L - 5/17 1200L	253.1+/-25.1	487.4+/-7.3	81.4+/-2.0	164.0+/-3.9		
5/17 1200L - 5/18 1058L	407.6+/-67.9	547.9+/-18.1	126.4+/-8.5	188.1+/-9.6		
5/18 1058L - 5/19 0815L	265.8+/-42.1	225.6+/-9.0	74.5+/-5.0	100.0+/-5.6		
5/19 0815L - 5/20 0815L	149.4+/-51.0	265.7+/-10.1	51.4+/-3.5	107.7+/-6.9		
5/20 0815L - 5/21 0815L	250.0+/-29.3	131.5+/-6.3	29.3+/-1.8	57.9+/-3.4		
5/21 0815L - 5/22 0815L	289.8+/-27.5	142.5+/-6.5	35.3+/-3.1	43.6+/-3.1		
5/22 0830L - 5/23 1040L	233.3+/-3.1	130.5+/-3.3	28.9+/-2.8	52.8+/-1.9	108.0+/-1.4	36.5+/-10.4
5/23 1100L - 5/27 0900L	461.2+/-2.2	79.5+/-1.2	29.4+/-0.4	55.5+/-0.4	99.9+/-0.3	42.3+/-2.2
5/27 0900L - 5/30 0845L	341.7+/-6.6	20.5+/-2.1	7.0+/-1.3	13.5+/-1.1	26.8+/-0.8	

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 16
Surface Air Concentrations at Rexburg, Idaho *
(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/01 1100L - 5/02 1115L	11.06+/-0.47	< 0.09	0.06+/-0.03	< 0.04		
5/02 1115L - 5/03 1300L	9.05+/-0.47	< 0.08	< 0.04	< 0.05		
5/03 1310L - 5/04 1245L	2.42+/-0.43	< 0.06	< 0.03	< 0.05		
5/04 1310L - 5/05 0905L	2.96+/-0.37	< 0.14	< 0.04	0.09+/-0.04		
5/05 0910L - 5/06 0805L	6.41+/-0.27	0.19+/-0.03	< 0.02	< 0.03		
5/06 0810L - 5/07 0855L	5.91+/-0.34	1.71+/-0.06	0.10+/-0.03	0.19+/-0.03		
5/07 0900L - 5/08 0815L	1.52+/-0.19	1.47+/-0.04	0.06+/-0.01	0.14+/-0.01		
5/08 0815L - 5/09 0840L	0.30+/-0.31	0.55+/-0.10	0.12+/-0.04	0.15+/-0.04		
5/09 1000L - 5/10 1030L	4.53+/-0.60	19.11+/-0.34	1.68+/-0.52	3.43+/-0.11		
5/10 1030L - 5/11 1115L	3.71+/-1.12	19.36+/-0.33	5.46+/-0.15	7.60+/-0.16		
5/11 1115L - 5/12 1530L	14.56+/-1.20	18.00+/-0.21	7.88+/-0.16	11.39+/-0.18		
5/12 1530L - 5/13 0925L	7.50+/-1.10	16.45+/-0.21	2.81+/-0.08	5.69+/-0.16		
5/13 0930L - 5/14 0805L	7.98+/-1.21	11.31+/-0.28	1.78+/-0.09	3.67+/-0.16		
5/14 0810L - 5/15 0815L	10.25+/-1.32	16.53+/-0.37	2.62+/-0.10	5.19+/-0.19		
5/15 0815L - 5/16 0815L	8.11+/-2.05	16.47+/-0.59	2.11+/-0.21	5.25+/-0.30		
5/16 0815L - 5/17 1200L	9.36+/-0.93	18.03+/-0.27	3.01+/-0.07	5.07+/-0.14		
5/17 1200L - 5/18 1058L	15.08+/-2.51	20.27+/-0.67	4.68+/-0.31	6.96+/-0.36		
5/18 1058L - 5/19 0815L	9.33+/-1.56	8.35+/-0.33	2.76+/-0.19	3.70+/-0.21		
5/19 0815L - 5/20 0815L	5.53+/-1.89	9.83+/-0.37	1.90+/-0.13	3.98+/-0.26		
5/20 0815L - 5/21 0815L	9.25+/-1.08	4.87+/-0.23	1.08+/-0.07	2.14+/-0.13		
5/21 0815L - 5/22 0815L	10.72+/-1.02	5.27+/-0.24	1.31+/-0.11	1.61+/-0.11		
5/22 0830L - 5/23 1040L	8.63+/-0.11	4.83+/-0.12	1.07+/-0.10	1.95+/-0.07	4.00+/-0.05	1.35+/-0.38
5/23 1100L - 5/27 0900L	17.06+/-0.01	2.94+/-0.04	1.09+/-0.01	2.05+/-0.01	3.70+/-0.01	1.57+/-0.08
5/27 0900L - 5/30 0845L	12.64+/-0.02	0.76+/-0.08	0.26+/-0.05	0.50+/-0.04	0.99+/-0.03	

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 17
 Surface Air Concentrations at Rexburg, Idaho *
 (Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/01 1100L - 5/02 1115L	< 5.2	< 3.2	< 2.3	< 6.4	< 1.2	< 4.3
5/02 1115L - 5/03 1300L	< 7.5	< 10.7	< 2.1	< 6.5	< 1.8	< 6.0
5/03 1310L - 5/04 1245L	< 5.7	< 6.6	< 1.8	< 3.7	< 1.4	< 4.7
5/04 1310L - 5/05 0905L	< 6.7	< 4.4	< 2.9	< 7.1	< 2.6	< 7.1
5/05 0910L - 5/06 0805L	< 4.9	< 6.6	< 4.1	< 2.3	< 0.6	< 3.3
5/06 0810L - 5/07 0855L	< 4.6	< 3.0	< 1.6	< 2.0	< 2.1	< 8.5
5/07 0900L - 5/08 0815L	< 4.4	< 3.1	< 1.3	< 0.7	< 0.6	< 2.6
5/08 0815L - 5/09 0840L	< 12.0	< 4.8	< 3.8	< 14.0	< 1.3	< 7.0
5/09 1000L - 5/10 1030L	75.2+/-11.9	41.1+/-3.7	< 2.7	< 47.5	3.3+/-1.5	< 15.0
5/10 1030L - 5/11 1115L	66.0+/-11.9	67.1+/-9.0	7.8+/-2.6	< 35.2	< 0.6	< 16.9
5/11 1115L - 5/12 1530L	65.2+/-10.0	66.7+/-6.8	5.9+/-2.7	7.8+/-3.3	< 4.8	< 19.3
5/12 1530L - 5/13 0925L	23.6+/-7.8	27.9+/-6.2	< 4.6	< 6.9	< 7.3	< 29.8
5/13 0930L - 5/14 0805L	24.8+/-9.3	< 20.9	< 5.0	< 7.5	< 4.0	< 19.9
5/14 0810L - 5/15 0815L	< 24.1	< 26.7	< 7.3	< 15.8	< 5.4	< 20.5
5/15 0815L - 5/16 0815L	71.8+/-19.5	< 39.9	< 8.6	< 35.6	< 9.6	< 37.7
5/16 0815L - 5/17 1200L	60.7+/-11.1	40.2+/-3.3	4.4+/-1.7	< 12.0	6.1+/-2.2	< 14.6
5/17 1200L - 5/18 1058L	60.7+/-19.5	60.1+/-22.1	< 9.4	< 22.9	11.2+/-4.6	< 31.6
5/18 1058L - 5/19 0815L	29.0+/-9.7	32.6+/-10.1	< 5.1	< 10.6	5.2+/-2.4	< 17.4
5/19 0815L - 5/20 0815L	28.7+/-11.8	< 24.9	< 5.6	< 6.7	< 5.6	< 18.9
5/20 0815L - 5/21 0815L	< 17.4	< 18.4	< 4.1	< 22.3	< 3.9	< 11.2
5/21 0815L - 5/22 0815L	19.0+/-6.7	< 21.9	< 4.0	< 9.9	5.3+/-1.6	< 8.6

* Air filter sample collected using a Brooks/Roots system (SASP pump)
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 18
Surface Air Concentrations at Rexburg, Idaho *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/01 1100L - 5/02 1115L	< 0.19	< 0.12	< 0.09	< 0.24	< 0.04	< 0.16
5/02 1115L - 5/03 1300L	< 0.28	< 0.40	< 0.08	< 0.24	< 0.07	< 0.22
5/03 1310L - 5/04 1245L	< 0.21	< 0.24	< 0.07	< 0.14	< 0.05	< 0.17
5/04 1310L - 5/05 0905L	< 0.25	< 0.16	< 0.11	< 0.26	< 0.10	< 0.26
5/05 0910L - 5/06 0805L	< 0.18	< 0.24	< 0.15	< 0.09	< 0.02	< 0.12
5/06 0810L - 5/07 0855L	< 0.17	< 0.11	< 0.06	< 0.07	< 0.08	< 0.31
5/07 0900L - 5/08 0815L	< 0.16	< 0.11	< 0.05	< 0.03	< 0.02	< 0.10
5/08 0815L - 5/09 0840L	< 0.44	< 0.18	< 0.14	< 0.52	< 0.05	< 0.26
5/09 1000L - 5/10 1030L	2.78+/-0.44	1.52+/-0.14	< 0.10	< 1.76	0.12+/-0.06	< 0.56
5/10 1030L - 5/11 1115L	2.44+/-0.44	2.48+/-0.33	0.29+/-0.10	< 1.30	< 0.02	< 0.63
5/11 1115L - 5/12 1530L	2.41+/-0.37	2.47+/-0.25	0.22+/-0.10	0.29+/-0.12	< 0.18	< 0.71
5/12 1530L - 5/13 0925L	0.87+/-0.29	1.03+/-0.23	< 0.17	< 0.26	< 0.27	< 1.10
5/13 0930L - 5/14 0805L	0.92+/-0.34	< 0.77	< 0.19	< 0.28	< 0.15	< 0.74
5/14 0810L - 5/15 0815L	< 0.89	< 0.99	< 0.27	< 0.58	< 0.20	< 0.76
5/15 0815L - 5/16 0815L	2.66+/-0.72	< 1.48	< 0.32	< 1.32	< 0.36	< 1.39
5/16 0815L - 5/17 1200L	2.25+/-0.41	1.49+/-0.12	0.16+/-0.06	< 0.44	0.23+/-0.08	< 0.54
5/17 1200L - 5/18 1058L	2.25+/-0.72	2.22+/-0.81	< 0.35	< 0.85	0.41+/-0.17	< 1.17
5/18 1058L - 5/19 0815L	1.07+/-0.36	1.21+/-0.37	< 0.19	< 0.39	0.19+/-0.09	< 0.64
5/19 0815L - 5/20 0815L	1.06+/-0.44	< 0.92	< 0.21	< 0.25	< 0.21	< 0.70
5/20 0815L - 5/21 0815L	< 0.64	< 0.68	< 0.15	< 0.83	< 0.14	< 0.41
5/21 0815L - 5/22 0815L	0.70+/-0.25	< 0.81	< 0.15	< 0.37	0.20+/-0.06	< 0.32

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 19
Surface Air ¹³⁵Cs Concentrations at Chester, New Jersey *

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/05 0730L - 5/06 0800L	292.9+/-12.5	< 1.9	< 1.4	< 1.0		
5/06 0800L - 5/07 1025L	196.0+/-18.2	< 3.9	< 1.5	< 1.8		
5/07 1025L - 5/09 0857L	56.8+/-6.6	13.5+/-1.2	3.4+/-0.5	4.4+/-0.7		
5/09 0850L - 5/10 0740L	118.2+/-43.0	235.5+/-8.5	46.0+/-3.1	92.4+/-6.1		
5/10 0740L - 5/12 0809L	224.0+/-25.1	316.4+/-5.1	102.8+/-2.3	196.4+/-4.5		
5/12 0809L - 5/13 1136L	110.9+/-20.8	146.5+/-3.8	33.3+/-1.6	65.3+/-2.9		
5/13 1136L - 5/14 1000L	197.1+/-18.8	93.0+/-2.9	70.8+/-2.8	107.8+/-3.3		
5/14 1000L - 5/15 1430L	127.4+/-14.2	131.0+/-3.0	27.0+/-1.1	50.8+/-2.0		
5/15 1430L - 5/16 0920L	183.3+/-14.5	51.1+/-1.9	51.1+/-1.2	99.0+/-2.3		
5/16 0920L - 5/19 0910L	147.1+/-5.7	11.1+/-0.8	21.1+/-0.7	29.6+/-0.8		
5/19 0910L - 5/21 0915L	155.1+/-8.6	12.4+/-1.5	21.3+/-1.1	27.6+/-1.1		
5/21 0915L - 5/22 1100L	102.8+/-8.4	6.5+/-0.8	4.3+/-0.8	5.5+/-0.7		
5/22 1100L - 5/23 0915L	60.3+/-11.3	14.0+/-0.1	2.5+/-0.8	4.9+/-1.0		
5/23 0915L - 5/26 0722L	120.7+/-5.7	21.0+/-1.4	15.8+/-0.6	31.0+/-0.9	61.6+/-1.2	19.9+/-3.3
5/26 0720L - 5/28 0855L	121.5+/-7.9	11.0+/-1.2	12.8+/-0.6	26.1+/-1.3	41.3+/-1.3	18.6+/-4.6
5/28 0855L - 5/29 1145L	207.2+/-13.0	18.9+/-2.5	18.6+/-1.4	31.4+/-1.6		
5/29 1145L - 5/30 0750L	231.4+/-25.6	14.5+/-4.3	23.5+/-2.8	34.9+/-3.1		
5/30 0755L - 6/02 0725L	151.8+/-16.0	6.1+/-1.8	10.2+/-1.1	19.7+/-1.6		
6/02 0725L - 6/04 0900L	172.8+/-22.0	30.2+/-3.0	28.5+/-1.5	60.6+/-3.1		

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 20
Surface Air Concentrations at Chester, New Jersey *
(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/05 0730L - 5/06 0800L	10.84+/-0.46	< 0.07	< 0.05	< 0.04		
5/06 0800L - 5/07 1025L	7.25+/-0.67	< 0.14	< 0.06	< 0.07		
5/07 1025L - 5/09 0857L	2.10+/-0.24	0.50+/-0.04	0.13+/-0.02	0.16+/-0.03		
5/09 0850L - 5/10 0740L	4.37+/-1.59	8.71+/-0.31	1.70+/-0.11	3.42+/-0.23		
5/10 0740L - 5/12 0809L	8.29+/-0.93	11.71+/-0.19	3.80+/-0.09	7.27+/-0.17		
5/12 0809L - 5/13 1136L	4.10+/-0.77	5.42+/-0.14	1.23+/-0.06	2.42+/-0.11		
5/13 1136L - 5/14 1000L	7.29+/-0.70	3.44+/-0.11	2.62+/-0.10	3.99+/-0.12		
5/14 1000L - 5/15 1430L	4.71+/-0.53	4.85+/-0.11	1.00+/-0.04	1.88+/-0.07		
5/15 1430L - 5/16 0920L	6.78+/-0.54	1.89+/-0.07	1.89+/-0.04	3.66+/-0.09		
5/16 0920L - 5/19 0910L	5.44+/-0.21	0.41+/-0.03	0.78+/-0.03	1.10+/-0.03		
5/19 0910L - 5/21 0915L	5.74+/-0.32	0.46+/-0.06	0.79+/-0.04	1.02+/-0.04		
5/21 0915L - 5/22 1100L	3.80+/-0.31	0.24+/-0.03	0.16+/-0.03	0.20+/-0.03		
5/22 1100L - 5/23 0915L	2.23+/-0.42	0.52+/-0.00	0.09+/-0.03	0.18+/-0.04		
5/23 0915L - 5/26 0722L	4.47+/-0.21	0.78+/-0.05	0.58+/-0.02	1.15+/-0.03	2.28+/-0.04	0.74+/-0.12
5/26 0720L - 5/28 0855L	4.50+/-0.29	0.41+/-0.04	0.47+/-0.02	0.97+/-0.05	1.53+/-0.05	0.69+/-0.17
5/28 0855L - 5/29 1145L	7.67+/-0.48	0.70+/-0.09	0.69+/-0.05	1.16+/-0.06		
5/29 1145L - 5/30 0750L	8.56+/-0.95	0.54+/-0.16	0.87+/-0.10	1.29+/-0.11		
5/30 0755L - 6/02 0725L	5.62+/-0.59	0.23+/-0.07	0.38+/-0.04	0.73+/-0.06		
6/02 0725L - 6/04 0900L	6.39+/-0.81	1.12+/-0.11	1.05+/-0.06	2.24+/-0.11		

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 21
Surface Air Concentrations at Chester, New Jersey *
(FemtoCurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/05 0730L - 5/06 0800L	10.3+/-3.2	< 3.4	2.4+/-1.0	< 5.5	< 1.1	< 3.1
5/06 0800L - 5/07 1025L	< 10.8	< 14.0	< 3.1	< 8.4	< 2.7	< 7.3
5/07 1025L - 5/09 0857L	< 4.3	< 2.0	< 1.3	< 1.8	< 0.9	< 2.6
5/09 0850L - 5/10 0740L	< 23.0	< 25.5	< 7.5	< 8.7	< 5.5	< 18.8
5/10 0740L - 5/12 0809L	33.1+/-7.8	19.9+/-2.4	< 2.6	< 3.1	< 2.7	< 9.9
5/12 0809L - 5/13 1136L	< 10.0	< 12.4	< 3.5	< 3.4	< 3.5	< 11.5
5/13 1136L - 5/14 1000L	12.2+/-4.2	13.1+/-5.4	< 2.4	< 2.3	< 2.0	< 7.7
5/14 1000L - 5/15 1430L	< 8.9	< 8.5	< 1.8	< 1.5	< 1.8	< 6.8
5/15 1430L - 5/16 0920L	18.1+/-4.9	11.8+/-1.3	< 1.7	< 2.0	< 1.6	< 5.3
5/16 0920L - 5/19 0910L	7.2+/-1.8	7.2+/-1.8	0.9+/-0.4	< 2.0	0.7+/-0.3	< 1.9
5/19 0910L - 5/21 0915L	1.0+/-0.4	0.8+/-0.3	< 1.7	< 6.4	< 1.5	< 5.6
5/21 0915L - 5/22 1100L	< 4.2	< 6.1	< 1.8	< 1.3	0.8+/-0.4	< 4.2
5/22 1100L - 5/23 0915L	< 7.3	< 7.0	4.1+/-1.2	< 2.2	< 2.2	< 5.7
5/23 0915L - 5/26 0722L	6.3+/-2.4	5.7+/-0.8	< 0.8	< 7.2	< 0.8	< 2.7
5/26 0720L - 5/28 0855L	7.6+/-2.9	5.0+/-1.0	< 1.4	< 3.7	< 1.1	< 3.1
5/28 0855L - 5/29 1145L	17.3+/-5.4	< 12.1	< 2.0	< 20.4	< 2.2	< 7.6
5/29 1145L - 5/30 0750L	< 15.7	< 23.8	< 6.3	< 17.3	< 4.4	< 15.0
5/30 0755L - 6/02 0725L	< 9.3	< 12.7	< 2.1	< 7.3	< 2.1	< 6.3
6/02 0725L - 6/04 0900L	< 11.5	< 12.7	< 3.4	< 5.2	< 2.2	< 7.7

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 22
Surface Air Concentrations at Chester, New Jersey *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/05 0730L - 5/06 0800L	0.38+/-0.12	< 0.13	0.09+/-0.04	< 0.20	< 0.04	< 0.11
5/06 0800L - 5/07 1025L	< 0.40	< 0.52	< 0.11	< 0.31	< 0.10	< 0.27
5/07 1025L - 5/09 0857L	< 0.16	< 0.07	< 0.05	< 0.07	< 0.03	< 0.10
5/09 0850L - 5/10 0740L	< 0.85	< 0.94	< 0.28	< 0.32	< 0.20	< 0.70
5/10 0740L - 5/12 0809L	1.22+/-0.29	0.74+/-0.09	< 0.10	< 0.11	< 0.10	< 0.37
5/12 0809L - 5/13 1136L	< 0.37	< 0.46	< 0.13	< 0.13	< 0.13	< 0.43
5/13 1136L - 5/14 1000L	0.45+/-0.16	0.48+/-0.20	< 0.09	< 0.09	< 0.07	< 0.28
5/14 1000L - 5/15 1430L	< 0.33	< 0.31	< 0.07	< 0.06	< 0.07	< 0.25
5/15 1430L - 5/16 0920L	0.67+/-0.18	0.44+/-0.05	< 0.06	< 0.07	< 0.06	< 0.20
5/16 0920L - 5/19 0910L	0.27+/-0.07	0.27+/-0.07	0.03+/-0.01	< 0.07	0.03+/-0.01	< 0.07
5/19 0910L - 5/21 0915L	0.04+/-0.01	0.03+/-0.01	< 0.06	< 0.24	< 0.06	< 0.21
5/21 0915L - 5/22 1100L	< 0.16	< 0.23	< 0.07	< 0.05	0.03+/-0.01	< 0.16
5/22 1100L - 5/23 0915L	< 0.27	< 0.26	0.15+/-0.04	< 0.08	< 0.08	< 0.21
5/23 0915L - 5/26 0722L	0.23+/-0.09	0.21+/-0.03	< 0.03	< 0.27	< 0.03	< 0.10
5/26 0720L - 5/28 0855L	0.28+/-0.11	0.19+/-0.04	< 0.05	< 0.14	< 0.04	< 0.11
5/28 0855L - 5/29 1145L	0.64+/-0.20	< 0.45	< 0.07	< 0.75	< 0.08	< 0.28
5/29 1145L - 5/30 0750L	< 0.58	< 0.88	< 0.23	< 0.64	< 0.16	< 0.56
5/30 0755L - 6/02 0725L	< 0.34	< 0.47	< 0.08	< 0.27	< 0.08	< 0.23
6/02 0725L - 6/04 0900L	< 0.43	< 0.47	< 0.13	< 0.19	< 0.08	< 0.28

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 23

Surface Air Concentrations at New York City *

(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/15 1155L - 5/16 1000L	249.0+/-29.4	59.8+/-3.3	72.2+/-3.9	107.2+/-4.6		
5/16 1000L - 5/17 0905L	120.0+/-15.9	28.4+/-1.8	30.7+/-1.6	60.6+/-2.2		
5/17 0905L - 5/18 0926L	89.6+/-11.3	12.0+/-1.2	10.0+/-0.7	19.3+/-1.3		
5/18 0926L - 5/19 1035L	119.3+/-19.1	10.4+/-1.7	10.1+/-1.6	25.4+/-2.1		
5/19 1040L - 5/20 0905L	142.9+/-14.8	18.1+/-1.3	22.6+/-1.0	46.6+/-1.9		

TABLE 24

Surface Air Concentrations at New York City *

(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/15 1155L - 5/16 1000L	9.21+/-1.09	2.21+/-0.12	2.67+/-0.14	3.97+/-0.17		
5/16 1000L - 5/17 0905L	4.44+/-0.59	1.05+/-0.07	1.14+/-0.06	2.24+/-0.08		
5/17 0905L - 5/18 0926L	3.32+/-0.42	0.44+/-0.04	0.37+/-0.03	0.71+/-0.05		
5/18 0926L - 5/19 1035L	4.41+/-0.71	0.38+/-0.06	0.37+/-0.06	0.94+/-0.08		
5/19 1040L - 5/20 0905L	5.29+/-0.55	0.67+/-0.05	0.84+/-0.04	1.72+/-0.07		

* Air filter sample collected using a Brooks/Roots system (SASP pump) - Sample plancheted
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 25
Surface Air Concentrations at New York City *
(Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/15 1155L - 5/16 1000L	24.1+/-7.6	19.2+/-2.9	< 5.1	< 2.9	< 2.7	< 15.2
5/16 1000L - 5/17 0905L	11.3+/-4.6	9.7+/-4.7	< 2.8	< 2.5	< 2.3	< 8.2
5/17 0905L - 5/18 0926L	< 6.9	< 6.8	< 1.9	< 1.9	< 1.4	< 4.9
5/18 0926L - 5/19 1035L	< 10.2	< 10.7	< 3.2	< 1.8	< 2.5	< 12.7
5/19 1040L - 5/20 0905L	17.0+/-1.4	9.9+/-1.4	< 1.8	< 2.1	< 2.3	< 6.6

TABLE 26
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/15 1155L - 5/16 1000L	0.89+/-0.28	0.71+/-0.11	< 0.19	< 0.11	< 0.10	< 0.56
5/16 1000L - 5/17 0905L	0.42+/-0.17	0.36+/-0.17	< 0.10	< 0.09	< 0.09	< 0.30
5/17 0905L - 5/18 0926L	< 0.26	< 0.25	< 0.07	< 0.07	< 0.05	< 0.18
5/18 0926L - 5/19 1035L	< 0.38	< 0.40	< 0.12	< 0.07	< 0.09	< 0.47
5/19 1040L - 5/20 0905L	0.63+/-0.05	0.37+/-0.05	< 0.07	< 0.08	< 0.09	< 0.24

* Air filter sample collected using a Brooks/Roots system (SASP pump) - Sample plancheted
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 27

Surface Air Concentrations at New York City *

(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/06 0915L - 5/07 0930L	243.1+/-12.0	< 1.5	< 1.6	< 1.6	< 1.2	< 16.8
5/07 0930L - 5/08 0930L	156.1+/-9.7	2.6+/-0.9	< 1.6	< 1.4	< 1.9	< 11.2
5/08 0930L - 5/09 0910L	41.3+/-2.5	19.6+/-0.5	3.7+/-0.3	6.6+/-0.4	2.7+/-0.2	< 4.1
5/09 0910L - 5/10 0730L	172.3+/-4.9	265.1+/-1.4	46.2+/-0.9	88.7+/-1.1	24.0+/-0.6	7.0+/-3.0
5/10 0730L - 5/11 0730L	275.3+/-6.3	560.1+/-2.1	136.5+/-1.7	262.7+/-1.8	50.1+/-0.8	< 8.0
5/11 0730L - 5/12 0930L	178.7+/-5.3	238.5+/-2.3	72.4+/-1.1	138.7+/-1.4	34.4+/-0.8	5.2+/-2.5
5/12 0935L - 5/13 0930L	110.7+/-4.2	151.6+/-1.3	21.2+/-0.7	40.4+/-0.8	18.5+/-0.5	7.0+/-3.1
5/13 0930L - 5/14 0930L	211.3+/-5.9	249.6+/-1.6	47.7+/-1.0	92.5+/-1.2	30.5+/-0.7	< 6.7
5/14 0930L - 5/15 1200L	163.3+/-5.3	85.4+/-1.0	52.9+/-1.3	101.9+/-1.3	28.7+/-0.7	< 5.6
5/15 1200L - 5/16 1000L	150.5+/-5.0	55.3+/-0.8	43.7+/-1.0	87.6+/-1.3	37.0+/-0.7	7.0+/-3.0
5/16 1000L - 5/17 0905L	118.7+/-3.3	26.2+/-0.5	28.6+/-0.6	54.5+/-0.7	35.0+/-0.8	8.5+/-3.3
5/17 0910L - 5/18 0926L	107.2+/-4.0	13.9+/-0.5	11.1+/-0.5	21.7+/-0.7	18.8+/-0.5	< 4.4
5/18 0927L - 5/19 1040L	279.0+/-8.6	10.9+/-0.5	12.2+/-0.5	25.1+/-0.7	19.8+/-0.5	5.3+/-2.2
5/19 1040L - 5/20 0905L	148.2+/-7.4	21.9+/-0.9	24.2+/-1.1	49.8+/-1.4	64.4+/-1.4	12.6+/-4.1
5/20 0905L - 5/21 0830L	106.2+/-5.1	8.5+/-0.6	7.7+/-0.6	15.0+/-0.8	21.7+/-0.7	< 4.5
5/21 0830L - 5/22 0830L	85.0+/-3.3	4.5+/-0.3	2.1+/-0.3	3.5+/-0.3	6.6+/-0.3	< 3.7
5/22 0830L - 5/23 1040L	68.6+/-2.3	7.9+/-0.3	1.9+/-0.2	3.9+/-0.3	7.3+/-0.3	< 2.6
5/23 1040L - 5/24 0830L	138.8+/-3.8	43.5+/-0.7	13.1+/-0.5	27.4+/-0.7	61.6+/-0.8	10.1+/-2.3
5/24 0830L - 5/25 0830L	124.3+/-4.2	26.4+/-0.6	10.3+/-0.6	21.2+/-0.7	46.4+/-0.8	6.5+/-2.1
5/25 0830L - 5/26 0830L	99.9+/-3.4	12.2+/-0.4	11.9+/-0.5	24.4+/-0.6	36.6+/-0.6	5.9+/-2.0
5/26 0830L - 5/27 0900L	83.8+/-3.6	8.9+/-0.4	10.9+/-0.5	20.5+/-0.6	34.6+/-0.6	7.0+/-2.8
5/27 0905L - 5/28 0920L	144.5+/-4.8	13.9+/-0.5	12.9+/-0.6	26.4+/-0.8	44.9+/-0.8	6.4+/-2.6
5/28 0920L - 5/29 1100L	177.8+/-4.7	21.3+/-0.6	14.0+/-0.6	30.4+/-0.8	49.7+/-0.8	8.0+/-2.6
5/29 1100L - 5/30 0915L	197.3+/-4.6	15.4+/-0.5	14.3+/-0.5	29.3+/-0.7	49.3+/-0.7	7.6+/-1.9

* Air filter sample collected using a Brooks/Roots system (SASP pump)

< Less than reported value

Errors reported represent two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 27 (Cont.)
Surface Air Concentrations at New York City *

(Femtocurie/Cubic Meter)						
Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/30 0915L - 5/31 0645L	184.9+/-4.5	14.5+/-0.5	14.9+/-0.5	31.1+/-0.7	47.2+/-0.7	7.2+/-2.3
5/31 0645L - 6/02 0835L	204.7+/-3.9	6.8+/-0.3	10.5+/-0.4	22.1+/-0.5	32.1+/-0.5	4.9+/-1.3
6/02 0840L - 6/06 0830L	239.8+/-3.0	14.1+/-0.3	24.8+/-0.4	52.1+/-0.5	9.1+/-0.1	1.5+/-0.1
6/06 0835L - 6/09 0855L	65.6+/-1.7	0.9+/-0.1	1.3+/-0.1	2.6+/-0.1	5.6+/-0.2	1.4+/-0.6
6/09 0855L - 6/13 0910L	56.6+/-1.9	0.3+/-0.0	1.1+/-0.1	2.2+/-0.1	4.0+/-0.1	1.1+/-0.3

* Air filter sample collected using a Brooks/Roots system (SASP pump)
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 28
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/06 0915L - 5/07 0930L	8.99+/-0.44	< 0.06	< 0.06	< 0.06	< 0.04	< 0.62
5/07 0930L - 5/08 0930L	5.78+/-0.36	0.10+/-0.03	< 0.06	< 0.05	< 0.07	< 0.42
5/08 0930L - 5/09 0910L	1.53+/-0.09	0.73+/-0.02	0.14+/-0.01	0.24+/-0.01	0.10+/-0.01	< 0.15
5/09 0910L - 5/10 0730L	6.38+/-0.18	9.81+/-0.05	1.71+/-0.03	3.28+/-0.04	0.89+/-0.02	0.26+/-0.11
5/10 0730L - 5/11 0730L	10.19+/-0.23	20.72+/-0.08	5.05+/-0.06	9.72+/-0.07	1.85+/-0.03	< 0.30
5/11 0730L - 5/12 0930L	6.61+/-0.20	8.82+/-0.09	2.68+/-0.04	5.13+/-0.05	1.27+/-0.03	0.19+/-0.09
5/12 0935L - 5/13 0930L	4.10+/-0.16	5.61+/-0.05	0.78+/-0.03	1.49+/-0.03	0.68+/-0.02	0.26+/-0.11
5/13 0930L - 5/14 0930L	7.82+/-0.22	9.24+/-0.06	1.76+/-0.04	3.42+/-0.04	1.13+/-0.03	< 0.25
5/14 0930L - 5/15 1200L	6.04+/-0.20	3.16+/-0.04	1.96+/-0.05	3.77+/-0.05	1.06+/-0.03	< 0.21
5/15 1200L - 5/16 1000L	5.57+/-0.19	2.05+/-0.03	1.62+/-0.04	3.24+/-0.05	1.37+/-0.03	0.26+/-0.11
5/16 1000L - 5/17 0905L	4.39+/-0.12	0.97+/-0.02	1.06+/-0.02	2.02+/-0.03	1.30+/-0.03	0.31+/-0.12
5/17 0910L - 5/18 0926L	3.97+/-0.15	0.51+/-0.02	0.41+/-0.02	0.80+/-0.03	0.68+/-0.02	< 0.16
5/18 0927L - 5/19 1040L	10.32+/-0.32	0.40+/-0.02	0.45+/-0.02	0.93+/-0.03	0.73+/-0.02	0.20+/-0.08
5/19 1040L - 5/20 0905L	5.48+/-0.27	0.81+/-0.03	0.90+/-0.04	1.84+/-0.05	2.38+/-0.05	0.47+/-0.15
5/20 0905L - 5/21 0830L	3.93+/-0.19	0.31+/-0.02	0.28+/-0.02	0.56+/-0.03	0.80+/-0.03	< 0.17
5/21 0830L - 5/22 0830L	3.14+/-0.12	0.17+/-0.01	0.08+/-0.01	0.13+/-0.01	0.24+/-0.01	< 0.14
5/22 0830L - 5/23 1040L	2.54+/-0.09	0.29+/-0.01	0.07+/-0.01	0.14+/-0.01	0.27+/-0.01	< 0.10
5/23 1040L - 5/24 0830L	5.14+/-0.14	1.61+/-0.03	0.48+/-0.02	1.01+/-0.03	2.28+/-0.03	0.37+/-0.09
5/24 0830L - 5/25 0830L	4.60+/-0.16	0.98+/-0.02	0.38+/-0.02	0.78+/-0.03	1.72+/-0.03	0.24+/-0.08
5/25 0830L - 5/26 0830L	3.70+/-0.13	0.45+/-0.01	0.44+/-0.02	0.90+/-0.02	0.90+/-0.02	0.22+/-0.07
5/26 0830L - 5/27 0900L	3.10+/-0.13	0.33+/-0.01	0.40+/-0.02	0.76+/-0.02	1.28+/-0.02	0.26+/-0.10
5/27 0905L - 5/28 0920L	5.35+/-0.18	0.51+/-0.02	0.48+/-0.02	0.98+/-0.03	1.66+/-0.03	0.24+/-0.10
5/28 0920L - 5/29 1100L	6.58+/-0.17	0.79+/-0.02	0.52+/-0.02	1.12+/-0.03	1.84+/-0.03	0.30+/-0.10
5/29 1100L - 5/30 0915L	7.30+/-0.17	0.57+/-0.02	0.53+/-0.02	1.08+/-0.03	1.82+/-0.03	0.28+/-0.07

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 28 (Cont.)

Surface Air Concentrations at New York City *

(Millibecquerel/Cubic Meter)

Collection Period	8e-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/30 0915L - 5/31 0645L	6.84+/-0.17	0.54+/-0.02	0.55+/-0.02	1.15+/-0.03	1.75+/-0.03	0.27+/-0.09
5/31 0645L - 6/02 0835L	7.57+/-0.14	0.25+/-0.01	0.39+/-0.01	0.82+/-0.02	1.19+/-0.02	0.18+/-0.05
6/02 0840L - 6/06 0830L	8.87+/-0.11	0.52+/-0.01	0.92+/-0.01	1.93+/-0.02	0.34+/-0.00	0.06+/-0.00
6/06 0835L - 6/09 0855L	2.43+/-0.06	0.03+/-0.00	0.05+/-0.00	0.10+/-0.00	0.21+/-0.01	0.05+/-0.02
6/09 0855L - 6/13 0910L	1.09+/-0.07	0.01+/-0.00	0.04+/-0.00	0.08+/-0.00	0.15+/-0.00	0.04+/-0.01

* Air filter sample collected using a Brooks/Roots system (SASP pump)

< Less than reported value

Errors reported represent two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 29

Surface Air Concentrations at New York City *

(FemtoCurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/06 0915L - 5/07 0930L	< 5.5	< 2.9	< 2.4	< 1.0	< 1.2	< 4.9
5/07 0930L - 5/08 0930L	< 6.2	< 2.7	3.4+/-1.4	< 1.0	< 1.1	< 6.8
5/08 0930L - 5/09 0910L		1.1+/-0.6	< 0.5	< 0.3	< 0.4	< 1.7
5/09 0910L - 5/10 0730L		7.4+/-0.8	1.1+/-0.5	1.9+/-0.4	1.2+/-0.5	< 2.9
5/10 0730L - 5/11 0730L		19.2+/-1.4	2.1+/-0.7	3.7+/-0.5	4.1+/-0.7	7.1+/-2.2
5/11 0730L - 5/12 0930L	15.4+/-2.6	17.0+/-2.3	2.0+/-0.2	< 4.3	2.2+/-0.4	< 2.8
5/12 0935L - 5/13 0930L		4.1+/-0.8	< 0.8	< 0.7	< 0.9	< 3.2
5/13 0930L - 5/14 0930L		7.2+/-1.0	< 0.9	1.1+/-0.4	1.2+/-0.6	< 3.0
5/14 0930L - 5/15 1200L		7.3+/-1.0	< 1.0	0.7+/-0.3	< 0.9	< 3.3
5/15 1200L - 5/16 1000L		0.7+/-0.1	< 1.0	0.7+/-0.3	1.1+/-0.5	< 3.3
5/16 1000L - 5/17 0905L	7.0+/-1.4	5.4+/-1.0	< 0.8	< 0.6	1.1+/-0.3	< 2.2
5/17 0910L - 5/18 0926L	3.5+/-1.2	1.7+/-0.7	< 0.9	< 0.4	0.5+/-0.2	< 2.3
5/18 0927L - 5/19 1040L	2.5+/-0.9	4.5+/-1.0	< 0.7	< 0.4	0.8+/-0.2	< 1.8
5/19 1040L - 5/20 0905L	9.3+/-1.9	12.3+/-1.4	< 1.2	< 0.7	2.2+/-0.5	< 3.8
5/20 0905L - 5/21 0830L	3.5+/-1.2	4.0+/-1.2	< 0.9	< 0.5	1.0+/-0.3	< 2.3
5/21 0830L - 5/22 0830L	1.8+/-0.7	< 1.7	< 0.6	< 0.2	< 0.5	< 1.5
5/22 0830L - 5/23 1040L	1.6+/-0.6	1.7+/-0.7	< 0.4	< 0.2	< 0.4	< 1.6
5/23 1040L - 5/24 0830L	4.3+/-1.1	5.8+/-1.1	< 0.8	< 0.3	1.1+/-0.3	< 2.4
5/24 0830L - 5/25 0830L	3.9+/-1.0	4.6+/-0.9	< 0.8	< 0.4	1.1+/-0.3	2.5+/-1.2
5/25 0830L - 5/26 0830L	4.3+/-0.9	4.8+/-0.9	< 0.7	< 0.2	1.0+/-0.2	< 2.0
5/26 0830L - 5/27 0900L	2.6+/-1.0	3.9+/-1.1	< 0.7	< 0.4	< 0.5	< 2.5
5/27 0905L - 5/28 0920L	3.4+/-1.2	5.2+/-1.2	< 1.2	< 0.4	1.3+/-0.4	< 3.3
5/28 0920L - 5/29 1100L	5.7+/-1.0	7.5+/-1.3	< 1.2	< 0.4	1.3+/-0.3	< 2.6
5/29 1100L - 5/30 0915L	3.9+/-1.0	5.4+/-0.7	< 0.8	< 0.6	1.3+/-0.3	2.2+/-1.0

* Air filter sample collected using a Brooks/Roots system (SASP pump)

< Less than reported value

Errors reported represent two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 29 (Cont.)
 Surface Air Concentrations at New York City *
 (Femtocuries/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/30 0915L - 5/31 0645L	3.9+/-0.9	6.3+/-1.3	< 0.6	< 0.5	1.4+/-0.3	< 1.9
5/31 0645L - 6/02 0835L	3.2+/-0.7	4.1+/-0.8	< 0.4	< 0.4	1.1+/-0.2	1.7+/-0.7
6/02 0840L - 6/06 0830L	3.8+/-0.6	5.7+/-0.7	< 0.3	< 0.5	1.5+/-0.2	2.0+/-0.4
6/06 0835L - 6/09 0855L	< 0.6	< 0.6	< 0.2	< 0.2	< 0.1	< 0.6
6/09 0855L - 6/13 0910L	< 0.2	< 0.3	< 0.1	< 0.1	< 0.1	< 0.2

* Air filter sample collected using a Brooks/Roots system (SASP pump)
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 30
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Ir-95	Mo-99	Ce-141	Ce-144
5/06 0915L - 5/07 0930L	< 0.20	< 0.11	< 0.09	< 0.04	< 0.04	< 0.18
5/07 0930L - 5/08 0930L	< 0.23	< 0.10	0.13+/-0.05	< 0.04	< 0.04	< 0.25
5/08 0930L - 5/09 0910L		0.04+/-0.02	< 0.02	< 0.01	< 0.01	< 0.06
5/09 0910L - 5/10 0730L		0.27+/-0.03	0.04+/-0.02	0.07+/-0.01	0.04+/-0.02	< 0.11
5/10 0730L - 5/11 0730L		0.71+/-0.05	0.08+/-0.03	0.14+/-0.02	0.15+/-0.03	0.26+/-0.08
5/11 0730L - 5/12 0930L	0.57+/-0.10	0.63+/-0.09	0.07+/-0.01	< 0.16	0.08+/-0.01	< 0.10
5/12 0935L - 5/13 0930L		0.15+/-0.03	< 0.03	< 0.03	< 0.03	< 0.12
5/13 0930L - 5/14 0930L		0.27+/-0.04	< 0.03	0.04+/-0.01	0.04+/-0.02	< 0.11
5/14 0930L - 5/15 1200L		0.27+/-0.04	< 0.04	0.03+/-0.01	< 0.03	< 0.12
5/15 1200L - 5/16 1000L		0.03+/-0.00	< 0.04	0.03+/-0.01	0.04+/-0.02	< 0.12
5/16 1000L - 5/17 0905L	0.26+/-0.05	0.20+/-0.04	< 0.03	< 0.02	0.04+/-0.01	< 0.08
5/17 0910L - 5/18 0926L	0.13+/-0.04	0.06+/-0.03	< 0.03	< 0.01	0.02+/-0.01	< 0.09
5/18 0927L - 5/19 1040L	0.09+/-0.03	0.17+/-0.04	< 0.03	< 0.01	0.03+/-0.01	< 0.07
5/19 1040L - 5/20 0905L	0.34+/-0.07	0.46+/-0.05	< 0.04	< 0.03	0.08+/-0.02	< 0.14
5/20 0905L - 5/21 0830L	0.13+/-0.04	0.15+/-0.04	< 0.03	< 0.02	0.04+/-0.01	< 0.09
5/21 0830L - 5/22 0830L	0.07+/-0.03	< 0.06	< 0.02	< 0.01	< 0.02	< 0.06
5/22 0830L - 5/23 1040L	0.06+/-0.02	0.06+/-0.03	< 0.01	< 0.01	< 0.01	< 0.06
5/23 1040L - 5/24 0830L	0.16+/-0.04	0.21+/-0.04	< 0.03	< 0.01	0.04+/-0.01	< 0.09
5/24 0830L - 5/25 0830L	0.14+/-0.04	0.17+/-0.03	< 0.03	< 0.01	0.04+/-0.01	0.09+/-0.04
5/25 0830L - 5/26 0830L	0.16+/-0.03	0.18+/-0.03	< 0.03	< 0.01	0.04+/-0.01	< 0.07
5/26 0830L - 5/27 0900L	0.10+/-0.04	0.14+/-0.04	< 0.03	< 0.01	< 0.02	< 0.09
5/27 0905L - 5/28 0920L	0.13+/-0.04	0.19+/-0.04	< 0.04	< 0.01	0.05+/-0.01	< 0.12
5/28 0920L - 5/29 1100L	0.21+/-0.04	0.28+/-0.05	< 0.04	< 0.01	0.05+/-0.01	< 0.10
5/29 1100L - 5/30 0915L	0.14+/-0.04	0.20+/-0.03	< 0.03	< 0.02	0.05+/-0.01	0.08+/-0.04

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 30 (Cont.)
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/30 0915L - 5/31 0645L	0.14+/-0.03	0.23+/-0.05	< 0.02	< 0.02	0.05+/-0.01	< 0.07
5/31 0645L - 6/02 0835L	0.12+/-0.03	0.15+/-0.03	< 0.01	< 0.01	0.04+/-0.01	0.06+/-0.03
6/02 0840L - 6/06 0830L	0.14+/-0.02	0.21+/-0.03	< 0.01	< 0.02	0.06+/-0.01	0.07+/-0.01
6/06 0835L - 6/09 0855L	< 0.02	< 0.02	< 0.01	< 0.01	< 0.01	< 0.02
6/09 0855L - 6/13 0910L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 31

Surface Air Concentrations at New York City *

(FemtoCurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/06 0915L - 5/07 0935L	266.5+/-9.6	< 1.2	< 1.8	< 1.0	< 0.9	< 9.9
5/07 0940L - 5/08 0930L	194.5+/-8.9	< 1.3	< 1.8	< 1.3	< 0.9	< 0.9
5/08 0940L - 5/09 0910L	39.7+/-5.4	22.7+/-0.9	3.9+/-0.9	8.8+/-0.9	5.3+/-0.6	< 9.7
5/09 0910L - 5/10 0750L	140.3+/-8.1	234.3+/-2.3	42.3+/-1.4	78.9+/-1.8	20.6+/-0.9	< 9.1
5/10 0730L - 5/11 0730L	237.3+/-11.9	491.3+/-3.5	124.8+/-2.4	238.6+/-3.2	45.8+/-1.5	< 12.9
5/11 0730L - 5/12 0935L	151.1+/-8.7	215.7+/-2.4	68.1+/-1.8	127.1+/-2.4		
5/12 0940L - 5/13 0930L	87.8+/-7.2	125.7+/-2.2	16.3+/-1.2	30.7+/-1.5	16.3+/-1.0	< 11.8
5/13 0930L - 5/14 0930L	208.6+/-10.4	242.5+/-2.8	48.9+/-1.7	91.0+/-2.4	32.7+/-1.4	< 14.3
5/14 0930L - 5/15 1205L	174.7+/-9.5	96.6+/-1.7	59.3+/-1.8	110.3+/-2.3	33.1+/-1.2	< 14.1
5/15 1205L - 5/16 1000L	167.4+/-9.8	70.0+/-1.8	54.3+/-1.8	104.9+/-2.5	46.0+/-1.5	< 17.3
5/16 1000L - 5/17 0855L	185.1+/-8.1	41.5+/-1.2	45.5+/-1.4	89.3+/-1.8	58.5+/-1.4	< 12.7
5/17 0900L - 5/18 0928L	102.1+/-8.4	12.5+/-1.0	11.3+/-1.2	18.8+/-1.3	18.3+/-1.2	< 16.4
5/18 0928L - 5/19 1045L	134.7+/-8.7	9.8+/-0.9	13.8+/-1.4	28.2+/-1.5	21.3+/-1.0	< 14.3
5/19 1045L - 5/20 0900L	177.3+/-9.6	26.0+/-1.2	30.1+/-1.5	59.6+/-2.0	80.0+/-1.9	< 11.6
5/20 0900L - 5/21 0830L	167.2+/-8.8	15.2+/-1.0	14.7+/-1.1	26.7+/-1.4	38.3+/-1.4	12.5+/-5.6
5/21 0830L - 5/22 0830L	82.1+/-6.2	4.1+/-0.6	2.1+/-0.8	3.6+/-0.7	5.9+/-0.7	< 9.8
5/22 0830L - 5/23 1040L	88.8+/-5.1	10.7+/-0.6	2.6+/-0.7	4.6+/-0.6	9.9+/-0.6	< 8.8
5/23 1040L - 5/24 0830L	130.7+/-7.4	38.7+/-1.1	13.2+/-0.9	26.1+/-1.2	59.0+/-1.3	12.9+/-4.7
5/24 0830L - 5/25 0830L	129.9+/-8.2	28.7+/-1.1	10.1+/-1.2	23.3+/-1.3	52.4+/-1.6	16.1+/-6.7
5/25 0830L - 5/26 0830L	139.8+/-7.1	16.3+/-0.8	17.4+/-1.0	33.9+/-1.3	53.8+/-1.3	< 11.8
5/26 0830L - 5/27 0905L	114.2+/-7.4	11.1+/-0.8	13.2+/-1.3	27.8+/-1.4	48.2+/-1.5	< 11.3
5/27 0905L - 5/28 0920L	185.2+/-9.7	17.9+/-1.1	17.8+/-1.7	37.1+/-1.7	62.3+/-1.6	20.4+/-7.3
5/28 0925L - 5/29 1100L	169.7+/-8.3	20.7+/-1.0	16.0+/-1.1	29.8+/-1.3	50.6+/-1.4	13.2+/-6.1
5/29 1100L - 5/30 0915L	190.7+/-7.3	15.2+/-0.9	15.0+/-0.9	30.4+/-1.2	53.0+/-1.3	16.4+/-4.7

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).

< Less than reported value

Errors reported represent two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 31 (Cont.)
 Surface Air Concentrations at New York City *
 (Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/30 0920L - 5/31 0645L	206.9+/-7.8	14.8+/-1.0	18.1+/-1.0	37.9+/-1.3	57.9+/-1.4	14.3+/-4.5
5/31 0645L - 6/02 0840L	240.8+/-6.2	7.4+/-0.6	13.5+/-0.6	27.2+/-0.9	42.1+/-0.9	10.1+/-3.2
6/02 0845L - 6/06 0835L	241.2+/-5.0	13.3+/-0.5	26.1+/-0.6	54.3+/-0.9	97.4+/-1.0	19.5+/-2.7
6/06 0840L - 6/09 0855L	67.3+/-2.8	1.1+/-0.3	1.6+/-0.3	3.0+/-0.3	6.4+/-0.3	< 3.1
6/09 0900L - 6/13 0912L	33.4+/-1.0	0.2+/-0.0	0.7+/-0.1	1.4+/-0.1	2.5+/-0.1	1.0+/-0.4

 * Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 32
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/06 0915L - 5/07 0935L	9.86+/-0.36	< 0.04	< 0.07	< 0.04	< 0.03	< 0.37
5/07 0940L - 5/08 0930L	7.20+/-0.33	< 0.05	< 0.07	< 0.05	< 0.03	< 0.03
5/08 0940L - 5/09 0910L	1.47+/-0.20	0.84+/-0.03	0.14+/-0.03	0.33+/-0.03	0.20+/-0.02	< 0.36
5/09 0910L - 5/10 0750L	5.19+/-0.30	8.67+/-0.09	1.57+/-0.05	2.92+/-0.07	0.76+/-0.03	< 0.34
5/10 0730L - 5/11 0730L	8.78+/-0.44	18.18+/-0.13	4.62+/-0.09	8.83+/-0.12	1.69+/-0.06	< 0.48
5/11 0730L - 5/12 0935L	5.59+/-0.32	7.98+/-0.09	2.52+/-0.07	4.70+/-0.09		
5/12 0940L - 5/13 0930L	3.25+/-0.27	4.65+/-0.08	0.60+/-0.04	1.14+/-0.06	0.60+/-0.04	< 0.44
5/13 0930L - 5/14 0930L	7.72+/-0.38	8.97+/-0.10	1.81+/-0.06	3.37+/-0.09	1.21+/-0.05	< 0.53
5/14 0930L - 5/15 1205L	6.46+/-0.35	3.57+/-0.06	2.19+/-0.07	4.08+/-0.09	1.22+/-0.04	< 0.52
5/15 1205L - 5/16 1000L	6.19+/-0.36	2.59+/-0.07	2.01+/-0.07	3.88+/-0.09	1.70+/-0.06	< 0.64
5/16 1000L - 5/17 0855L	6.85+/-0.30	1.54+/-0.04	1.68+/-0.05	3.30+/-0.07	2.16+/-0.05	< 0.47
5/17 0900L - 5/18 0928L	3.78+/-0.31	0.46+/-0.04	0.42+/-0.04	0.70+/-0.05	0.68+/-0.04	< 0.61
5/18 0928L - 5/19 1045L	4.98+/-0.32	0.36+/-0.03	0.51+/-0.05	1.04+/-0.06	0.79+/-0.04	< 0.53
5/19 1045L - 5/20 0900L	6.56+/-0.36	0.96+/-0.04	1.11+/-0.06	2.21+/-0.07	2.96+/-0.07	< 0.43
5/20 0900L - 5/21 0830L	6.19+/-0.33	0.56+/-0.04	0.54+/-0.04	0.99+/-0.05	1.42+/-0.05	0.46+/-0.21
5/21 0830L - 5/22 0830L	3.04+/-0.23	0.15+/-0.02	0.08+/-0.03	0.13+/-0.03	0.22+/-0.03	< 0.36
5/22 0830L - 5/23 1040L	3.29+/-0.19	0.40+/-0.02	0.10+/-0.03	0.17+/-0.02	0.37+/-0.02	< 0.33
5/23 1040L - 5/24 0830L	4.84+/-0.27	1.43+/-0.04	0.49+/-0.03	0.97+/-0.04	2.18+/-0.05	0.48+/-0.17
5/24 0830L - 5/25 0830L	4.81+/-0.30	1.06+/-0.04	0.37+/-0.04	0.86+/-0.05	1.94+/-0.06	0.60+/-0.25
5/25 0830L - 5/26 0830L	5.17+/-0.26	0.60+/-0.03	0.64+/-0.04	1.25+/-0.05	1.99+/-0.05	< 0.44
5/26 0830L - 5/27 0905L	4.23+/-0.27	0.41+/-0.03	0.49+/-0.05	1.03+/-0.05	1.78+/-0.06	< 0.42
5/27 0905L - 5/28 0920L	6.85+/-0.36	0.66+/-0.04	0.66+/-0.06	1.37+/-0.06	2.31+/-0.06	0.75+/-0.27
5/28 0925L - 5/29 1100L	6.28+/-0.31	0.77+/-0.04	0.59+/-0.04	1.10+/-0.05	1.87+/-0.05	0.49+/-0.23
5/29 1100L - 5/30 0915L	7.06+/-0.27	0.56+/-0.03	0.56+/-0.03	1.12+/-0.04	1.96+/-0.05	0.61+/-0.17

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 32 (Cont'd)
Surface Air Concentrations at New York City *
(Milibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/30 0920L - 5/31 0645L	7.66+/-0.29	0.55+/-0.04	0.67+/-0.04	1.40+/-0.05	2.14+/-0.05	0.53+/-0.17
5/31 0645L - 6/02 0840L	8.91+/-0.23	0.27+/-0.02	0.50+/-0.02	1.01+/-0.03	1.56+/-0.03	0.37+/-0.12
6/02 0845L - 6/06 0835L	8.92+/-0.19	0.49+/-0.02	0.97+/-0.02	2.01+/-0.03	3.60+/-0.04	0.72+/-0.10
6/06 0840L - 6/09 0855L	2.49+/-0.10	0.04+/-0.01	0.06+/-0.01	0.11+/-0.01	0.24+/-0.01	< 0.11
6/09 0900L - 6/13 0912L	1.24+/-0.04	0.01+/-0.00	0.03+/-0.00	0.05+/-0.00	0.09+/-0.00	0.04+/-0.01

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 33
Surface Air Concentrations at New York City *

		(Femtocurie/Cubic Meter)					
Collection Period		Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/06 0915L - 5/07 0935L	< 3.5	< 3.6	< 2.4	< 0.8	< 0.7	< 3.2	
5/07 0940L - 5/08 0930L	< 3.7	< 3.7	< 4.0	< 0.9	< 0.8	< 3.6	
5/08 0940L - 5/09 0910L	< 4.4	< 3.8	< 2.3	< 0.4	< 0.8	< 3.7	
5/09 0910L - 5/10 0750L	9.5+/-2.8	9.1+/-2.5	< 3.9	1.3+/-0.4	< 1.0	< 3.8	
5/10 0730L - 5/11 0730L	22.0+/-4.2	27.7+/-4.2	< 5.4	2.5+/-0.8	< 2.2	< 6.1	
5/11 0730L - 5/12 0935L		9.2+/-3.0	< 4.5	1.3+/-0.4		< 4.4	
5/12 0940L - 5/13 0930L		< 5.2	< 4.0	< 0.7		< 4.4	
5/13 0930L - 5/14 0930L		7.0+/-2.8	27.2+/-2.7	< 0.8		< 4.4	
5/14 0930L - 5/15 1205L		< 5.2	< 3.1	< 0.7	1.2+/-0.5	< 3.7	
5/15 1205L - 5/16 1000L		< 6.3	< 3.4	< 0.7	1.4+/-0.7	< 4.2	
5/16 1000L - 5/17 0855L		7.4+/-2.6	< 2.8	< 1.1	1.5+/-0.7	< 4.5	
5/17 0900L - 5/18 0928L	< 6.5	< 3.4	< 3.6	< 0.8	< 1.2	< 5.8	
5/18 0928L - 5/19 1045L	6.1+/-2.8	5.2+/-1.7	< 3.6	< 0.7	< 1.0	< 4.5	
5/19 1045L - 5/20 0900L	9.5+/-2.9	14.9+/-3.0	< 3.6	< 0.8	2.2+/-0.5	< 5.1	
5/20 0900L - 5/21 0830L	< 5.0	6.1+/-2.4	< 2.8	< 0.7	< 0.9	< 3.8	
5/21 0830L - 5/22 0830L	< 3.9	< 2.9	< 2.3	< 0.4	< 1.0	< 3.4	
5/22 0830L - 5/23 1040L	< 3.1	4.3+/-1.6	< 1.6	< 0.7	< 0.7	< 3.0	
5/23 1040L - 5/24 0830L	4.8+/-2.1	5.5+/-2.0	< 2.3	< 0.5	< 1.0	< 3.4	
5/24 0830L - 5/25 0830L	7.3+/-2.7	4.3+/-2.1	< 3.0	< 0.8	< 1.0	< 4.1	
5/25 0830L - 5/26 0830L	4.5+/-2.2	6.6+/-2.1	< 2.3	< 0.5	1.0+/-0.4	< 4.4	
5/26 0830L - 5/27 0905L	6.6+/-2.4	7.3+/-2.4	< 3.2	< 0.5	1.0+/-0.5	< 3.7	
5/27 0905L - 5/28 0920L	6.1+/-3.0	11.9+/-3.2	< 3.6	< 0.8	< 1.2	< 5.3	
5/28 0925L - 5/29 1100L	7.0+/-2.5	8.0+/-2.5	< 2.5	< 0.5	1.5+/-0.5	< 3.5	
5/29 1100L - 5/30 0915L	5.4+/-2.2	7.7+/-2.1	< 1.8	< 0.9	1.4+/-0.4	< 2.6	

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 33 (Cont'd)
Surface Air Concentrations at New York City *
(Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/30 0920L - 5/31 0645L	6.2+/-2.5	7.9+/-2.1	< 1.9	< 1.0	1.6+/-0.4	4.1+/-1.7
5/31 0645L - 6/02 0840L	4.7+/-1.6	6.8+/-1.4	< 1.3	< 0.5	1.1+/-0.3	< 2.1
6/02 0845L - 6/06 0835L	3.8+/-1.3	6.8+/-1.4	< 1.1	< 0.7	1.0+/-0.3	< 1.7
6/06 0840L - 6/09 0855	< 1.0	< 1.3	< 0.6	< 0.5	< 0.2	< 0.9
6/09 0900L - 6/13 0912L	< 0.3	< 0.3	< 0.2	< 0.1	< 0.1	< 0.3

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 34
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/06 0915L - 5/07 0935L	< 0.13	< 0.13	< 0.09	< 0.03	< 0.03	< 0.12
5/07 0940L - 5/08 0930L	< 0.14	< 0.14	< 0.15	< 0.03	< 0.03	< 0.13
5/08 0940L - 5/09 0910L	< 0.16	< 0.14	< 0.09	< 0.01	< 0.03	< 0.14
5/09 0910L - 5/10 0750L	0.35+/-0.10	0.34+/-0.09	< 0.14	0.05+/-0.01	< 0.04	< 0.14
5/10 0730L - 5/11 0730L	0.81+/-0.16	1.02+/-0.16	< 0.20	0.09+/-0.03	< 0.08	< 0.23
5/11 0730L - 5/12 0935L		0.34+/-0.11	< 0.17	0.05+/-0.01		< 0.16
5/12 0940L - 5/13 0930L		< 0.19	< 0.15	< 0.03		< 0.16
5/13 0930L - 5/14 0930L		0.26+/-0.10	1.01+/-0.10	< 0.03		< 0.16
5/14 0930L - 5/15 1205L		< 0.19	< 0.11	< 0.03	0.04+/-0.02	< 0.14
5/15 1205L - 5/16 1000L		< 0.23	< 0.13	< 0.03	0.05+/-0.03	< 0.16
5/16 1000L - 5/17 0855L		0.27+/-0.10	< 0.10	< 0.04	0.06+/-0.03	< 0.17
5/17 0900L - 5/18 0928L	< 0.24	< 0.13	< 0.13	< 0.03	< 0.04	< 0.21
5/18 0928L - 5/19 1045L	0.23+/-0.10	0.19+/-0.06	< 0.13	< 0.03	< 0.04	< 0.17
5/19 1045L - 5/20 0900L	0.35+/-0.11	0.55+/-0.11	< 0.13	< 0.03	0.08+/-0.02	< 0.19
5/20 0900L - 5/21 0830L	< 0.19	0.23+/-0.09	< 0.10	< 0.03	< 0.03	< 0.14
5/21 0830L - 5/22 0830L	< 0.14	< 0.11	< 0.09	< 0.01	< 0.04	< 0.13
5/22 0830L - 5/23 1040L	< 0.11	0.16+/-0.06	< 0.06	< 0.03	< 0.03	< 0.11
5/23 1040L - 5/24 0830L	0.18+/-0.08	0.20+/-0.07	< 0.09	< 0.02	< 0.04	< 0.13
5/24 0830L - 5/25 0830L	0.27+/-0.10	0.16+/-0.08	< 0.11	< 0.03	< 0.04	< 0.15
5/25 0830L - 5/26 0830L	0.17+/-0.08	0.24+/-0.08	< 0.09	< 0.02	0.04+/-0.01	< 0.16
5/26 0830L - 5/27 0905L	0.24+/-0.09	0.27+/-0.09	< 0.12	< 0.02	0.04+/-0.02	< 0.14
5/27 0905L - 5/28 0920L	0.23+/-0.11	0.44+/-0.12	< 0.13	< 0.03	< 0.04	< 0.20
5/28 0925L - 5/29 1100L	0.26+/-0.09	0.30+/-0.09	< 0.09	< 0.02	0.06+/-0.02	< 0.13
5/29 1100L - 5/30 0915L	0.20+/-0.08	0.28+/-0.08	< 0.07	< 0.03	0.05+/-0.01	< 0.10

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 34 (Cont'd)
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/30 0920L - 5/31 0645L	0.23+/-0.09	0.29+/-0.08	< 0.07	< 0.04	0.06+/-0.01	0.15+/-0.06
5/31 0645L - 6/02 0840L	0.17+/-0.06	0.25+/-0.05	< 0.05	< 0.02	0.04+/-0.01	< 0.08
6/02 0845L - 6/06 0835L	0.14+/-0.05	0.25+/-0.05	< 0.04	< 0.03	0.04+/-0.01	< 0.06
6/06 0840L - 6/09 0855	< 0.04	< 0.05	< 0.02	< 0.02	< 0.01	< 0.03
6/09 0900L - 6/13 0912L	< 0.01	< 0.01	< 0.01	< 0.00	< 0.00	< 0.01

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump).
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 35
Surface Air Concentrations at New York City *
(Femtocuria/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/06 0915L - 5/07 0930L	257.4+/-7.5	< 1.4	< 1.7	< 1.3	< 1.1	< 13.4
5/07 0930L - 5/08 0930L	176.9+/-6.6	2.6+/-0.9	< 1.4	< 1.4	< 1.4	< 6.1
5/08 0930L - 5/09 0910L	41.0+/-2.3	20.3+/-0.4	3.7+/-0.3	7.0+/-0.4	3.0+/-0.2	< 6.9
5/09 0910L - 5/10 0730L	163.7+/-4.2	256.8+/-1.2	45.1+/-0.8	86.0+/-0.9	23.0+/-0.5	7.0+/-3.0
5/10 0730L - 5/11 0730L	267.0+/-5.6	541.9+/-1.8	132.6+/-1.4	256.9+/-1.6	49.1+/-0.7	< 10.5
5/11 0730L - 5/12 0930L	171.2+/-4.5	227.2+/-1.7	71.2+/-0.9	135.8+/-1.2	34.4+/-0.8	5.2+/-2.5
5/12 0935L - 5/13 0930L	105.0+/-3.6	144.9+/-1.1	20.0+/-0.6	38.3+/-0.7	18.1+/-0.4	7.0+/-3.0
5/13 0930L - 5/14 0930L	210.6+/-5.1	247.9+/-1.4	48.0+/-0.9	92.2+/-1.1	30.9+/-0.6	< 10.5
5/14 0930L - 5/15 1200L	166.0+/-4.6	88.3+/-0.9	55.1+/-1.1	103.9+/-1.1	29.8+/-0.6	< 9.9
5/15 1200L - 5/16 1000L	154.0+/-4.5	57.7+/-0.7	46.2+/-0.9	91.3+/-1.2	38.6+/-0.6	7.0+/-3.0
5/16 1000L - 5/17 0905L	128.0+/-3.1	28.5+/-0.5	31.2+/-0.6	59.1+/-0.7	40.8+/-0.7	8.5+/-3.3
5/17 0910L - 5/18 0926L	106.3+/-3.6	13.6+/-0.4	11.2+/-0.5	21.0+/-0.6	18.5+/-0.5	< 10.4
5/18 0927L - 5/19 1040L	207.7+/-6.1	10.6+/-0.4	12.4+/-0.5	25.7+/-0.6	20.1+/-0.4	5.3+/-2.2
5/19 1040L - 5/20 0905L	159.0+/-5.9	23.4+/-0.7	26.3+/-0.9	53.0+/-1.1	69.9+/-1.1	12.6+/-4.1
5/20 0905L - 5/21 0830L	121.5+/-4.4	10.3+/-0.5	9.3+/-0.5	17.9+/-0.7	25.0+/-0.6	12.5+/-5.6
5/21 0830L - 5/22 0830L	84.4+/-2.9	4.4+/-0.3	2.1+/-0.3	3.5+/-0.3	6.5+/-0.3	< 6.8
5/22 0830L - 5/23 1040L	72.0+/-2.1	8.5+/-0.3	2.0+/-0.2	4.0+/-0.3	7.8+/-0.3	< 5.7
5/23 1040L - 5/24 0830L	137.1+/-3.4	42.1+/-0.6	13.1+/-0.4	27.1+/-0.6	60.7+/-0.7	10.6+/-2.1
5/24 0830L - 5/25 0830L	125.5+/-3.7	26.9+/-0.5	10.3+/-0.5	21.7+/-0.6	47.6+/-0.7	7.4+/-2.0
5/25 0830L - 5/26 0830L	107.3+/-3.1	13.0+/-0.4	13.0+/-0.4	26.1+/-0.5	39.6+/-0.5	5.9+/-2.0
5/26 0830L - 5/27 0900L	89.6+/-3.2	9.3+/-0.4	11.2+/-0.5	21.6+/-0.6	36.5+/-0.6	7.0+/-2.8
5/27 0905L - 5/28 0920L	152.5+/-4.3	14.6+/-0.5	13.4+/-0.6	28.3+/-0.7	48.4+/-0.7	8.0+/-2.4
5/28 0920L - 5/29 1100L	175.8+/-4.1	21.1+/-0.5	14.5+/-0.5	30.2+/-0.7	49.9+/-0.7	8.8+/-2.4
5/29 1100L - 5/30 0915L	195.4+/-3.9	15.4+/-0.4	14.5+/-0.4	29.6+/-0.6	50.1+/-0.6	8.8+/-1.8

* Weighted mean and standard deviation of NYC SEAREX and SASP system
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 35 (Cont'd)
Surface Air Concentrations at New York City *
(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/30 0915L - 5/31 0645L	190.4+/-3.9	14.6+/-0.4	15.5+/-0.4	32.6+/-0.6	49.3+/-0.6	8.7+/-2.0
5/31 0645L - 6/02 0835L	214.9+/-3.3	6.9+/-0.3	11.4+/-0.3	23.3+/-0.4	34.5+/-0.4	5.6+/-1.2
6/02 0840L - 6/06 0830L	240.2+/-2.6	13.9+/-0.3	25.2+/-0.3	52.6+/-0.4	10.0+/-0.1	1.5+/-0.1
6/06 0835L - 6/09 0855L	66.1+/-1.5	0.9+/-0.1	1.3+/-0.1	2.6+/-0.1	5.8+/-0.2	1.4+/-0.6
6/09 0855L - 6/13 0910L	38.4+/-0.9	0.3+/-0.0	0.9+/-0.1	1.8+/-0.1	3.3+/-0.1	1.1+/-0.2

* Weighted mean and standard deviation of NYC SEAREX and SASP system
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 36
Surface Air Concentrations at New York City *

Collection Period	(Millibecquerel/Cubic Meter)					
	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/06 0915L - 5/07 0930L	9.52+/-0.28	< 0.05	< 0.06	< 0.05	< 0.04	< 0.50
5/07 0930L - 5/08 0930L	6.55+/-0.24	0.10+/-0.03	< 0.05	< 0.05	< 0.05	< 0.23
5/08 0930L - 5/09 0910L	1.52+/-0.09	0.75+/-0.01	0.14+/-0.01	0.26+/-0.01	0.11+/-0.01	< 0.26
5/09 0910L - 5/10 0730L	6.06+/-0.16	9.50+/-0.04	1.67+/-0.03	3.18+/-0.03	0.85+/-0.02	0.26+/-0.11
5/10 0730L - 5/11 0730L	9.88+/-0.21	20.05+/-0.07	4.91+/-0.05	9.51+/-0.06	1.82+/-0.03	< 0.39
5/11 0730L - 5/12 0930L	6.33+/-0.17	8.41+/-0.06	2.63+/-0.03	5.02+/-0.04	1.27+/-0.03	0.19+/-0.09
5/12 0935L - 5/13 0930L	3.88+/-0.13	5.36+/-0.04	0.74+/-0.02	1.42+/-0.03	0.67+/-0.01	0.26+/-0.11
5/13 0930L - 5/14 0930L	7.79+/-0.19	9.17+/-0.05	1.78+/-0.03	3.41+/-0.04	1.14+/-0.02	< 0.39
5/14 0930L - 5/15 1200L	6.14+/-0.17	3.27+/-0.03	2.04+/-0.04	3.84+/-0.04	1.10+/-0.02	< 0.37
5/15 1200L - 5/16 1000L	5.70+/-0.17	2.13+/-0.03	1.71+/-0.03	3.38+/-0.04	1.43+/-0.02	0.26+/-0.11
5/16 1000L - 5/17 0905L	4.74+/-0.11	1.05+/-0.02	1.15+/-0.02	2.19+/-0.03	1.51+/-0.03	0.31+/-0.12
5/17 0910L - 5/18 0926L	3.93+/-0.13	0.50+/-0.01	0.41+/-0.02	0.78+/-0.02	0.68+/-0.02	< 0.38
5/18 0927L - 5/19 1040L	7.68+/-0.23	0.39+/-0.01	0.46+/-0.02	0.95+/-0.02	0.74+/-0.01	0.20+/-0.08
5/19 1040L - 5/20 0905L	5.88+/-0.22	0.87+/-0.03	0.97+/-0.03	1.96+/-0.04	2.59+/-0.04	0.47+/-0.15
5/20 0905L - 5/21 0830L	4.50+/-0.16	0.38+/-0.02	0.34+/-0.02	0.66+/-0.03	0.93+/-0.02	0.46+/-0.21
5/21 0830L - 5/22 0830L	3.12+/-0.11	0.16+/-0.01	0.08+/-0.01	0.13+/-0.01	0.24+/-0.01	< 0.25
5/22 0830L - 5/23 1040L	2.66+/-0.08	0.31+/-0.01	0.07+/-0.01	0.15+/-0.01	0.29+/-0.01	< 0.21
5/23 1040L - 5/24 0830L	5.07+/-0.13	1.56+/-0.02	0.48+/-0.01	1.00+/-0.02	2.25+/-0.03	0.39+/-0.08
5/24 0830L - 5/25 0830L	4.64+/-0.14	1.00+/-0.02	0.38+/-0.02	0.80+/-0.02	1.76+/-0.03	0.27+/-0.07
5/25 0830L - 5/26 0830L	3.97+/-0.11	0.48+/-0.01	0.48+/-0.01	0.97+/-0.02	1.47+/-0.02	0.22+/-0.07
5/26 0830L - 5/27 0900L	3.32+/-0.12	0.34+/-0.01	0.41+/-0.02	0.80+/-0.02	1.35+/-0.02	0.26+/-0.10
5/27 0905L - 5/28 0920L	5.64+/-0.16	0.54+/-0.02	0.50+/-0.02	1.05+/-0.03	1.79+/-0.03	0.30+/-0.09
5/28 0920L - 5/29 1100L	6.50+/-0.15	0.78+/-0.02	0.54+/-0.02	1.12+/-0.03	1.85+/-0.03	0.33+/-0.09
5/29 1100L - 5/30 0915L	7.23+/-0.14	0.57+/-0.01	0.54+/-0.01	1.10+/-0.02	1.85+/-0.02	0.33+/-0.07

* Weighted mean and standard deviation of NYC SEAREX and SASP system
 < Less than reported value
 Errors reported represent two sigma of the counting error
 Blank spaces represent data calculations in progress

TABLE 36 (Cont'd)
Surface Air Concentrations at New York City *

(Millibecquerel/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/30 0915L - 5/31 0645L	7.04+/-0.14	0.54+/-0.01	0.57+/-0.01	1.21+/-0.02	1.82+/-0.02	0.32+/-0.07
5/31 0645L - 6/02 0835L	7.95+/-0.12	0.26+/-0.01	0.42+/-0.01	0.86+/-0.01	1.28+/-0.01	0.21+/-0.04
6/02 0840L - 6/06 0830L	8.89+/-0.10	0.51+/-0.01	0.93+/-0.01	1.95+/-0.01	0.37+/-0.00	0.06+/-0.00
6/06 0835L - 6/09 0855L	2.45+/-0.06	0.03+/-0.00	0.05+/-0.00	0.10+/-0.00	0.21+/-0.01	0.05+/-0.02
6/09 0855L - 6/13 0910L	1.42+/-0.03	0.01+/-0.00	0.03+/-0.00	0.07+/-0.00	0.12+/-0.00	0.04+/-0.01

* Weighted mean and standard deviation of NYC SEAREX and SASP system
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 37
Surface Air Concentrations at New York City *
(Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/06 0915L - 5/07 0930L	< 4.5	< 3.3	< 2.4	< 0.9	< 1.0	< 4.1
5/07 0930L - 5/08 0930L	< 5.0	< 3.2	3.4+/-1.4	< 1.0	< 1.0	< 5.2
5/08 0930L - 5/09 0910L	< 4.4	1.1+/-0.6	< 1.4	< 0.4	< 0.4	< 2.7
5/09 0910L - 5/10 0730L	9.5+/-2.8	7.6+/-0.8	1.1+/-0.5	1.6+/-0.3	1.2+/-0.5	< 3.4
5/10 0730L - 5/11 0730L	22.0+/-4.2	20.1+/-1.3	2.1+/-0.7	3.4+/-0.4	4.1+/-0.7	7.1+/-2.2
5/11 0730L - 5/12 0930L	15.4+/-2.6	14.1+/-1.8	2.0+/-0.2	1.3+/-0.4	2.2+/-0.4	< 3.6
5/12 0935L - 5/13 0930L		4.1+/-0.8	< 2.4	< 0.7	< 0.9	< 3.8
5/13 0930L - 5/14 0930L		7.2+/-0.9	27.2+/-2.7	1.1+/-0.4	1.2+/-0.6	< 3.7
5/14 0930L - 5/15 1200L		7.3+/-1.0	< 2.1	0.7+/-0.3	1.2+/-0.5	< 3.5
5/15 1200L - 5/16 1000L		0.7+/-0.1	< 2.2	0.7+/-0.3	1.2+/-0.4	< 3.8
5/16 1000L - 5/17 0905L	7.0+/-1.4	5.7+/-0.9	< 1.8	< 0.9	1.2+/-0.3	< 3.4
5/17 0910L - 5/18 0926L	3.5+/-1.2	1.7+/-0.7	< 2.3	< 0.6	0.5+/-0.2	< 4.1
5/18 0927L - 5/19 1040L	2.8+/-0.9	4.7+/-0.9	< 2.2	< 0.6	0.8+/-0.2	< 3.2
5/19 1040L - 5/20 0905L	9.4+/-1.6	12.8+/-1.3	< 2.4	< 0.8	2.2+/-0.4	< 4.5
5/20 0905L - 5/21 0830L	3.5+/-1.2	4.4+/-1.1	< 1.9	< 0.6	1.0+/-0.3	< 3.1
5/21 0830L - 5/22 0830L	1.8+/-0.7	< 2.3	< 1.5	< 0.3	< 0.8	< 2.5
5/22 0830L - 5/23 1040L	1.6+/-0.6	2.1+/-0.6	< 1.0	< 0.5	< 0.6	< 2.3
5/23 1040L - 5/24 0830L	4.4+/-1.0	5.7+/-1.0	< 1.6	< 0.4	1.1+/-0.3	< 2.9
5/24 0830L - 5/25 0830L	4.3+/-0.9	4.6+/-0.8	< 1.9	< 0.6	1.1+/-0.3	2.5+/-1.2
5/25 0830L - 5/26 0830L	4.3+/-0.8	5.1+/-0.8	< 1.5	< 0.4	1.1+/-0.2	< 3.2
5/26 0830L - 5/27 0900L	3.2+/-0.9	4.5+/-1.0	< 2.0	< 0.5	1.0+/-0.5	< 3.1
5/27 0905L - 5/28 0920L	3.8+/-1.1	6.0+/-1.1	< 2.4	< 0.6	1.3+/-0.4	< 4.3
5/28 0920L - 5/29 1100L	5.9+/-0.9	7.6+/-1.2	< 1.9	< 0.5	1.4+/-0.3	< 3.1
5/29 1100L - 5/30 0915L	4.2+/-0.9	5.6+/-0.7	< 1.3	< 0.8	1.3+/-0.2	2.2+/-1.0

* Weighted mean and standard deviation of NYC SEAREX and SASP system
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 37 (Cont'd)
Surface Air Concentrations at New York City *
(FemtoCurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/29 1100L - 5/30 0915L	4.2+/-0.9	5.6+/-0.7	< 1.3	< 0.8	1.3+/-0.2	2.2+/-1.0
5/30 0915L - 5/31 0645L	4.2+/-0.8	6.7+/-1.1	< 1.3	< 0.8	1.5+/-0.2	4.1+/-1.7
5/31 0645L - 6/02 0835L	3.4+/-0.6	4.8+/-0.7	< 0.9	< 0.5	1.1+/-0.2	1.7+/-0.7
6/02 0840L - 6/06 0830L	3.8+/-0.5	5.9+/-0.6	< 0.7	< 0.6	1.3+/-0.2	2.0+/-0.4
6/06 0835L - 6/09 0855L	< 0.8	< 1.0	< 0.4	< 0.4	< 0.2	< 0.8
6/09 0855L - 6/13 0910L	< 0.3	< 0.3	< 0.2	< 0.1	< 0.2	< 0.3

* Weighted mean and standard deviation of NYC SEAREX and SASP system
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 38
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/06 0915L - 5/07 0930L	< 0.17	< 0.12	< 0.09	< 0.03	< 0.04	< 0.15
5/07 0930L - 5/08 0930L	< 0.19	< 0.12	0.13+/-0.05	< 0.04	< 0.04	< 0.19
5/08 0930L - 5/09 0910L	< 0.16	0.04+/-0.02	< 0.05	< 0.01	< 0.01	< 0.10
5/09 0910L - 5/10 0730L	0.35+/-0.10	0.28+/-0.03	0.04+/-0.02	0.06+/-0.01	0.04+/-0.02	< 0.13
5/10 0730L - 5/11 0730L	0.81+/-0.16	0.74+/-0.05	0.08+/-0.03	0.13+/-0.01	0.15+/-0.03	0.26+/-0.08
5/11 0730L - 5/12 0930L	0.57+/-0.10	0.52+/-0.07	0.07+/-0.01	0.05+/-0.01	0.08+/-0.01	< 0.13
5/12 0935L - 5/13 0930L		0.15+/-0.03	< 0.09	< 0.03	< 0.03	< 0.14
5/13 0930L - 5/14 0930L		0.27+/-0.03	1.01+/-0.10	0.04+/-0.01	0.04+/-0.02	< 0.14
5/14 0930L - 5/15 1200L		0.27+/-0.04	< 0.08	0.03+/-0.01	0.04+/-0.02	< 0.13
5/15 1200L - 5/16 1000L		0.03+/-0.00	< 0.08	0.03+/-0.01	0.04+/-0.01	< 0.14
5/16 1000L - 5/17 0905L	0.26+/-0.05	0.21+/-0.03	< 0.07	< 0.03	0.04+/-0.01	< 0.13
5/17 0910L - 5/18 0926L	0.13+/-0.04	0.06+/-0.03	< 0.09	< 0.02	0.02+/-0.01	< 0.15
5/18 0927L - 5/19 1040L	0.10+/-0.03	0.17+/-0.03	< 0.08	< 0.02	0.03+/-0.01	< 0.12
5/19 1040L - 5/20 0905L	0.35+/-0.06	0.47+/-0.05	< 0.09	< 0.03	0.08+/-0.01	< 0.17
5/20 0905L - 5/21 0830L	0.13+/-0.04	0.16+/-0.04	< 0.07	< 0.02	0.04+/-0.01	< 0.11
5/21 0830L - 5/22 0830L	0.07+/-0.03	< 0.09	< 0.06	< 0.01	< 0.03	< 0.09
5/22 0830L - 5/23 1040L	0.06+/-0.02	0.08+/-0.02	< 0.04	< 0.02	< 0.02	< 0.09
5/23 1040L - 5/24 0830L	0.16+/-0.04	0.21+/-0.04	< 0.06	< 0.01	0.04+/-0.01	< 0.11
5/24 0830L - 5/25 0830L	0.16+/-0.03	0.17+/-0.03	< 0.07	< 0.02	0.04+/-0.01	0.09+/-0.04
5/25 0830L - 5/26 0830L	0.16+/-0.03	0.19+/-0.03	< 0.06	< 0.01	0.04+/-0.01	< 0.12
5/26 0830L - 5/27 0900L	0.12+/-0.03	0.17+/-0.04	< 0.07	< 0.02	0.04+/-0.02	< 0.11
5/27 0905L - 5/28 0920L	0.14+/-0.04	0.22+/-0.04	< 0.09	< 0.02	0.05+/-0.01	< 0.16
5/28 0920L - 5/29 1100L	0.22+/-0.03	0.28+/-0.04	< 0.07	< 0.02	0.05+/-0.01	< 0.11
5/29 1100L - 5/30 0915L	0.16+/-0.03	0.21+/-0.03	< 0.05	< 0.03	0.05+/-0.01	0.08+/-0.04

* Weighted mean and standard deviation of NYC SEAREX and SASP system
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 38 (Cont'd)
Surface Air Concentrations at New York City *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/29 1100L - 5/30 0915L	0.16+/-0.03	0.21+/-0.03	< 0.05	< 0.03	0.05+/-0.01	0.08+/-0.04
5/30 0915L - 5/31 0645L	0.16+/-0.03	0.25+/-0.04	< 0.05	< 0.03	0.06+/-0.01	0.15+/-0.06
5/31 0645L - 6/02 0835L	0.13+/-0.02	0.18+/-0.03	< 0.03	< 0.02	0.04+/-0.01	0.06+/-0.03
6/02 0840L - 6/06 0830L	0.14+/-0.02	0.22+/-0.02	< 0.03	< 0.02	0.05+/-0.01	0.07+/-0.01
6/06 0835L - 6/09 0855L	< 0.03	< 0.04	< 0.01	< 0.01	< 0.01	< 0.03
6/09 0855L - 6/13 0910L	< 0.01	< 0.01	< 0.01	< 0.00	< 0.01	< 0.01

* Weighted mean and standard deviation of NYC SEAREX and SASP system
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 39
Surface Air Concentrations at Key Biscayne, Florida *
(Femtocurie/Cubic Meter)

Collection Period	Hours of Sampling	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/07 0900L - 5/08 0900L	18.1	232.6+/-20.7	< 22.7	< 1.2	< 1.0		
5/08 0900L - 5/09 0900L	13.6	166.9+/-37.2	< 67.4	< 2.9	< 3.6		
5/09 0900L - 5/12 0900L	29.2	266.3+/-18.9	448.0+/-17.7	52.5+/-1.5	102.9+/-2.3		
5/12 0900L - 5/13 0900L	20.3	251.6+/-30.9	192.2+/-20.9	59.2+/-1.9	112.6+/-3.7		
5/13 0900L - 5/14 0900L	23.8	218.5+/-35.3	39.8+/-16.1	31.9+/-2.1	59.0+/-3.9		

TABLE 40
Surface Air Concentrations at Key Biscayne, Florida *
(Millibecquerel/Cubic Meter)

Collection Period	Hours of Sampling	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/07 0900L - 5/08 0900L	18.1	8.61+/-0.77	< 0.84	< 0.04	< 0.04		
5/08 0900L - 5/09 0900L	13.6	6.18+/-1.38	< 2.49	< 0.11	< 0.13		
5/09 0900L - 5/12 0900L	29.2	9.85+/-0.70	16.58+/-0.63	1.94+/-0.06	3.81+/-0.09		
5/12 0900L - 5/13 0900L	20.3	9.31+/-1.14	7.11+/-0.74	2.19+/-0.07	4.17+/-0.14		
5/13 0900L - 5/14 0900L	23.8	8.08+/-1.31	1.47+/-0.59	1.18+/-0.08	2.18+/-0.14		

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump) with wind directional control, Sampling sector is from NE to SE
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 41
Surface Air Concentrations at Key Biscayne, Florida *
(Femtocurie/Cubic Meter)

Collection Period	Hours of Sampling	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/07 0900L - 5/08 0900L	18.1	< 38.1	< 21.1	< 5.3		< 2.8	< 8.4
5/08 0900L - 5/09 0900L	13.6	< 66.1	< 76.5	< 9.1		< 7.4	< 13.8
5/09 0900L - 5/12 0900L	29.2	< 41.6	< 37.1	< 2.8		< 2.4	< 5.9
5/12 0900L - 5/13 0900L	20.3	< 42.9	< 42.9	< 5.0		< 2.9	< 8.3
5/13 0900L - 5/14 0900L	23.8	< 52.9	< 61.7	< 5.3		< 4.0	< 11.6

TABLE 42
Surface Air Concentrations at Key Biscayne, Florida *
(Millibecquerel/Cubic Meter)

Collection Period	Hours of Sampling	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/07 0900L - 5/08 0900L	18.1	< 1.41	< 0.78	< 0.20		< 0.10	< 0.31
5/08 0900L - 5/09 0900L	13.6	< 2.45	< 2.83	< 0.34		< 0.27	< 0.51
5/09 0900L - 5/12 0900L	29.2	< 1.54	< 1.37	< 0.10		< 0.09	< 0.22
5/12 0900L - 5/13 0900L	20.3	< 1.59	< 1.59	< 0.19		< 0.11	< 0.31
5/13 0900L - 5/14 0900L	23.8	< 1.96	< 2.28	< 0.20		< 0.15	< 0.43

* Air filter sample collected using a Fuji Ring Compressor system (SEAREX pump) with wind directional control, Sampling sector is from NE to SE
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 43
Surface Air Concentrations at Miami, Florida *

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/01 0420L - 5/08 0420L	214.3+/-3.0	< 4.9	< 1.0	0.2+/-0.1		
5/08 0420L - 5/15 0420L	294.1+/-3.8	98.2+/-3.8	45.5+/-0.4	68.8+/-0.5		
5/15 0420L - 5/22 0420L	104.4+/-1.8	7.8+/-1.0	9.1+/-0.1	18.2+/-0.2		
5/22 0420L - 6/01 0420L	140.0+/-0.2	4.4+/-0.6	10.9+/-0.1	23.7+/-0.2		

TABLE 44
Surface Air Concentrations at Miami, Florida *

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/01 0420L - 5/08 0420L	7.93+/-0.11	< 0.18	< 0.04	0.01+/-0.00		
5/08 0420L - 5/15 0420L	10.88+/-0.14	3.63+/-0.14	1.68+/-0.01	2.55+/-0.02		
5/15 0420L - 5/22 0420L	3.86+/-0.07	0.29+/-0.04	0.34+/-0.00	0.67+/-0.01		
5/22 0420L - 6/01 0420L	5.18+/-0.01	0.16+/-0.02	0.40+/-0.00	0.88+/-0.01		

* Air filter sample collected using a Brooks/Roots system (SASP pump)

< Less than reported value

Errors reported represent two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 45
Surface Air Concentrations at Miami, Florida *
(Femtocurie/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/01 0420L - 5/08 0420L	< 3.7	< 1.7	< 0.3	< 1.6	< 0.2	< 0.6
5/08 0420L - 5/15 0420L	< 5.9	< 10.3	< 0.4	< 4.3	0.7+/-0.3	< 1.3
5/15 0420L - 5/22 0420L	3.6+/-1.4	< 3.8	< 0.2	< 2.7	< 0.3	< 0.4
5/22 0420L - 6/01 0420L	5.9+/-1.0	6.1+/-1.4	0.7+/-0.1	< 5.0	1.6+/-0.1	2.3+/-0.4

TABLE 46
Surface Air Concentrations at Miami, Florida *
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/01 0420L - 5/08 0420L	< 0.14	< 0.06	< 0.01	< 0.06	< 0.01	< 0.02
5/08 0420L - 5/15 0420L	< 0.22	< 0.38	< 0.01	< 0.16	0.03+/-0.01	< 0.05
5/15 0420L - 5/22 0420L	0.13+/-0.05	< 0.14	< 0.01	< 0.10	< 0.01	< 0.01
5/22 0420L - 6/01 0420L	0.22+/-0.04	0.23+/-0.05	0.03+/-0.0	< 0.19	0.06+/-0.00	0.09+/-0.01

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 47
Surface Air Concentrations at Mauna Loa, Hawaii *
(Femtocurie/Cubic Meter)

Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106
5/01 1133L - 5/02 1210L	246.0+/-16.1	< 5.3	< 1.5	< 1.7		
5/02 1212L - 5/05 1055L	119.6+/-8.3	< 1.7	< 0.6	< 0.7		
5/08 1108L - 5/09 1034L	146.9+/-24.1	< 5.4	< 2.5	< 3.2		
5/09 1035L - 5/12 1050L	165.6+/-6.2	1.1+/-0.4	< 0.5	< 0.6		
5/12 1050L - 5/13 1124L	283.1+/-18.1	< 4.0	4.9+/-1.7	< 2.5		
5/13 1125L - 5/14 1128L	308.8+/-25.4	< 14.9	< 2.2	3.5+/-1.3		
5/14 1129L - 5/15 1121L	304.2+/-16.7	< 12.1	< 1.1	2.3+/-0.7		
5/15 1121L - 5/16 1100L	313.2+/-2.7	< 12.6	< 1.0	1.8+/-1.4		
5/16 1101L - 5/19 1130L	35.7+/-2.0	12.3+/-4.8	< 1.6	< 1.3		
5/21 1127L - 5/22 1049L	26.6+/-2.2	< 10.5	< 2.9	< 2.3		
5/22 1049L - 5/23 1038L	235.5+/-9.7	2.6+/-1.9	< 0.7	0.9+/-0.5	1.3+/-0.6	< 0.5
5/23 1039L - 5/27 1120L	187.4+/-3.5	3.4+/-0.4	1.1+/-0.2	2.2+/-0.2	4.3+/-0.2	1.5+/-0.7
5/27 1120L - 5/28 1102L	186.5+/-14.0	19.1+/-3.3	5.8+/-1.0	9.9+/-1.3	24.9+/-1.8	< 10.6
5/28 1103L - 5/29 1219L	360.8+/-16.3	28.5+/-3.3	11.2+/-1.6	22.9+/-1.5	46.9+/-2.0	< 11.6
5/29 1220L - 5/30 1030L	125.4+/-5.4	4.8+/-1.3	2.6+/-0.4	5.2+/-0.5	10.8+/-0.6	< 6.4
5/30 1032L - 6/02 1140L	179.4+/-2.6	7.1+/-0.4	2.9+/-0.2	6.3+/-0.2	15.2+/-0.3	3.8+/-0.9

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 48
Surface Air Concentrations at Mauna Loa, Hawaii *

(Millibecquerel/Cubic Meter)							
Collection Period	Be-007	I-131	Cs-134	Cs-137	Ru-103	Ru-106	
5/01 1133L - 5/02 1210L	9.10+/-0.60	< 0.20	< 0.06	< 0.06			
5/02 1212L - 5/05 1055L	4.43+/-0.31	< 0.06	< 0.02	< 0.03			
5/08 1108L - 5/09 1034L	5.44+/-0.89	< 0.20	< 0.09	< 0.12			
5/09 1035L - 5/12 1050L	6.13+/-0.23	0.04+/-0.01	< 0.02	< 0.02			
5/12 1050L - 5/13 1124L	10.47+/-0.67	< 0.15	0.18+/-0.06	< 0.09			
5/13 1125L - 5/14 1128L	11.43+/-0.94	< 0.55	< 0.08	0.13+/-0.05			
5/14 1129L - 5/15 1121L	11.26+/-0.62	< 0.45	< 0.04	0.09+/-0.03			
5/15 1121L - 5/16 1100L	11.59+/-0.10	< 0.47	< 0.04	0.07+/-0.05			
5/16 1101L - 5/19 1130L	1.32+/-0.07	0.46+/-0.18	< 0.06	< 0.05			
5/21 1127L - 5/22 1049L	0.98+/-0.08	< 0.39	< 0.11	< 0.09			
5/22 1049L - 5/23 1038L	8.71+/-0.36	0.10+/-0.07	< 0.03	0.03+/-0.02	0.05+/-0.02	< 0.02	
5/23 1039L - 5/27 1120L	6.93+/-0.13	0.13+/-0.01	0.04+/-0.01	0.08+/-0.01	0.16+/-0.01	0.06+/-0.03	
5/27 1120L - 5/28 1102L	6.90+/-0.52	0.71+/-0.12	0.21+/-0.04	0.37+/-0.05	0.92+/-0.07	< 0.39	
5/28 1103L - 5/29 1219L	13.35+/-0.60	1.05+/-0.12	0.41+/-0.06	0.85+/-0.06	1.74+/-0.07	< 0.43	
5/29 1220L - 5/30 1030L	4.64+/-0.20	0.18+/-0.05	0.10+/-0.01	0.19+/-0.02	0.40+/-0.02	< 0.24	
5/30 1032L - 6/02 1140L	6.64+/-0.10	0.26+/-0.01	0.11+/-0.01	0.23+/-0.01	0.56+/-0.01	0.14+/-0.03	

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
blank spaces represent data calculations in progress

TABLE 49
Surface Air Concentrations at Mauna Loa, Hawaii*
(Femtocuries/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/01 1133L - 5/02 1210L	< 15.3	< 17.4	< 2.3	< 22.9	< 2.0	< 6.9
5/02 1212L - 5/05 1055L	< 6.8	< 9.0	< 1.2	< 9.3	< 0.7	< 3.2
5/08 1108L - 5/09 1034L	< 19.5	< 17.2	< 6.6	< 11.2	< 3.3	< 14.0
5/09 1035L - 5/12 1050L	< 2.9	< 4.6	< 1.0	< 0.9	< 0.5	< 1.9
5/12 1050L - 5/13 1124L	< 13.9	< 7.3	< 4.0	< 4.7	< 2.6	9.2+/-4.4
5/13 1125L - 5/14 1128L	< 30.3	< 35.0	< 4.1		< 3.0	< 6.9
5/14 1129L - 5/15 1121L	< 23.2	< 29.5	< 2.6		< 1.6	< 6.6
5/15 1121L - 5/16 1100L	< 15.0	< 21.5	< 2.9		< 2.2	< 5.1
5/16 1101L - 5/19 1130L	< 13.8	< 6.6	< 3.1		< 1.4	< 0.4
5/21 1127L - 5/22 1049L	< 26.8	< 11.4	< 5.3		< 2.9	< 10.7
5/22 1049L - 5/23 1038L	< 4.5	< 4.8	< 1.1	< 33.8	< 0.7	< 2.5
5/23 1039L - 5/27 1120L	< 1.4	1.4+/-0.5	< 0.4	< 5.2	0.5+/-0.2	< 0.9
5/27 1120L - 5/28 1102L	< 11.5	< 9.8	< 3.9	< 33.0	< 1.7	< 5.4
5/28 1103L - 5/29 1219L	11.6+/-5.0	12.1+/-3.1	< 2.2	< 30.6	2.4+/-0.9	< 5.1
5/29 1220L - 5/30 1030L	< 5.0	< 5.3	< 1.3	< 16.3	< 0.8	< 1.9
5/30 1032L - 6/02 1140L	1.7+/-0.6	2.7+/-0.7	< 0.3	< 2.7	< 0.5	< 0.9

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma of the counting error
Blank spaces represent data calculations in progress

TABLE 50
Surface Air Concentrations at Mauna Loa, Hawaii*
(Millibecquerel/Cubic Meter)

Collection Period	Ba-140	La-140	Zr-95	Mo-99	Ce-141	Ce-144
5/01 1133L - 5/02 1210L	< 0.57	< 0.64	< 0.09	< 0.85	< 0.07	< 0.26
5/02 1212L - 5/05 1055L	< 0.25	< 0.33	< 0.04	< 0.34	< 0.03	< 0.12
5/08 1108L - 5/09 1034L	< 0.72	< 0.64	< 0.24	< 0.41	< 0.12	< 0.52
5/09 1035L - 5/12 1050L	< 0.11	< 0.17	< 0.04	< 0.03	< 0.02	< 0.07
5/12 1050L - 5/13 1124L	< 0.51	< 0.27	< 0.15	< 0.17	< 0.10	0.34+/-0.16
5/13 1125L - 5/14 1128L	< 1.12	< 1.30	< 0.15		< 0.11	< 0.26
5/14 1129L - 5/15 1121L	< 0.86	< 1.09	< 0.10		< 0.06	< 0.24
5/15 1121L - 5/16 1100L	< 0.56	< 0.80	< 0.11		< 0.08	< 0.19
5/16 1101L - 5/19 1130L	< 0.51	< 0.24	< 0.11		< 0.05	< 0.01
5/21 1127L - 5/22 1049L	< 0.99	< 0.42	< 0.20		< 0.11	< 0.40
5/22 1049L - 5/23 1038L	< 0.17	< 0.18	< 0.04	< 1.25	< 0.03	< 0.09
5/23 1039L - 5/27 1120L	< 0.05	0.05+/-0.02	< 0.01	< 0.19	0.02+/-0.01	< 0.03
5/27 1120L - 5/28 1102L	< 0.43	< 0.36	< 0.14	< 1.22	< 0.06	< 0.20
5/28 1103L - 5/29 1219L	0.43+/-0.19	0.45+/-0.11	< 0.08	< 1.13	0.09+/-0.03	< 0.19
5/29 1220L - 5/30 1030L	< 0.19	< 0.20	< 0.05	< 0.60	< 0.03	< 0.07
5/30 1032L - 6/02 1140L	0.06+/-0.02	0.10+/-0.03	< 0.01	< 0.10	< 0.02	< 0.03

* Air filter sample collected using a Brooks/Roots system (SASP pump)
< Less than reported value
Errors reported represent two sigma the counting error
Blank spaces represent data calculations in progress

TABLE 51
Activity Ratios of Surface Air Concentrations at Barrow, Alaska

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	Cs-137	Cs-137	Cs-134*	Cs-137
5/07 1445L - 5/08 1445L	30.9	10.9	0.7	
5/08 1445L - 5/09 1440L	35.1	11.4	1.9	3.6
5/09 1440L - 5/11 1410L	5.9	1.7	1.5	
5/11 1410L - 5/12 1445L	5.1	1.3	1.4	
5/12 1445L - 5/13 1450L	9.6	2.2	2.0	
5/13 1450L - 5/14 1405L	7.9	1.7	1.3	
5/14 1405L - 5/15 1455L	---	---	---	---
5/15 1455L - 5/16 1455L	23.7	4.2	2.0	
5/16 1455L - 5/17 1455L	34.2	5.6	2.5	
5/17 1455L - 5/18 1425L	189.8	28.4	1.5	
5/18 1425L - 5/19 1340L	92.9	12.8	1.9	0.6
5/19 1340L - 5/20 1445L	39.4	5.0	2.0	0.5
5/20 1445L - 5/21 1445L	32.2	3.7	1.9	0.6
5/21 1445L - 5/22 1505L	133.5	14.1	1.9	0.8
5/22 1505L - 5/23 1445L	42.7	4.1	2.2	1.0
5/23 1445L - 5/24 1445L	88.1	7.9	1.9	1.0
5/24 1445L - 5/25 1430L	55.3	4.5	2.0	0.9
5/25 1430L - 5/26 1440L	40.9	3.1	2.0	1.4
5/26 1440L - 5/27 1520L	22.2	1.5	2.0	1.6
Mean +/- One SD	49.4+/-48.5		1.8+/-0.4	1.2+/-0.9

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
Blank spaces represent data calculations in progress

TABLE 52
Activity Ratios of Surface Air Concentrations at Moosonee, Ontario

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	----- Cs-137	----- Cs-137	----- Cs-134*	----- Cs-137
5/06 1400L - 5/07 1400L	---	---	2.5	
5/07 1400L - 5/08 1400L	7.9	3.1	1.9	
5/08 1400L - 5/09 1400L	11.3	4.0	3.1	
5/09 1400L - 5/10 1400L	22.8	7.4	2.0	
5/10 1400L - 5/11 1400L	7.3	2.2	0.9	
5/11 1400L - 5/12 1400L	2.2	0.6	1.4	
5/12 1400L - 5/13 1400L	2.5	0.6	1.9	
5/13 1400L - 5/14 1400L	5.5	1.3	1.5	
5/14 1400L - 5/15 1400L	4.1	0.9	1.5	
5/15 1400L - 5/16 1400L	3.7	0.7	2.0	
5/16 1400L - 5/17 1400L	4.2	0.7	1.3	
5/17 1400L - 5/18 1400L	6.7	1.1	2.6	
5/18 1400L - 5/19 1400L	10.0	1.5	1.9	
5/19 1400L - 5/20 1400L	11.8	1.6	2.1	
5/20 1400L - 5/21 1400L	11.2	1.4	1.8	1.5
5/21 1400L - 5/22 1400L	7.4	0.9	1.9	1.6
5/22 1400L - 5/23 1400L	7.1	0.8	1.9	1.6
5/23 1400L - 5/24 1400L	6.3	0.6	2.0	1.6
5/24 1400L - 5/25 1400L	3.5	0.3	2.1	1.7
5/25 1400L - 5/26 1400L	8.0	0.6	1.9	1.7
5/26 1400L - 5/27 1400L	8.1	0.6	1.9	1.7
5/27 1400L - 5/28 1400L	7.8	0.5	2.1	1.7
5/28 1400L - 5/29 1400L	9.4	0.6	2.0	1.8
Mean +/- One SD	7.7+/-4.4		1.9+/-0.5	1.7+/-0.1

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
Blank spaces represent data calculations in progress

TABLE 53
Activity Ratios of Surface Air Concentrations at Beaverton, Oregon

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	----- Cs-137	----- Cs-137	----- Cs-134*	----- Cs-137
5/06 1120L - 5/07 1110L	14.3	5.3	----	
5/07 1110L - 5/08 1020L	9.9	3.5	0.8	
5/08 1020L - 5/09 1400L	10.2	3.4	1.9	
5/09 1400L - 5/10 1400L	5.1	1.5	1.9	
5/10 1400L - 5/11 1730L	9.8	2.7	2.0	
5/11 1730L - 5/12 1000L	7.4	1.9	1.9	
5/12 1000L - 5/13 1045L	6.4	1.5	1.5	
5/13 1050L - 5/14 0911L	19.1	4.1	2.0	
5/14 0910L - 5/15 1100L	12.1	2.4	2.0	
5/15 1100L - 5/16 1000L	11.4	2.0	2.0	
5/16 1000L - 5/18 1100L	6.6	1.0	2.0	
5/18 1100L - 5/19 1330L	5.8	0.8	1.3	
5/19 1330L - 5/20 1545L	9.6	1.2	2.2	
5/20 1545L - 5/21 1400L	10.8	1.3	1.9	
5/21 1400L - 5/22 1400L	17.4	1.8	1.4	
5/22 1400L - 5/23 1000L	19.9	1.9	2.1	2.7
5/23 1000L - 5/24 1120L	18.3	1.6	1.8	2.8
5/24 1123L - 5/26 1200L	10.3	0.8	1.9	3.0
5/26 1200L - 5/27 1400L	----	----	----	----
5/27 1400L - 6/03 1400L	18.7	1.2	2.0	4.5
Mean +/- One SD	11.7+/-4.8		1.8+/-0.3	3.3+/-0.8

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
Blank spaces represent data calculations in progress

TABLE 54
Activity Ratios of Surface Air Concentrations at Rexburg, Idaho

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	Cs-137	Cs-137	Cs-134*	Cs-137
5/01 1100L - 5/02 1115L	----	----	----	----
5/02 1115L - 5/03 1300L	----	----	----	----
5/03 1310L - 5/04 1245L	----	----	----	----
5/04 1310L - 5/05 0905L	----	----	----	----
5/05 0910L - 5/06 0805L	----	----	----	----
5/06 0810L - 5/07 0855L	23.0	9.0	2.0	
5/07 0900L - 5/08 0815L	29.7	10.7	2.3	
5/08 0815L - 5/09 0840L	13.2	4.4	1.1	
5/09 1000L - 5/10 1030L	18.5	5.6	2.0	
5/10 1030L - 5/11 1115L	9.2	2.5	1.4	
5/11 1115L - 5/12 1530L	6.3	1.6	1.4	
5/12 1530L - 5/13 0925L	12.5	2.9	2.0	
5/13 0930L - 5/14 0805L	14.3	3.1	2.0	
5/14 0810L - 5/15 0815L	16.1	3.2	2.0	
5/15 0815L - 5/16 0815L	17.3	3.1	2.4	
5/16 0815L - 5/17 1200L	18.0	3.0	2.0	
5/17 1200L - 5/18 1058L	19.3	2.9	1.5	
5/18 1058L - 5/19 0815L	16.2	2.3	1.3	
5/19 0815L - 5/20 0815L	19.2	2.5	2.1	
5/20 0815L - 5/21 0815L	19.2	2.3	1.9	
5/21 0815L - 5/22 0815L	30.2	3.3	1.2	
5/22 0830L - 5/23 1040L	25.2	2.5	1.8	3.3
5/23 1100L - 5/27 0900L	15.9	1.4	1.8	3.0
5/27 0900L - 5/30 0845L	24.9	1.5	1.9	3.5
Mean +/- One SD	18.3+/-6.3		1.8+/-0.4	3.3+/-0.3

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
blank spaces represent data calculations in progress

TABLE 55
Activity Ratios of Surface Air Concentrations at Chester, New Jersey

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	Cs-137	Cs-137	Cs-134*	Cs-137
5/05 0730L - 5/06 0800L	----	----	----	----
5/06 0800L - 5/07 1025L	----	----	----	----
5/07 1025L - 5/09 0857L	8.9	3.1	1.3	
5/09 0850L - 5/10 0740L	8.2	2.6	2.0	
5/10 0740L - 5/12 0809L	6.0	1.6	1.9	
5/12 0809L - 5/13 1136L	9.6	2.2	1.9	
5/13 1136L - 5/14 1000L	4.0	0.9	1.5	
5/14 1000L - 5/15 1430L	13.2	2.6	1.8	
5/15 1430L - 5/16 0920L	3.1	0.5	1.9	
5/16 0920L - 5/19 0910L	2.5	0.4	1.4	
5/19 0910L - 5/21 0915L	3.7	0.5	1.3	
5/21 0915L - 5/22 1100L	11.2	1.2	1.3	
5/22 1100L - 5/23 0915L	28.9	2.9	1.9	
5/23 0915L - 5/26 0722L	8.1	0.7	1.9	3.4
5/26 0720L - 5/28 0855L	6.3	0.4	2.0	2.7
5/28 0855L - 5/29 1145L	10.4	0.6	1.6	
5/29 1145L - 5/30 0750L	7.7	0.4	1.4	
5/30 0755L - 6/02 0725L	8.4	0.3	1.9	
6/02 0725L - 6/04 0900L	10.9	0.5	2.1	
Mean +/- One SD	8.8+/-6.0		1.7+/-0.3	3.1+/-0.5

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
Blank spaces represent data calculations in progress

TABLE 56
Activity Ratios of Surface Air Concentrations at New York City, New York

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	Cs-137	Cs-137	Cs-134*	Cs-137
5/06 0915L - 5/07 0930L	----	----	----	----
5/07 0930L - 5/08 0930L	----	----	----	----
5/08 0930L - 5/09 0910L	8.8	2.9	1.9	0.5
5/09 0910L - 5/10 0730L	9.8	3.0	1.9	0.3
5/10 0730L - 5/11 0730L	7.5	2.1	1.9	0.3
5/11 0730L - 5/12 0930L	6.5	1.7	1.9	0.3
5/12 0935L - 5/13 0930L	16.2	3.8	1.9	0.6
5/13 0930L - 5/14 0930L	12.5	2.7	1.9	0.5
5/14 0930L - 5/15 1200L	4.3	0.9	1.9	0.4
5/15 1200L - 5/16 1000L	3.5	0.6	1.9	0.6
5/16 1000L - 5/17 0905L	2.9	0.5	1.9	1.0
5/17 0910L - 5/18 0926L	4.3	0.7	1.8	1.3
5/18 0927L - 5/19 1040L	3.0	0.4	2.0	1.2
5/19 1040L - 5/20 0905L	3.5	0.4	2.0	2.0
5/20 0905L - 5/21 0830L	4.9	0.6	1.9	2.2
5/21 0830L - 5/22 0830L	11.6	1.3	1.6	2.9
5/22 0830L - 5/23 1040L	21.5	2.1	1.9	3.1
5/23 1040L - 5/24 0830L	17.1	1.6	2.0	3.7
5/24 0830L - 5/25 0830L	14.8	1.2	2.1	3.2
5/25 0830L - 5/26 0830L	6.5	0.5	2.0	2.6
5/26 0830L - 5/27 0900L	6.1	0.4	1.9	2.9
5/27 0905L - 5/28 0920L	8.0	0.5	2.1	3.0
5/28 0920L - 5/29 1100L	11.9	0.7	2.0	3.0
5/29 1100L - 5/30 0915L	9.6	0.5	2.0	3.1

* Decay corrected to April 26, 1986 0123L
 ---- Represent ratios which were not calculated because of less than values
 Blank spaces represent data calculations in progress

TABLE 56 (Cont'd)
Activity Ratios of Surface Air Concentrations at New York City, New York

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	----- Cs-137	----- Cs-137	----- Cs-134*	----- Cs-137
5/30 0915L - 5/31 0645L	9.0	0.5	2.0	2.8
5/31 0645L - 6/02 0835L	6.8	0.3	2.0	2.8
6/02 0840L - 6/06 0830L	7.8	0.7	4.5	0.3
6/06 0835L - 6/09 0855L	13.9	0.4	1.9	4.7
6/09 0855L - 6/13 0910L	10.7	0.2	2.0	4.3
Mean +/- One SD	8.8+/-4.9		1.9+/-0.1	1.8+/-1.2

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
Blank spaces represent data calculations in progress

TABLE 57
Activity Ratios of Surface Air Concentrations at Miami, Florida

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	Cs-137	Cs-137	Cs-134*	Cs-137
5/01 0420L - 5/08 0420L	----	----	----	----
5/08 0420L - 5/15 0420L	5.4	1.4	1.5	
5/15 0420L - 5/22 0420L	2.9	0.4	2.0	
5/22 0420L - 6/01 0420L	3.0	0.2	2.1	
Mean +/- One SD	3.8+/-1.4		1.9+/-0.3	

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
Blank spaces represent data calculations in progress

TABLE 58
Activity Ratios of Surface Air Concentrations at Mauna Loa, Hawaii *

Collection Period	I-131*	I-131	Cs-137	Ru-103*
	----- Cs-137	----- Cs-137	----- Cs-134*	----- Cs-137
5/22 1049L - 5/23 1038L	29.3	2.9	----	2.2
5/23 1039L - 5/27 1120L	23.1	1.5	2.2	3.4
5/27 1120L - 5/28 1102L	30.3	1.9	1.7	4.4
5/28 1103L - 5/29 1219L	21.0	1.2	2.0	3.7
5/29 1220L - 5/30 1030L	38.1	0.9	1.9	3.8
5/30 1032L - 6/02 1140L	24.5	1.1	2.1	4.5
Mean +/- One SD	27.7+/-6.2		2.0+/-0.2	3.7+/-0.8

* Decay corrected to April 26, 1986 0123L

---- Represent ratios which were not calculated because of less than values
Blank spaces represent data calculations in progress

TABLE 59
Total Deposition at Beaverton, Oregon

Collection Period	Precipitation Inches*	I-131 Depo. (mCi/Km ²)	Cs-134 Depo. (mCi/Km ²)	Cs-137 Depo. (mCi/Km ²)	I-131 ----- Cs-137
5/02 1500L - 5/03 1230L	0.14	< 0.11	< 0.05	< 0.06	----
5/03 1230L - 5/04 1330L	0.14	< 0.15	< 0.10	< 0.14	----
5/04 1330L - 5/05 1030L	0.28	0.37+/-0.09	< 0.12	< 0.14	----
5/05 1030L - 5/06 1120L	0.12	0.02+/-0.01			
5/07 1110L - 5/08 1020L	0.04	0.17+/-0.02	< 0.03	0.04+/-0.02	4.3+/-2.2 (3.5+/-0.4)
5/08 1020L - 5/09 1400L	0.01	0.74+/-0.10	< 0.05	0.10+/-0.05	7.4+/-3.8 (3.3+/-0.2)
5/09 1400L - 5/10 1400L	0.23	2.04+/-0.20	0.13+/-0.06	0.32+/-0.09	6.4+/-1.9 (1.5+/-0.1)
5/10 1400L - 5/11 1730L	0.09	0.39+/-0.10	0.20+/-0.05	0.15+/-0.05	6.6+/-2.6 (2.7+/-0.2)
5/12 1000L - 5/13 1045L	0.10	0.71+/-0.11	< 0.01	0.13+/-0.05	5.5+/-2.3 (1.5+/-0.1)
5/13 1045L - 5/19 1330L	0.00	1.40+/-0.70	0.12+/-0.03	0.16+/-0.02	8.8+/-4.5 (1.2+/-0.2)
5/19 1330L - 5/20 1545L	0.33	< 3.55	< 0.43	0.21+/-0.09	----
5/20 1545L - 5/21 1400L	0.11	< 1.01	< 0.13	0.07+/-0.01	----
5/21 1400L - 5/22 1400L	0.01	< 0.16	< 0.02	0.04+/-0.02	----

Estimated Total Wet Deposition		10.02+/-3.71	1.27+/-0.49	1.41+/-0.31	
Estimated Total Dry Deposition		1.40+/-0.70	0.12+/-0.03	0.16+/-0.02	
Estimated Total Deposition		11.42+/-3.78	1.39+/-0.24	1.57+/-0.31	
Relative Contribution W=Wet D=Dry		D=12% W=88%	D=9% W=91%	D=10% W=90%	

< Less than reported value

* Estimation based on volume of sample

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 60

Total Deposition at Heaverton, Oregon

Collection Period	Precipitation Cm*	I-131 Depo. (8q/m2)	Cs-134 Depo. (8q/m2)	Cs-137 Depo. (8q/m2)	I-131 ----- Cs-137
5/02 1500L - 5/03 1230L	0.36	< 4.1	< 1.9	< 2.2	----
5/03 1230L - 5/04 1330L	0.36	< 5.6	< 3.7	< 5.2	----
5/04 1330L - 5/05 1030L	0.71	13.7+/-3.3	< 4.4	< 5.2	----
5/05 1030L - 5/06 1120L	0.30	0.7+/-0.4			
5/07 1110L - 5/08 1020L	0.10	6.3+/-0.7	< 1.1	1.5+/-0.7	4.3+/-2.2 (3.5+/-0.4)
5/08 1020L - 5/09 1400L	0.03	27.4+/-3.7	< 1.9	3.7+/-1.9	7.4+/-3.8 (3.3+/-0.2)
5/09 1400L - 5/10 1400L	0.58	75.5+/-7.4	4.8+/-2.2	11.8+/-3.3	6.4+/-1.9 (1.5+/-0.1)
5/10 1400L - 5/11 1730L	0.23	36.6+/-3.7	7.4+/-1.9	5.6+/-1.9	6.6+/-2.6 (2.7+/-0.2)
5/12 1000L - 5/13 1045L	0.25	26.3+/-4.1	< 0.4	4.8+/-1.9	5.5+/-2.3 (1.5+/-0.1)
5/13 1045L - 5/19 1330L	0.00	51.8+/-25.9	4.4+/-1.1	5.9+/-0.7	8.8+/-4.5 (1.2+/-0.2)
5/19 1330L - 5/20 1545L	0.84	<131.4	< 15.9	7.8+/-3.3	----
5/20 1545L - 5/21 1400L	0.28	< 37.4	< 4.8	2.6+/-0.4	----
5/21 1400L - 5/22 1400L	0.03	< 5.9	< 0.7	1.5+/-0.7	----

Estimated Total Wet Deposition		370.7+/-137.3	47.0+/-18.1	52.2+/-11.5	
Estimated Total Dry Deposition		51.8+/-25.9	4.4+/-1.1	5.9+/-0.7	
Estimated Total Deposition		422.5+/-139.9	51.5+/-8.9	58.1+/-11.5	
Relative Contribution W=Wet D=Dry		0=12% W=88%	0=9% W=91%	0=10% W=90%	

< Less than reported value

* Estimation based on volume of sample

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 61

Total Deposition at Rexburg, Idaho

Collection Period	Precipitation Inches*	I-131 Depo. (mCi/Km ²)	Cs-134 Depo. (mCi/Km ²)	Cs-137 Depo. (mCi/Km ²)	I-131 ----- Cs-137
5/05 0910L - 5/07 0855L	0.09	0.50+/-0.03	< 0.06	< 0.08	----
5/07 0900L - 5/08 0815L	0.09	0.22+/-0.04	0.15+/-0.04	< 0.08	----
5/08 0815L - 5/09 0840L	0.17	< 0.58	< 0.16	< 0.22	----
5/09 1000L - 5/10 1030L	0.04	3.06+/-0.20	0.20+/-0.04	0.39+/-0.06	7.8+/-1.3 (5.6+/-0.2)
5/10 1030L - 5/11 1115L	0.08	2.51+/-0.27	< 0.11	0.25+/-0.07	10.0+/-3.0 (2.5+/-0.1)
5/11 1115L - 5/12 1530L	0.02	1.87+/-0.13	0.24+/-0.03	0.46+/-0.06	4.1+/-0.6 (1.6+/-0.0)
5/12 1530L - 5/15 0815L	0.00	0.65+/-0.06	0.13+/-0.08	0.24+/-0.06	2.7+/-0.7 (3.0+/-0.1)
5/15 0815L - 5/16 0815L	0.10	4.98+/-0.61	0.23+/-0.05	0.54+/-0.07	9.2+/-1.6 (3.1+/-0.2)
5/16 0815L - 5/18 1058L	0.00	0.55+/-0.28	0.09+/-0.06	0.11+/-0.04	5.0+/-3.1 (2.9+/-0.1)
5/18 1058L - 5/20 0815L	0.00	< 0.26	< 0.07	< 0.33	----
5/20 0815L - 5/21 0815L	0.01	0.58+/-0.22	0.12+/-0.04	0.07+/-0.03	8.3+/-4.8 (2.3+/-0.2)
5/21 0815L - 5/22 0815L	0.39	< 3.36	< 0.34	< 0.47	----

Estimated Total Wet Deposition		17.66+/-3.49	1.61+/-0.41	2.56+/-0.55	
Estimated Total Dry Deposition		1.46+/-0.39	0.29+/-0.12	0.68+/-0.34	
Estimated Total Deposition		19.12+/-3.51	1.90+/-0.43	3.24+/-0.65	
Relative Contribution W=Wet D=Dry		D=8% W=92%	D=15% W=85%	D=21% W=79%	

< Less than reported value

* Estimation based on volume of sample

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 62

Total Deposition at Rexburg, Idaho

Collection Period	Precipitation Cm*	I-131 Depo. (Bq/m ²)	Cs-134 Depo. (Bq/m ²)	Cs-137 Depo. (Bq/m ²)	I-131 ----- Cs-137
5/05 0910L - 5/07 0855L	0.23	18.5+/-3.0	< 2.2	< 3.0	----
5/07 0900L - 5/08 0815L	0.23	3.1+/-1.5	5.6+/-1.5	< 3.0	----
5/08 0815L - 5/09 0840L	0.43	< 21.5	< 5.9	< 8.1	----
5/09 1000L - 5/10 1030L	0.10	113.2+/-7.4	7.4+/-1.5	14.4+/-2.2	7.8+/-1.3 (5.6+/-0.2)
5/10 1030L - 5/11 1115L	0.20	92.9+/-10.0	< 4.1	9.3+/-2.0	10.0+/-3.0 (2.5+/-0.1)
5/11 1115L - 5/12 1530L	0.05	69.2+/-4.8	8.9+/-1.1	17.0+/-2.2	4.1+/-0.6 (1.6+/-0.0)
5/12 1530L - 5/15 0815L	0.00	24.1+/-2.2	4.8+/-3.0	8.9+/-2.2	2.7+/-0.7 (3.0+/-0.1)
5/15 0815L - 5/16 0815L	0.25	184.3+/-22.6	8.5+/-1.9	20.0+/-2.6	9.2+/-1.6 (3.1+/-0.2)
5/16 0815L - 5/18 1058L	0.00	20.4+/-10.4	3.3+/-2.2	4.1+/-1.5	5.0+/-3.1 (2.9+/-0.1)
5/18 1058L - 5/20 0815L	0.00	< 9.6	< 2.6	< 12.2	----
5/20 0815L - 5/21 0815L	0.03	21.5+/-8.1	4.4+/-1.5	2.6+/-1.1	8.3+/-4.8 (2.3+/-0.2)
5/21 0815L - 5/22 0815L	0.99	< 124.3	< 12.6	< 17.4	----

Estimated Total Wet Deposition		653.4+/-129.1	59.6+/-15.2	94.7+/-20.4	
Estimated Total Dry Deposition		54.0+/-14.4	10.7+/-4.4	25.2+/-12.6	
Estimated Total Deposition		707.4+/-129.9	70.3+/-15.9	119.9+/-24.1	
Relative Contribution W=Wet D=Dry		D=8% W=92%	D=15% W=85%	D=21% W=79%	

< Less than reported value

* Estimation based on volume of sample

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 63
Total Deposition at Chester, New Jersey

Collection Period	Precipitation Inches*	I-131 Depo. (mCi/Km2)	Cs-134 Depo. (mCi/Km2)	Cs-137 Depo. (mCi/Km2)	I-131 ----- Cs-137
5/06 0800L - 5/07 1025L	0.40	< 0.95	< 0.35	< 0.48	----
5/07 1025L - 5/10 0740L	0.07	< 0.12	< 0.06	< 0.09	----
5/10 0740L - 5/14 1000L	0.00	0.76+/-0.24	0.13+/-0.02	0.18+/-0.02	4.2+/-1.4 (1.5+/-0.4)
5/14 1000L - 5/16 0920L	0.02	0.19+/-0.09	< 0.03	0.05+/-0.03	3.8+/-2.9 (2.4+/-0.05)
5/16 0920L - 5/19 0910L	0.08	0.24+/-0.15	< 0.03	0.06+/-0.04	4.0+/-3.7 (0.4+/-0.03)
5/19 0910L - 5/21 0915L	0.35	1.06+/-0.63	< 0.04	0.26+/-0.25	4.1+/-4.6 (0.4+/-0.05)
5/21 0915L - 5/23 0915L	0.83	< 1.23	< 0.08	0.73+/-0.46	----

Estimated Total Wet Deposition		3.79+/-1.69	0.59+/-0.37	1.67+/-0.81	
Estimated Total Dry Deposition		0.76+/-0.24	0.13+/-0.02	0.18+/-0.02	
Estimated Total Deposition		4.55+/-1.71	0.72+/-0.37	1.85+/-0.81	
Relative Contribution W=Wet D=Dry		D=17% W=83%	D=18% W=82%	D=10% W=90%	

< Less than reported value

* Precipitation data from a weighting bucket rain gauge

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 64

Total Deposition at Chester, New Jersey

Collection Period	Precipitation Cm*	I-131 Depo. (Bq/m ²)	Cs-134 Depo. (Bq/m ²)	Cs-137 Depo. (Bq/m ²)	I-131 ----- Cs-137
5/06 0800L - 5/07 1025L	1.02	< 35.2	< 13.0	< 17.8	----
5/07 1025L - 5/10 0740L	0.18	< 4.4	< 2.2	< 3.3	----
5/10 0740L - 5/14 1000L	0.00	28.1+/-8.9	4.8+/-0.7	6.7+/-0.7	4.2+/-1.4 (1.5+/-0.4)
5/14 1000L - 5/16 0920L	0.05	7.0+/-3.3	< 1.1	1.9+/-1.1	3.8+/-2.9 (2.4+/-0.05)
5/16 0920L - 5/19 0910L	0.20	8.9+/-5.6	< 1.1	2.2+/-1.5	4.0+/-3.7 (0.4+/-0.03)
5/19 0910L - 5/21 0915L	0.49	39.2+/-23.3	< 1.5	9.6+/-9.3	4.1+/-4.6 (0.4+/-0.05)
5/21 0915L - 5/23 0915L	2.11	< 45.5	< 3.0	27.0+/-17.0	----

Estimated Total Wet Deposition		140.2+/-62.5	11.8+/-13.7	51.8+/-30.0	
Estimated Total Dry Deposition		28.1+/-8.9	4.8+/-0.7	6.7+/-0.7	
Estimated Total Deposition		168.4+/-63.3	26.6+/-13.7	58.5+/-30.0	
Relative Contribution W=Wet D=Dry		D=17% W=83%	D=18% W=82%	D=10% W=90%	

< Less than reported value

* Precipitation data from a weighting bucket rain gauge

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 65

Total Deposition at New York City, NY

Collection Period	Precipitation Inches*	I-131 Depo. (mCi/Km ²)	Cs-134 Depo. (mCi/Km ²)	Cs-137 Depo. (mCi/Km ²)	I-131 ----- Cs-137
5/06 1600L - 5/07 0900L	0.22	< 0.02	< 0.04	< 0.02	----
5/08 0930L - 5/09 0910L	0.06	0.08+/-0.03	< 0.04	< 0.05	----
5/09 0910L - 5/14 0930L	0.00	0.70+/-0.40		0.16+/-0.04	4.4+/-2.7 (2.3+/-0.05)
5/14 0930L - 5/15 1200L	0.07	0.30+/-0.05	< 0.06	0.10+/-0.04	3.0+/-1.3 (0.8+/-0.05)
5/16 1000L - 5/17 0905L	0.07	0.30+/-0.14	< 0.07	< 0.09	----
5/20 0905L - 5/21 0830L	0.32	< 0.49	< 0.10	< 0.16	----
5/21 0830L - 5/22 0830L	0.37	1.03+/-0.84	< 0.24	0.53+/-0.33	1.9+/-1.9 (1.3+/-0.2)

Estimated Total Wet Deposition		2.22+/-0.98	0.55+/-0.28	0.95+/-0.48	
Estimated Total Dry Deposition		0.70+/-0.40		0.16+/-0.04	
Estimated Total Deposition		2.92+/-1.06	0.55+/-0.28	1.11+/-0.48	
Relative Contribution W=Wet D=Dry		D=24% W=76%		D=14% W=86%	

< Less than reported value

* Precipitation data from a weighting bucket rain gauge

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 66

Total Deposition at New York City, NY

Collection Period	Precipitation Cm*	I-131 Depo. (Bq/m ²)	Cs-134 Depo. (Bq/m ²)	Cs-137 Depo. (Bq/m ²)	I-131 ----- Cs-137
5/06 1600L - 5/07 0900L	0.56	< 0.7	< 1.5	< 0.7	----
5/08 0930L - 5/09 0910L	0.15	3.0+/-1.1	< 1.5	< 1.9	----
5/09 0910L - 5/14 0930L	0.00	25.9+/-14.8		5.9+/-1.5	4.4+/-2.7 (2.3+/-0.05)
5/14 0930L - 5/15 1200L	0.18	11.1+/-1.9	< 2.2	3.7+/-1.5	3.0+/-1.3 (0.8+/-0.05)
5/16 1000L - 5/17 0905L	0.18	11.1+/-5.2	< 2.6	< 3.3	----
5/20 0905L - 5/21 0830L	0.81	< 18.1	< 3.7	< 5.9	----
5/21 0830L - 5/22 0830L	0.94	38.1+/-31.1	< 8.9	19.6+/-12.2	1.9+/-1.9 (1.3+/-0.2)

Estimated Total Wet Deposition		82.1+/-36.3	20.4+/-10.4	35.2+/-17.8	
Estimated Total Dry Deposition		25.9+/-14.8		5.9+/-1.5	
Estimated Total Deposition		108.0+/-39.2	20.4+/-10.4	41.1+/-17.8	
Relative Contribution W=Wet D=Dry		D=24% W=76%		D=14% W=86%	

< Less than reported value

* Precipitation data from a weighting bucket rain gauge

---- Represent ratios which were not calculated because of less than values

() Represent the corresponding I-131/Cs-137 activity ratio in the surface air

Errors reported are two sigma of the counting error

Blank spaces represent data calculations in progress

TABLE 67

Estimation of Deposition Velocities

Site: Rexburg, Idaho

Collection Period: 5/12 1530L - 5/15 0815L (3885 Min)

Nuclide	Air Concentration (fCi/m3)	Deposition Rate (mCi/km2)	Deposition Velocity (cm/sec)
I-131	399.+/-3.	0.65+/-0.06	0.70+/-0.07
Cs-134	65.+/-1.	0.13+/-0.08	0.86+/-0.53
Cs-137	131.+/-3.	0.24+/-0.06	0.79+/-0.20

Site: Rexburg, Idaho

Collection Period: 5/16 0815L - 5/18 1058L (3040 Min)

Nuclide	Air Concentration (fCi/m3)	Deposition Rate (mCi/km2)	Deposition Velocity (cm/sec)
I-131	518.+/-19.	0.55+/-0.28	0.58+/-0.32
Cs-134	104.+/-7.	0.09+/-0.06	0.47+/-0.31
Cs-137	176.+/-16.	0.11+/-0.04	0.34+/-0.13

Site: Beaverton, Oregon

Collection Period: 5/13 1045L - 5/19 1330L (8805 Min)

Nuclide	Air Concentration (fCi/m3)	Deposition Rate (mCi/km2)	Deposition Velocity (cm/sec)
I-131	85.+/-11.	1.40+/-0.70	3.14+/-1.62
Cs-134	39.+/-5.	0.12+/-0.03	0.59+/-0.17
Cs-137	68.+/-9.	0.16+/-0.02	0.45+/-0.08

Site: New York City, NY

Collection Period: 5/09 0910L - 5/14 0930L (7220 Min)

Nuclide	Air Concentration (fCi/m3)	Deposition Rate (mCi/km2)	Deposition Velocity (cm/sec)
I-131	283.+/-1.	0.70+/-0.40	0.57+/-0.33
Cs-137	122.+/-1.	0.16+/-0.04	0.30+/-0.09

Site: Chester, NJ

Collection Period: 5/10 0840L - 5/14 1100L (5900 Min)

Nuclide	Air Concentration (fCi/m3)	Deposition Rate (mCi/km2)	Deposition Velocity (cm/sec)
I-131	185.+/-3.	0.76+/-0.24	1.16+/-0.37
Cs-134	69.+/-2.	0.13+/-0.03	0.53+/-0.12
Cs-137	123.+/-2.	0.18+/-0.02	0.41+/-0.05

Figure 1. Sampling sites.

Figure 2. Surface air concentrations and precipitation, Barrow, Alaska.

Figure 3. Surface air concentrations and precipitation, Moosonee, Ontario, Canada.

Figure 4. Surface air concentrations and precipitation, Beaverton, Oregon.

Figure 5. Surface air concentrations and precipitation, Rexburg, Idaho.

Figure 6. Surface air concentrations and precipitation, Chester, New Jersey.

Figure 7. Surface air concentrations and precipitation, New York City, New York.

Figure 8. Surface air concentrations and precipitation, Miami, Florida.

Figure 9. Surface air concentrations and precipitation, Mauna Loa Observatory, Hawaii.

Figure 10. Surface air concentrations of Beryllium-7.

Figure 11. Surface air concentrations of Iodine-131.

Figure 12. Surface air concentrations of Cesium-137.

Figure 13. Activity ratio of $^{131}\text{I}^*/^{137}\text{Cs}$ in surface air.

DEPOSITION OF RADIONUCLIDES IN THE NORTHERN HEMISPHERE FOLLOWING THE CHERNOBYL ACCIDENT

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and Susan Silvestri

INTRODUCTION

The Environmental Measurements Laboratory (EML) has long had an interest in, and responsibility for, determining the fate of radionuclides released into the atmosphere. When it was learned that a radioactive release had occurred from a nuclear reactor near Chernobyl, USSR (~51°N), we began collecting deposition samples. Described in this report are the results of gamma-ray spectroscopy performed on deposition samples collected at selected sites in the United States, Japan and Iceland during May 1986. The gamma emitting radionuclides reported here are ^{131}I , ^{134}Cs , ^{137}Cs and ^{103}Ru . Other gamma emitters were detectable, but were not found at significant levels. Measurable fallout of ^{131}I , ^{137}Cs , ^{134}Cs and ^{103}Ru was observed at a number of United States sites following the Chernobyl nuclear reactor accident of April 26, 1986. The highest integrated deposits of radionuclides in North America were observed in the northwestern United States and Alaska during May 1986. Radionuclide deposition was significantly lower in the northeastern United States during May 1986. These deposition measurements will provide the data needed to estimate regional fallout patterns and aid in calculating estimates of the radiation exposures to humans.

METHODS AND MATERIALS

Samples

Deposition samples were collected from 15 sites during May 1986. Table 1 shows the site location, collector type, collection description and the number of individual or composited samples analyzed for each site. (Small volume precipitation collections were composited for some sites.)

All collectors were placed outdoors in unobstructed areas. At Chester, NJ; New York, NY; Hilo, HI and Mauna Loa, HI fallout samples were generally collected after a precipitation event. Fallout collections from Argonne, IL were made at random times during May.

Deposition samples, collected in rain gauges, were also obtained from the National Weather Service Offices in Juneau and Cold Bay, AK after each precipitation event.

Separate wet and dry deposition samples were obtained from sites 8 to 12 in Table 1. These sites were chosen from a sampling network that comprises the EML ^{90}Sr Global Fallout Program (Larsen, 1985). A white plastic bucket and a set of plastic bags were sent to each of the five sites. Each day a new plastic bag was used to line the bucket. If any precipitation had occurred, the liquid was poured into a plastic bottle and shipped to EML along with the daily change of plastic bags. Thus, some of these samples represented dry deposition only, while some represented integrated wet plus dry deposition.

Sample collection was requested from site operators at three EML ^{90}Sr fallout network sites outside the United States (Keflavik, Iceland, and Hiroshima and Nagasaki, Japan). Because of logistical problems, only three wet deposition samples were received from each of the Japanese sites. The collector used at the Japanese sites was the plastic bucket. Unfortunately, these samples were collected late in the fallout episode during the last days of May. The Keflavik site was the first to begin sampling. The collector used at the Keflavik site was an onsite rain gauge. Because of the small amount of measurable precipitation at Keflavik during late April and early May, a single integrated sample (April 27 to May 18) was collected.

Analysis

Routine gamma-ray spectrometry measurements at EML are performed with 7 high resolution germanium detectors in three different configurations. These consist of two-1.5 cm diameter wells, two n-type low energy coaxials and 3 germanium lithium (Ge(Li)) or HPGe coaxials. The relative efficiencies (^{60}Co 25 cm) of these detectors range from 15% to 35%. Due to the large number of samples, a 35% resolution n-type Ge detector was also utilized. For the analyses presented here, two different counting geometries were used: a 600 cm³ Marinelli (reentrant) beaker and a 90 cm³ aluminum can. Marinelli beakers were used for analysis of dry deposition samples. For precipitation samples, the geometrical configuration and the detector selected for gamma-ray spectrometry usually depended upon the volume of the sample. Counting times ranged between 200 to 4000 min.

Deionized water samples were submitted as blanks for quality control purposes. These samples showed no detectable levels of radioactivity. Duplicate analyses were carried out on some samples and results showed similar activities, within the counting errors.

RESULTS

The results of measurements made on deposition collections from 15 sites are presented in Tables 2a to 2g, 3a to 3e and 4a to 4c. Tables 2a to 2g represent results of measurements of integrated deposition collections from Chester, NJ; New York, NY; Argonne, IL; Hilo and Mauna Loa, HI; and Cold Bay and Juneau, AK. Tables 3a to 3e lists results of measurements made of deposition collections from Forks, WA; Medford, OR; Vermillion, SD; Williston, ND; and West Columbia, SC. Reported on the upper portions of Tables 3a to 3e are results of measurements of predominantly wet deposition collections. The bottom portion of Tables 3a to 3e represent the results of dry deposition collections.

Results for wet deposition collections from Hiroshima and Nagasaki, Japan are presented in Tables 4a and 4b, respectively. Results for the integrated deposition collection from Keflavik, Iceland are reported on Table 4c.

In all of the tables, deposition of ^{131}I , ^{137}Cs , ^{134}Cs and ^{106}Ru is reported in both mCi/km² and, in brackets, Bq/m². Dry deposition samples were not counted soon enough after collection to measure ^{131}I at those sites represented in Tables 3a to 3e. Shown in Table 5 is the total deposition, comprised of the predominantly wet plus the dry deposition, for the sites represented in Tables 3a to 3e. Tables presenting total deposition include propagated errors based on 1 σ (coefficients of variation) counting statistics. Total deposition amounts in Tables 2a to 4c do not include values below the lower limit of detection.

The most complete sets of deposition collections were obtained from Chester, NJ; New York, NY; Forks, WA; Juneau, AK; Vermillion, SD; and Cold Bay, AK. These sites will be referred to as principal sites. Ratios of $^{131}\text{I}/^{137}\text{Cs}$ and $^{134}\text{Cs}/^{137}\text{Cs}$ for the principal sites are presented in Table 6a to 6b. ^{131}I results used in these ratios are decay corrected to their appropriate collection periods. Ratios of $^{134}\text{Cs}/^{137}\text{Cs}$ have been calculated for dry deposition collections and are presented in Table 6c.

Figures 1 to 6 display the deposition rates of ^{131}I for the six principal sites. Figures 7 to 12 display the deposition rates of ^{137}Cs for the six principal sites. The vertical scales for Figures 1 to 12 change according to deposition ranges. The line through the rectangles represents the mean. The associated error is expressed by the top and bottom lines of the rectangle.

For comparative purposes, Figures 13 to 15 and 16 to 18 display ^{131}I and ^{137}Cs deposition rates, respectively, with the vertical scale fixed at 0 to 20 mCi/km² and 0 to 4 mCi/km², respectively, for the six principal sites. Figures 19 to 22 allow for a comparison of the deposition of ^{131}I and ^{137}Cs to precipitation between Chester, NJ and New York, NY, and between Forks, WA and Juneau, AK.

A geographical distribution of ^{131}I and ^{137}Cs deposition and precipitation amounts is shown in Figure 23.

A number of the results presented in this section indicate relatively high lower limits of detection. Future reanalysis on some samples will allow for more conclusive results for the long-lived radioisotopes (^{137}Cs , ^{134}Cs).

DISCUSSION

Northwestern United States and Alaska

Measurable amounts of radioactivity were found in deposition collections from Cold Bay, AK, Juneau, AK, Forks, WA and Medford, OR about 1 week after the initial Chernobyl nuclear reactor explosion. Figure 23 illustrates deposited amounts of ^{131}I and ^{137}Cs and precipitation amounts at these and other sites. During 1983 and 1984, Cambray et al. (1985) reported quarterly ^{137}Cs deposition rates at sites in the Northern Hemisphere to be below the lower limit of detection (~ 0.1 mCi/km²).

Cold Bay, AK was the first site in our network to receive measurable fallout, the majority of which occurred between May 2 to 8. About 15 mCi/km² of ^{131}I and about 1 mCi/km² of ^{137}Cs were deposited at Cold Bay during May. Similar amounts of ^{131}I and ^{137}Cs were deposited at Juneau during May.

The highest deposits of ^{131}I and ^{137}Cs were measured at Forks, WA, with about 32 mCi/km² of ^{131}I and about 8 mCi/km² of ^{137}Cs . The large amount of precipitation that occurred at Forks during May contributed significantly to the relatively high fallout.

About 12 mCi/km² of ^{131}I and about 2 mCi/km² of ^{137}Cs were deposited at Medford, OR during May. Most of the wet deposited ^{131}I at Medford, OR was deposited between May 9 to 10.

The activity ratio of $^{134}\text{Cs}/^{137}\text{Cs}$ for the dry deposition collections from Forks, WA and Medford, OR are 0.47 ± 0.06 and 0.49 ± 0.03 respectively. These ratios are in good agreement with $^{134}\text{Cs}/^{137}\text{Cs}$ ratios for dry deposition from other sites (see Table 6c). Air filters collected during May, at a number of United States sites, had $^{134}\text{Cs}/^{137}\text{Cs}$ ratios of ~ 0.5 (Larsen, this report).

Midwestern United States

Deposition collections were made during May 1986 at three Midwestern locations: Vermillion, SD; Argonne, IL; and Williston, ND. Deposition of ^{137}Cs during May was about 1.4 mCi/km^2 at Vermillion, about 1.3 mCi/km^2 at Argonne and about 0.7 mCi/km^2 at Williston. A significant amount of the total ^{137}Cs was deposited at Argonne and Vermillion during large thunderstorms in mid-May. This indicates the effectiveness of precipitation scavenging the radioactive aerosol during large storms.

About 8.3 mCi/km^2 and about 1.4 mCi/km^2 of ^{131}I were deposited at Vermillion and Williston, respectively. Measurable ^{131}I was deposited at Williston between May 11 to 15. Other deposition collections from Williston and Argonne were not counted soon enough to measure ^{131}I .

The activity ratio of $^{134}\text{Cs}/^{137}\text{Cs}$ for two dry deposition collections from Vermillion are 0.57 ± 0.06 and 0.48 ± 0.05 . One dry deposition collection from Williston had a $^{134}\text{Cs}/^{137}\text{Cs}$ ratio of 0.48 ± 0.03 .

Eastern United States

Sites sampled in the eastern United States had less deposition of ^{131}I and ^{137}Cs than sites in the northwestern United States and Alaska.

About 2.4 mCi/km^2 of ^{131}I and about 0.7 mCi/km^2 of ^{137}Cs were deposited at Chester during May. About 1.2 mCi/km^2 of ^{131}I and about 0.3 mCi/km^2 of ^{137}Cs were deposited at New York during May. The differences between deposition rates at Chester and New York can be attributed to variations in local meteorology.

Grass and soil samples taken at Chester, NJ show about 0.9 mCi/km^2 of ^{131}I deposited as of June 3 (Helfer, 1986). Integrated deposition results as of June 3 show 0.6 mCi/km^2 of ^{131}I deposited at Chester. This is good agreement between these two sampling methods, considering that grass and soil are considered more efficient collectors of small particles by dry deposition (Hicks et al., 1980).

Similar deposition collections were made after the 1976 Chinese atmospheric weapons test, and these showed total deposition of ^{131}I to have been about 14 mCi/km^2 and about 7 mCi/km^2 at Chester and New York, respectively (HASL, 1976). These deposition amounts were about 7 times greater than the amounts deposited at Chester and New York following the Chernobyl accident.

Deposition collections from West Columbia, SC were not counted soon enough to measure ^{131}I . About 0.5 mCi/km^2 of ^{137}Cs was deposited at West Columbia during May and the activity ratio of $^{134}\text{Cs}/^{137}\text{Cs}$ in dry deposition was 0.50 ± 0.04 .

Other Sites

The deposition collection from Keflavik, Iceland showed the deposited amount of ^{131}I to be about 1.3 mCi/km^2 ; ^{137}Cs was at its lower limit of detection ($<0.6 \text{ mCi/km}^2$). Because of the long sampling period, it is not evident whether the ^{131}I deposited at Keflavik, Iceland arrived on an eastward or westward trajectory from Chernobyl.

Only one deposition collection from Hiroshima and Nagasaki, Japan between May 27 to 30 showed measurable ^{131}I and ^{137}Cs . About 0.4 mCi/km^2 of ^{131}I and about 0.2 mCi/km^2 of ^{137}Cs was deposited at Nagasaki between May 27 to 28. Independent fallout measurements made by the Japanese Meteorological Research Institute show spatial deposition of ^{131}I over several locations in Japan

ranged from about 1 mCi/km² to about 70 mCi/km² between May 1 to 8 (Aoyama et al., 1986).

Only one deposition collection from Hilo and Mauna Loa, HI during May showed any measurable ¹³⁷Cs. This one collection showed about 0.5 mCi/km² of ¹³⁷Cs at Hilo between May 11 to 17.

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REFERENCES

- Aoyama, M., K. Hirose, Y. Suzuki, M. Inoue and Y. Sugimura
'High Level Radioactive Nuclides in Japan in May'
Nature, 321, 819-820 (1986)
- Cambray, R. S., K. Playford and G. N. J. Lewis
'Radioactive Fallout in Air and Rain: Results to the End of 1984'
U.K. Atomic Energy Authority Report AERE-R-11915, October (1985)
- 'HASL Measurements of Fallout Following the September 26, 1976
Chinese Nuclear Test'
USERDA Report HASL-314 (1976)
- Helfer, I.
EML, Private Communication (1986)
- Hicks, B. B., M. L. Wesely, and J. L. Durham
'Critique of Methods to Measure Dry Deposition'
Environmental Protection Agency Report EPA-600/9-80-050, September (1980)
- Larsen, R. J.
'Worldwide Deposition of ^{90}Sr through 1983'
USDOE Report EML-444, July (1985)
- Larsen, R. J.
'The Characterization of Radionuclides in North American and Hawaiian
Surface Air and Deposition Following the Chernobyl Accident'
This report
- Volchok, H. L. and G. de Planque (Editors)
'EML Procedures Manual'
USDOE Report EML-300, 26th Edition (1983)

TABLE 1
DEPOSITION: SITE AND SAMPLE DESCRIPTION^a

Site	Collector Type ^b	Collection Description ^c	Samples ^d
1 Chester, NJ	Bucket	Total	8
2 New York, NY	Pot	Total	10
3 Argonne, IL	Bucket	Total	5
4 Hilo, HI	Bucket	Total	4
5 Mauna Loa, HI	Bucket	Total	3
6 Cold Bay, AK	Rain Gauge	Total	5
7 Juneau, AK	Rain Gauge	Total	6
8 Medford, OR	Bucket with liner	Wet-Dry	3
9 Forks, WA	Bucket with liner	Wet-Dry	13
10 Vermillion, SD	Bucket with liner	Wet-Dry	7
11 Williston, ND	Bucket with liner	Wet-Dry	5
12 West Columbia, SC	Bucket with liner	Wet-Dry	4
13 Keflavik, Iceland	Rain Gauge	Total	1
14 Hiroshima, Japan	Bucket with liner	Wet	3
15 Nagasaki, Japan	Bucket with liner	Wet	3

^a Samples collected during May 1986.

^b Bucket: white plastic; height ~27 cm, collection area 638 cm².

Pot: stainless steel; height ~28 cm, collection area 760 cm²

(Volchok and de Planque, 1983).

Rain Gauge (Juneau, AK): collection area 324 cm².

Rain Gauge (Cold Bay, AK): collection area 730 cm².

Rain Gauge (Keflavik, Iceland): collection area 127 cm².

Bucket with liner: plastic liner inserted into bucket; removed daily.

^c Total refers to wet plus dry deposition.

Wet-dry refers to predominantly wet deposition with separate dry deposition collections.

^d Number of composited samples analyzed.

TABLE 2a

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
CHESTER, NEW JERSEY

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/6-5/9	1.19	0.06±19 [2.22]	<0.03 [<1.2]	<0.03 [<1.2]	<0.03 [<1.2]
5/9-5/15	0.08	0.56± 4 [20.72]	0.21± 7 [7.77]	0.11±10 [4.07]	
5/15-5/17	0.15	0.17±11 [6.29]	0.11±28 [4.07]	0.04±37 [1.48]	0.05±28 [1.85]
5/17-5/21	0.76	0.42±17 [15.54]	0.10±7 [3.7]	0.04±16 [1.5]	0.15±18 [5.55]
5/21-5/22	0.58	0.39±25 [14.43]	0.05±9 [<1.9]	0.02±15 [0.74]	0.19±38 [7.13]
5/22-5/23	1.78	0.73±26 [27.01]	0.13±6 [4.8]	0.07±7 [2.6]	0.27±39 [9.99]
5/23-5/29	-	0.02±57 [0.74]	0.02±50 [0.74]	<0.03 [<1.2]	0.03±29 [1.11]
5/29-6/2	T	0.03±40 [1.11]	0.03±30 [1.11]	0.01±30 [0.37]	0.03±28 [1.11]
Total (5/6-6/2)	4.54	2.38±10 [88.06]	0.65±6 [24.05]	0.29±7 [10.73]	0.72±18 [26.64]

^aDecayed to midpoint of sample period.

Notes:

- = No precipitation
- < = Lower limit of detection
- T = Trace

TABLE 2b

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
NEW YORK, NEW YORK

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/6-5/9	0.71	0.09±5 [3.33]	0.01±55 [0.37]	<0.01 [<0.4]	0.01±27 [0.37]
5/9-5/15	0.18	0.56±4 [20.72]	0.11±12 [4.07]	0.06±26 [2.22]	0.08±18 [2.96]
5/15-5/17	0.18	0.20±13 [7.40]	0.04±8 [1.48]	0.02±15 [0.74]	0.04±35 [1.48]
5/17-5/20	0.25	0.02±22 [0.74]	0.01±45 [0.37]	<0.01 [<0.4]	<0.01 [<0.4]
5/20-5/21	0.56	0.10±31 [3.70]	0.03±13 [<4.0]	<0.01 [<0.4]	0.05±45 [1.85]
5/21-5/22	0.94	0.19±56 [7.03]	0.02±29 [0.74]	0.02±23 [0.74]	0.01±67 [0.37]
5/22-5/23	-	0.01±58 [0.37]	0.01±64 [0.37]	0.02±37 [0.74]	<0.03 [<1.2]
5/23-5/25	-	<0.02 [<0.8]	<0.03 [<1.2]	<0.02 [<0.8]	<0.02 [<0.8]
5/25-5/26	-	<0.01 [<0.4]	0.01±27 [0.37]	<0.01 [<0.4]	<0.01 [<0.4]
5/26-6/2	T	0.03±42 [1.11]	0.02±35 [0.74]	0.02±37 [0.74]	0.04±17 [0.74]
Total (5/6-6/2)	2.82	1.20±10 [44.40]	0.26±9 [9.62]	0.14±14 [5.18]	0.23±14 [8.51]

^aDecayed to midpoint of sample period.

Notes:

- = No Precipitation

< = Lower Limit of detection

T = Trace

TABLE 2c

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
ARGONNE, ILLINIOS

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/5-5/12	0.18	<0.7 [<26]	<0.06 [<2.3]	<0.05 [<1.9]	<0.10 [<4]
5/11-5/15	0.94	<0.84 [<31.08]	0.16±24 [5.92]	<0.10 [<3.70]	<0.16 [<5.92]
5/16-5/20	3.66	<4.67 [<172.79]	1.06±24 [39.22]	<0.65 [<24.05]	<0.89 [<32.93]
5/20-5/30	1.27		0.08±63 [2.96]	0.09±38 [3.33]	0.23±31 [8.51]
5/28-5/30	0.86	0.13±67 [4.81]	<0.02 [<0.74]	<0.02 [<0.74]	<0.02 [<0.74]
Total (5/5-5/30)	6.91	0.13±67 [4.81]	1.30±20 [48.10]	0.09±38 [3.33]	0.23±31 [8.51]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 2d

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
HILO, HAWAII

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/2-5/10	9.12	<2.0 [<73.0]	<0.9 [<32.0]	<0.9 [<32.0]	<1.0 [<37.0]
5/11-5/17	2.43	<1.8 [<65.0]	0.51±21 [18.87]	<0.4 [<13.0]	0.97±18 [35.89]
5/18-5/27	1.27	<3.0 [<110]	<0.5 [<16]	<0.4 [<12.0]	<0.7 [<23.0]
5/28-5/30	5.06	<4.5 [<160.0]	<1.4 [<52.0]	<1.3 [<47.0]	<2.2 [<79.0]
Total (5/2-5/30)	17.88		0.51±21 [18.87]		0.97±18 [35.89]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 2e

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
MAUNA LOA, HAWAII

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/9-5/12	2.95	<5.59 [<206.83]	<0.35 [<12.95]	<0.21 [<7.77]	<0.45 [<16.65]
5/27-5/29	0.03	<0.21 [7.77]	<0.04 [<1.48]	<0.05 [<3.42]	<0.07 [<2.59]
5/30-6/2	0.43	<0.50 [<18.50]	<0.20 [<7.40]	0.35±16 [12.95]	
Total (5/9-6/2)	3.41			0.35±16 [12.95]	

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 2f

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
COLD BAY, ALASKA

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
4/29-5/1	1.32	<0.38 [<14.06]	<0.08 [<2.96]	<0.07 [<2.59]	
5/2-5/8	1.86	14.31±14 [529.47]	0.87± 8 [32.19]	0.38±13 [14.06]	<0.60 [<22.2]
5/21-5/23	0.28	0.05± 9 [1.85]	0.09± 6 [3.33]	0.04±12 [1.48]	0.02±23 [0.74]
5/29-5/31	1.72	0.79±16 [29.23]	0.31±12 [11.47]	0.13±23 [4.81]	<0.13 [<4.81]
6/3-6/7	1.50	<0.60 [<22.2]	<0.35 [<12.95]	<0.23 [<8.51]	<0.27 [<9.99]
Total (4/29-6/7)	6.68	15.15±13 [560.55]	1.27±6 [46.99]	0.55±11 [20.35]	0.02±23 [0.74]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 2g

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
JUNEAU, ALASKA

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/5-5/10	1.42	1.69±36 [62.53]	0.07±35 [2.59]	0.06±39 [2.22]	<0.01 [<0.4]
5/11-5/16	3.54	6.96±15 [257.52]	0.45± 9 [16.65]	0.28±13 [10.36]	0.36±18 [13.32]
5/18-5/25	2.54	3.10±18 [114.7]	0.41±14 [15.17]	0.14±35 [5.18]	0.24±29 [8.88]
5/25-5/27	2.64	0.96±31 [35.52]	0.19±25 [7.03]	0.12±45 [4.44]	<0.02 [<0.8]
5/31-6/3	2.77	0.46±36 [17.02]	0.20±19 [7.4]	<0.01 [<0.4]	0.19±22 [7.03]
6/6-6/8	2.49	<0.72 [<27]	<0.55 [<21]	<0.43 [<20]	
Total (5/5-6/8)	15.4	13.17±10 [487.29]	1.32± 7 [48.84]	0.60±14 [22.2]	0.79±13 [29.23]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 3a

RADIONUCLIDE DEPOSITION - PREDOMINANTLY WET FALLOUT SAMPLES
FORKS, WASHINGTON

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/9-5/10	0.56	0.57±11 [21.09]	0.05±21 [1.85]	<0.04 [<1.5]	<0.04 [<1.5]
5/11	1.42	4.82± 5 [178.34]	0.76± 8 [28.12]	0.35± 9 [12.95]	0.41±12 [15.17]
5/12	8.53	9.42±20 [348.54]	2.66±17 [98.42]	<1.2 [<43.0]	<1.5 [<55.0]
5/13-5/14	0.30	0.25±14 [9.25]	<0.03 [<1.2]	<0.03 [<1.2]	<0.03 [<1.2]
5/16-5/17	1.42	6.02±10 [222.74]	1.22±15 [45.14]	0.33±3 [<22.0]	0.67±8 [<22.0]
5/18-5/19	7.57	7.64±10 [282.68]	1.91± 9 [70.67]	0.88±14 [32.56]	
5/20	0.28	0.98±12 [36.26]	0.24±15 [8.88]	0.05±14 [1.85]	<0.03 [<1.1]
5/21-5/23	0.05	0.17±14 [6.29]	0.03±22 [1.11]	<0.02 [<1.0]	<0.04 [<1.5]
5/24	2.36	0.98±28 [36.26]	0.37±28 [13.69]	<0.18 [<7.0]	0.47±24 [17.39]
5/25	1.35	<1.03 [<39.0]	0.06±15 [<2.22]	<0.03 [<1.1]	<0.04 [<1.5]
5/26	1.35	0.98±25 [36.26]	<0.52 [<20.0]	<0.53 [<20.0]	
Total (5/9-5/26)	25.19	31.83± 7 [1177.71]	7.3± 7 [270.1]	1.61±8 [59.57]	1.55±13 [57.35]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 3a (Cont'd)

RADIONUCLIDE DEPOSITION - DRY FALLOUT SAMPLES

Sample Period	mCi/km ² ± coefficients of variation (%) [Bq/m ²]		
	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/11-5/21	0.76±14 [28.12]	0.36± 2 [13.32]	1.87± 1 [69.19]
5/22-5/30	0.09±16 [3.33]	<0.04 [<1.5]	0.22±12 [8.14]
Total (5/11-5/30)	0.85±13 [31.45]	0.36± 2 [13.32]	2.09± 2 [77.33]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 3b

RADIONUCLIDE DEPOSITION - PREDOMINANTLY WET AND DRY FALLOUT SAMPLE
MEDFORD, OREGON

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
<u>Wet Samples</u>					
5/9-5/10	0.28	11.98± 6 [443.26]	0.83± 7 [30.71]	0.53± 8 [19.61]	
5/19-5/22	0.33	<2.0 [<73.26]	0.45±17 [16.65]	<0.22 [<8.2]	
Total (5/9-5/22)	0.61	11.98± 6 [443.26]	1.28± 8 [47.36]	0.53± 8 [19.61]	
<u>Dry Samples</u>					
5/8-5/22			0.80± 1 [29.6]	0.39± 7 [14.43]	0.99±10 [36.63]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 3c

RADIONUCLIDE DEPOSITION - PREDOMINANTLY WET AND DRY FALLOUT SAMPLES
VERMILLION, SOUTH DAKOTA

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
<u>Wet Samples</u>					
5/9-5/11	2.54	3.92±26 [145.04]	0.14±20 [5.18]	0.12±26 [4.44]	<0.1 [<4]
5/16	2.54	4.01±16 [148.37]	0.53± 8 [19.61]	0.28±14 [10.36]	0.51±11 [18.87]
5/23-5/26	0.89	0.33±45 [12.21]	0.17±13 [6.29]	0.07±28 [2.59]	0.14±19 [5.18]
5/27-5/28	~3.00	<0.33 [<13]	0.15±22 [5.55]	0.09±25 [3.33]	0.13±31 [4.81]
5/29-6/5	0.23	<0.31 [<12]	<0.05 [<2]	<0.05 [<2]	
Total (5/9-6/5)	8.97	8.26±15 [305.62]	0.99± 7 [36.63]	0.56±10 [20.72]	0.78± 9 [28.86]
<u>Dry Samples</u>					
5/9-5/18			0.23± 8 [8.51]	0.13± 7 [4.81]	0.49± 7 [18.13]
5/20-6/5			0.21± 7 [7.77]	0.10± 9 [3.7]	0.32± 8 [11.84]
Total (5/9-6/5)			0.44± 5 [16.28]	0.23± 6 [8.51]	0.81± 5 [29.97]

^aDecayed to midpoint of sample period.

Note:
< = Lower limit of detection

TABLE 3d

RADIONUCLIDE DEPOSITION - PREDOMINANTLY WET AND DRY FALLOUT SAMPLES
WILLISTON, NORTH DAKOTA

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
<u>Wet Samples</u>					
5/9	3.07	<10.0 [<370]	<0.75 [<30.0]	<0.25 [<9.0]	
5/11-5/19	0.23	1.37±14 [50.69]	0.06±23 [2.22]	<0.04 [<1.5]	0.08±25 [2.96]
5/22	1.63	<12.0 [<440]	<2.6 [<94.0]	<2.3 [<83.0]	<2.7 [<97.0]
5/23	1.09	<5.5 [<202]	<1.2 [<42]	<0.9 [<34.0]	<1.3 [<48]
Total (5/9-5/23)	6.02	1.37±14 [50.69]	0.06±23 [2.22]		0.08±25 [2.96]
<u>Dry Samples</u>					
5/9-5/23			0.65± 4 [24.05]	0.31± 4 [11.47]	0.77± 5 [28.49]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 3e

RADIONUCLIDE DEPOSITION - PREDOMINANTLY WET AND DRY FALLOUT SAMPLES
WEST COLUMBIA, SOUTH CAROLINA

mCi/km ² ± coefficients of variation (%) [Bq/m ²]					
Sample Period	Precip. (cm)	¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
<u>Wet Samples</u>					
5/8-5/19	0.33	<0.89 [<32.93]	<0.03 [<1.11]	0.07±28 [2.59]	<0.05 [<1.85]
5/19-5/27	0.64	<0.64 [<23.68]	0.12±23 [4.44]	<0.01 [<0.37]	0.12±31 [4.44]
5/27-5/29	1.80	<0.25 [<9.25]	0.08±28 [2.96]	<0.03 [<1.11]	0.08±43 [2.96]
Total (5/8-5/29)	2.77		0.2±18 [7.40]	0.07±28 [2.59]	0.2±25 [7.40]
<u>Dry Samples</u>					
5/8-5/29			0.3±5 [11.1]	0.15± 6 [5.55]	0.22±12 [8.14]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 4a

RADIONUCLIDE DEPOSITION - PREDOMINANTLY WET FALLOUT SAMPLES
HIROSHIMA, JAPAN

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/27-5/28	NA	<0.3 [<9]	<0.04 [<2]	<0.04 [<2]	<0.05 [<2]
5/28-5/29	NA	<3.3 [<120]	<0.6 [<23]	<0.7 [<24]	<0.8 [<29]
5/29-5/30	NA	<13.0 [<475]	<3.5 [<130]	<3.3 [<122]	<3.7 [<140]

^aDecayed to midpoint of sample period.

Notes:

< = Lower limit of detection

NA = Not available

TABLE 4b

RADIONUCLIDE DEPOSITION - PREDOMINANTLY WET FALLOUT SAMPLES
NAGASAKI, JAPAN

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]			
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru ^a
5/27-5/28	NA	0.36±22 [13.32]	0.18± 9 [6.66]	0.08±18 [2.96]	0.54± 5 [19.98]
5/28-5/29	NA	<0.9 [<32]	<0.3 [<8]	<0.2 [<7]	
5/29-5/30	NA	<5.06 [<190]	<1.1 [<40]	<0.8 [<29]	
Total (5/27-5/30)		0.36±22 [13.32]	0.18± 9 [6.66]	0.08±18 [2.96]	0.54± 5 [19.98]

^aDecayed to midpoint of sample period.

Notes:

< = Lower limit of detection

NA = Not available

TABLE 4c

RADIONUCLIDE DEPOSITION - INTEGRATED WET-DRY FALLOUT SAMPLES
KEFLAVIK, ICELAND

Sample Period	Precip. (cm)	mCi/km ² ± coefficients of variation (%) [Bq/m ²]		
		¹³¹ I ^a	¹³⁷ Cs	¹³⁴ Cs
4/27-5/18	~1.0	1.34±48 [49.58]	<0.06 [<2.3]	<0.06 [<2.3]

^aDecayed to midpoint of sample period.

Note:

< = Lower limit of detection

TABLE 5
TOTAL WET AND DRY DEPOSITION

	mCi/km ² [Bq/m ²] + % error		
	¹³⁷ Cs	¹³⁴ Cs	¹⁰³ Ru
Forks, WA	8.15[301.55]±6	1.97[72.89]± 7	3.64[134.68]± 6
Williston, ND	0.71[26.27] ±4	0.31[11.47]± 4	0.85[31.45] ± 5
Medford, OR	2.08[76.96] ±5	0.92[34.04]± 6	0.99[36.63] ±10
Vermillion, SD	1.43[52.91] ±5	0.79[29.23]± 7	1.59[58.83] ± 5
West Columbia, SC	0.50[18.50] ±8	0.22[8.14] ±10	0.43[15.54] ±13

^a % Error based on propagation of 1 σ counting statistics.

TABLE 6b

 $^{134}\text{Cs}/^{137}\text{Cs}$ RATIO - INTEGRATED DEPOSITION COLLECTIONS

New York, NY		Chester, NJ		Juneau, AK		Forks, WA ^a		Vermillion, SD ^a		Cold Bay, AK	
Sample period	Ratio	Sample period	Ratio	Sample period	Ratio	Sample period	Ratio	Sample period	Ratio	Sample period	Ratio
5/9-15	0.55±0.16	5/9-15	0.52±0.06	5/5-10	0.86±0.45	5/11	0.46±0.06	5/9-11	0.86±0.27	5/2-8	0.44±0.07
5/15-17	0.50±0.16	5/15-17	0.36±0.17	5/11-16	0.62±0.10	5/18-19	0.46±0.08	5/16	0.53±0.09	5/21-23	0.44±0.07
5/21-22	1.00±0.39	5/17-21	0.40±0.07	5/18-25	0.34±0.13	5/16-17	0.27±0.04	5/23-26	0.41±0.13	5/29-31	0.42±0.11
5/22-23	2.00±1.39	5/21-22	0.40±0.07	5/25-27	0.63±0.31	5/20	0.21±0.04	5/27-28	0.60±0.18		
5/26-6/2	1.00±0.49	5/22-23	0.54±0.05								
		5/29-6/2	0.33±0.14								

^a Predominantly wet deposition collections.

TABLE 6a
 $^{131}\text{I}/^{137}\text{Cs}$ RATIO - INTEGRATED DEPOSITION COLLECTIONS^a

New York, NY		Chester, NJ		Juneau, AK		Forks, WA ^b		Vermillion, SD ^b		Cold Bay, AK	
Sample period	Ratio	Sample period	Ratio	Sample period	Ratio	Sample period	Ratio	Sample period	Ratio	Sample period	Ratio
5/6-9	9.0±5.0	5/9-15	2.6±0.2	5/5-10	24.1±11.1	5/9-10	11.4±2.7	5/9-11	28.0 ±9.19	5/2-8	16.45±2.65
5/9-15	5.1±0.6	5/15-17	1.5±0.5	5/11-16	15.5± 2.7	5/11	6.3±0.6	5/16	7.57±1.34	5/21-23	0.56±0.05
5/15-17	5.0±1.6	5/17-21	4.2±0.8	5/18-25	7.6± 1.8	5/12	3.5±0.9	5/23-26	1.94±0.91	5/29-31	2.55±0.51
5/17-20	2.0±1.0	5/21-22	7.8±2.1	5/25-27	5.1± 2.1	5/16-17	4.9±0.9				
5/20-21	3.3±1.1	5/22-23	5.6±1.5	5/31-6/3	2.3± 1.9	5/18-19	4.0±0.5				
5/21-22	9.5±6.2	5/23-29	1.0±0.8			5/20	4.1±0.8				
5/22-23	1.0±0.9	5/29-6/2	1.0±0.5			5/21-23	5.7±1.5				
5/26-6/2	1.5±0.8					5/24	2.7±1.1				

^a ^{131}I decayed to midpoint of sample period.

^b Predominantly wet deposition collections.

TABLE 6c

 $^{134}\text{Cs}/^{137}\text{Cs}$ RATIO IN
DRY DEPOSITION COLLECTIONS

Forks, WA 5/11-5/21	0.47 $\pm$ 0.06
Williston, ND 5/9-5/23	0.48 $\pm$ 0.03
Medford, OR 5/8-5/22	0.49 $\pm$ 0.03
Vermillion, SD 5/9-5/18	0.57 $\pm$ 0.06
5/20-6/5	0.48 $\pm$ 0.05
West Columbia, SC 5/8-5/29	0.50 $\pm$ 0.04

Figure 1. Deposition of ^{131}I at Chester, NJ.

Figure 2. Deposition of ¹³¹I at New York, NY.

Figure 3. Deposition of ^{131}I at Forks, WA.

Figure 4. Deposition of ^{131}I at Vermillion, S. Dakota.

Figure 5. Deposition of ^{131}I at Juneau, AK.

Figure 6. Deposition of ^{131}I at Cold Bay, Ak.

Figure 7. Deposition of ¹³⁷Cs at Chester, NJ.

Figure 8. Deposition of ¹³⁷Cs at New York, NY.

Figure 9. Deposition of ^{137}Cs at Forks, WA.

Figure 10. Deposition of ^{137}Cs at Vermillion, S. Dakota.

Figure 11. Deposition of ¹³⁷Cs at Juneau, AK.

Figure 12. Deposition of ^{137}Cs at Cold Bay, AK.

Figure 13. Deposition of ^{131}I at: a) New York, NY; b) Chester, NJ.

Figure 14. Deposition of ^{131}I at: a) Forks, WA; b) Vermillion, S. Dakota.

Figure 15. Deposition of ^{131}I at: a) Juneau, AK; b) Cold Bay, AK.

Figure 16. Deposition of ^{137}Cs at: a) New York, NY; b) Chester, NJ.

Figure 17. Deposition of ^{137}Cs at: a) Forks, WA; b) Vermillion, S. Dakota.

Figure 18. Deposition of ^{137}Cs at: a) Juneau, AK; b) Cold Bay, AK.

Figure 19. Integrated deposition of ^{131}I at New York, NY and Chester, NJ.

Figure 18. Deposition of ^{137}Cs at: a) Juneau, AK; b) Cold Bay, AK.

Figure 19. Integrated deposition of ^{131}I at New York, NY and Chester, NJ.

Figure 20. Deposition of ^{131}I at Forks, WA and Juneau, AK.

Figure 21. Integrated deposition at ^{137}Cs at New York, NY and Chester, NJ.

Figure 22. Deposition of ^{137}Cs at Forks, WA and Juneau, AK.

Figure 23. Geographical display of total integrated deposition.

RADIOCHEMICAL CHARACTERIZATION OF CHERNOBYL FALLOUT IN EUROPE

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INTRODUCTION

The Chernobyl explosion and fire is the first accident of its kind and magnitude in the nuclear industry. Consequently, it is important to determine the events that took place during the accident, and the quantity and composition of the radioactivity released into the environment by each event. This report describes EML's analyses of environmental samples collected in Europe to address some of these issues, and includes a preliminary interpretation of the results.

Specifically the objectives of this report are:

1. To document the radiochemical composition of fallout from the first massive accident of the nuclear power industry. Because of the chemical properties of the radionuclides in the reactor core and the varying processes taking place in the reactor during the course of the accident, we expect large variations in the radiochemical composition of the fallout (i.e., fractionation) with time and location.
2. To interpret the radiochemical data to provide an understanding of the processes that took place during the accident.
3. To accumulate data which, together with future soil sampling measurements in previously unmonitored areas, will allow an integration of the total fallout that occurred in those areas sampled including the short-lived radionuclides that will have long since decayed away. The European scientific community responded extremely well to the health physics needs of the general population following Chernobyl. However, some rural or remote areas may have gone unmonitored because of limited technical resources during the course of the accident. If the short lived Chernobyl fallout in any unmonitored areas were to be of interest, the data accumulated in this study, plus future soil measurements in the areas sampled, will permit a reconstruction of the total fallout. This is exactly the technique employed by the Environmental Measurements Laboratory (EML) in reconstructing the fallout in the southwestern United States from nuclear explosions conducted at the Nevada Test Site in the 1950's (Beck and Krey, 1983).
4. To provide early data on the European fallout for comparison with EML measurements of Chernobyl fallout around the world. Immediately following the accident, EML upgraded the frequency of radioactive fallout measurements at many of its global monitoring sites as described in other sections of this report. A knowledge of the radiochemical composition of the fallout in Europe will assist in the understanding and interpretation of the fallout measurements made at those sites.

EXPERIMENTAL METHOD

Sample Collection

The samples analyzed in this study were acquired through several independent activities. The first developed when the National Radiation Protection Institute of Sweden invited an EML scientist to visit and observe their radioactivity monitoring operations following the accident. Samples of soil and vegetation were collected during that visit as described in Hardy et al. (1986). In addition, a portion of an air filter sample exposed at Grindsjon, Sweden was also obtained by Hardy from the Swedish Defense Research Establishment.

A second development occurred as a result of EML's long experience and recognized expertise in fallout measurements. Dr. Alan Walton, Director of the International Atomic Energy's Monaco Marine laboratory, volunteered some samples as a measure of intercomparison between our two laboratories. We were fortunate to receive samples of an air filter, vegetation and precipitation from Monaco.

Another sample of opportunity was provided by Mr. W. Clarke of the Woods Hole Oceanographic Institution (WHOI). WHOI was conducting maritime experiments in the Black Sea following the Chernobyl accident, as described by Livingston et al. (this report). During those studies a sample of surface soil was collected at Izmir, Turkey and dispatched to EML for analysis. We are still waiting that sample's arrival.

The last activity was an attempt to better delineate the radiochemical composition of the Chernobyl fallout with location in Europe, especially for the short-lived radionuclides. To accomplish this, we wrote to our European colleagues requesting that they collect and return samples of surface soil to EML. The European sites are located in an approximate north-south vector about 1400 km west of Chernobyl. The standard EML procedure for collecting soil was used (Volchok and de Planque, 1983), i.e., ten-8.9 cm diameter cores spaced 0.5 m apart on a flat grassy lawn are collected to a depth of 5 cm, representing an area of 620 cm². The overlying grass is retained as part of the sample.

Sample Preparation

A new soil sample preparation procedure was devised to allow rapid processing, aliquoting and gamma ray spectrometric analysis, especially for short-lived radionuclides. After weighing, the entire sample was sieved through a steel mesh screen with square openings, 1.27 cm on edge. Rocks and pebbles of greater size were brushed and discarded. Vegetation and root mat were cut to a size that permitted them to pass through the sieve. The mixture of soil and vegetation was homogenized by hand for several minutes before duplicate aliquots of about 100 g each were removed for gamma ray spectrometry. The samples are identified as aliquots of wet soil.

The remaining soil sample was then either dried at about 100°C overnight or air dried in an open tray for several days. The sample was then pulverized with a hammer mill (mass median diameter usually about 150 μ m), mixed by shaking in a 1.5 L polyethylene bottle, and duplicate aliquots of about 125 g each taken for additional gamma-ray spectrometry. These are subsequently called aliquots of dry sample.

Large vegetation samples were scissored to small lengths (about 0.6 cm). Where the sample size was sufficient, duplicate aliquots were removed for gamma spectrometric analysis, otherwise the entire sample was packed into

counting containers. The counting containers for the soil and vegetation samples were 95 cm³ aluminum cans with sealed covers.

The portion of the air filter sample that was exposed at Grindsjon, Sweden was large enough to be folded properly and packed into an aluminum counting can. The smaller air filter sample obtained from Monaco was analyzed in an EML Germanium well detector. The precipitation sample collected at Monaco was radioassayed in a 600 ml Marinelli beaker.

RESULTS

The collection parameters of the soil and vegetation samples are given in Table 1. Similar parameters for the air filters and precipitation samples are given in Table 2.

To ascertain the effect of heating the soil to 100°C, especially for potentially volatile radionuclides, the duplicate counting cans from the Skutskar wet soil sample were opened and heated overnight. The contents of the cans were carefully transferred to fresh cans, resealed and recounted. The results presented in Table 3, show no significant loss in the activity per can following heating. There is evidence of a slightly increased activity for the heated sample for most nuclides (5 to 10%) and a potential for greater activity changes for refractory nuclides such as ⁹⁵Zr, ⁹⁵Nb and ¹⁴¹Ce.

The generally increased activity of the heated samples may be due to a slightly poorer mix of grass and soil in the heated sample. When the heated sample was transferred to a fresh can, it appeared that the dried soil transferred more readily than the dried vegetation. This could produce a slightly less homogenized sample, bring the greater amount of radioactivity in the soil fraction as opposed to the grass fraction closer to the detector, and result in a slightly higher count rate.

The reason for the greater variation in the wet/heated ratios of the refractory nuclides will be discussed in greater detail later in the report, but it centers on the presence of relatively few hot particles containing relatively high concentrations of these nuclides. A slightly greater number of these particles positioned closer to the detector in the heated sample, as in the manner described above, could produce a relatively higher increase in the counting rate over the wet sample for the refractory nuclides than the slightly less homogenized sample would increase the counting rate of the volatile radionuclides. Nevertheless, the experiment demonstrated no perceptible loss of volatile radionuclides by heating.

The deposition values for soil and vegetation at each of the sites are reported in both traditional and international units in Tables 4 through 32. The data for the Neuherberg, FRG location are not available for this report. The radionuclide concentration in air filter and precipitation samples are given in Table 33 and 34. All the data are decay-corrected to April 26. The radionuclide ratios to ¹³⁴Cs are listed in Tables 35 through 46.

DISCUSSION

Quality Assessment

An estimate of the precision of aliquoting the wet and dry soil can be made from an evaluation of the results of the duplicate samples. For the wet samples, 65 out of 75 sets and for the dry samples, 72 out of 80 sets of duplicate nuclide analyses agreed with each other to within two standard deviations of the propagated Poisson counting uncertainties. These results indicate a reasonable degree of homogenization for the wet and dry samples within the uncertainty of the measurements.

In addition to the wet/heated experiments described earlier, an examination of the soil deposition values at each site from both the wet and dry samples provides additional insight to sample homogenization and aliquoting. Table 47 lists the ratios of the mean wet/ mean dry deposition of all radionuclides reported to date. The weighted mean of all the sites (within the uncertainty of twice the standard deviation) is close to unity for most radionuclides even though there appears to be a consistent bias for samples at some locations (i.e., Skutskar and Uppsala). However, for refractory nuclides, that is nuclides with very high boiling points (^{90}Zr , ^{95}Nb and marginally ^{141}Ce), there is evidence of generally higher wet values. As will be discussed in greater detail later in this report, we can conjecture that these refractory nuclides in the samples collected in Sweden are primarily associated with infrequently occurring, relatively large size particles ($>$ a few μm) as opposed to the other volatile (lower boiling point) nuclides associated with the more frequent submicrometer particles. Our experience in other soil investigations indicates that homogenizing the dry pulverized samples has been successful in most cases. Consequently, we are inclined to suspect that the homogenization of the wet samples (a relatively new technique) is not as efficient in homogenizing the infrequent particles enriched in refractory nuclides, resulting in the discrepancy between the wet and dry sample results. We do not imply that dry sample aliquoting eliminates the problem of the infrequent hot particle, but we suspect that it reduces the effects of the problem as compared to wet sample aliquoting. Other explanations are possible and additional experiments are planned to resolve this issue which may be especially relevant to Chernobyl fallout studies.

The gamma ray spectrometric systems are calibrated with standards traceable to the National Bureau of Standards. The accuracy of the calibrations and consequently of the gamma spectrometric analyses is estimated to be within $\pm 5\%$ for all nuclides except ^{134}Cs , which is estimated to be within $\pm 10\%$.

Deposition Values

The deposition values reported here generally cover the range of values reported by the European community. The highest deposition value recorded for the remote Chernobyl fallout as far as we are aware is from Skutskar, Sweden. For comparison, global weapons fallout contributed on the order of $100 \text{ mCi } ^{137}\text{Cs}/\text{km}^2$ ($3.7 \text{ kBq}/\text{m}^2$) in Central Europe, of which about half still reside in the top 5 cm of an undisturbed soil.

Vegetation and underlying surface soil was collected and analyzed from Stockholm, Tarnsjo and Oland. The retention of radioactivity by the overlying vegetation at the time of sample collection was about 5% or less. However, it should be noted that spring growth of vegetation had barely begun in Sweden at the time of the Chernobyl accident.

Another point of interest is that at Tarnsjo, the ^{137}Cs and ^{131}I concentrations in grass increased only slightly in the lower sections of the plant (5 cm height to soil surface) as compared to the upper sections of the plant (top of grass to 5 cm height above the soil surface). The deposition values of 3.82 and $2.80 \text{ mCi } ^{131}\text{I}/\text{km}^2$ in the lower and upper section of the plant correspond to concentrations of 104 and 89 pCi (3.85 and 3.3 Bq) $^{131}\text{I}/\text{g}$ of wet weight, respectively.

Description of Accident

While details of the Chernobyl accident are still sketchy, the World Health Organization (WHO, 1986) postulated the following scenario. On April 26, 1986, very early in the morning the Chernobyl reactor ignited following an explosion caused by hydrogen generated from a zirconium-water reaction in the fuel cladding and a partial meltdown of the fuel. The temperatures in the graphite fire, which was finally extinguished on May 5, exceeded 2000°C.

The plume from the initial explosion reached as high as 1500 m, while subsequent emissions from the fire reached much lower altitudes. While the WHO did not address this point, it seems reasonable to postulate that there would be a gradation of radioactive particles in the plume with enhancement of small particles in the upper altitudes and of larger particles in the lower altitudes. The WHO did report that radionuclides of volatile elements prevailed in the release, but we conjecture that the volatile radionuclides in association with the small particles would be enhanced in the upper reaches of the plume, while the refractory radionuclides would be associated with the larger particles in the lower regions of the plume.

The WHO utilized the plume trajectory maps submitted by the Swedish Meteorological and Hydrological Institute and concluded that most of the radioactivity was released during two periods with the following trajectories.

Period 1: For the explosion on April 26, the 1500 m winds carried the upper cloud over Scandinavia and Finland. The lower cloud as represented by the 750 m level, was also transported northwestward but only reached the southwestern coast of Sweden.

Period 2: The emissions from the fire on April 27 were transported in a southwesterly direction over eastern central Europe, southern Germany, Italy and Yugoslavia.

Trends in Radiochemical Composition

We think that most of the radiochemical data in this report can be explained on the basis of the accident description thereby offering some corroboration of that description. But first it is useful to refer to the melting and boiling points in Table 48 to define the term volatile and refractory nuclides.

If we assign 2000°C as a reasonable maximum temperature of the core, then Table 48 easily identifies Cs, I, Te, Ba and Sr as volatiles, and Ce, La, Zr, Ru and Nb as refractories. If some oxidation of the nuclides is involved, then some of the Ru might react as a volatile, and Ba and Sr as a refractory.

To investigate the degree of fractionation of the Chernobyl fallout and any consistency of that fractionation, we plotted in Figure 1 the ratio of a refractory nuclide to a volatile nuclide ($^{103}\text{Ru}/^{134}\text{Cs}$) versus the ratio of a volatile nuclide to a volatile nuclide ($^{131}\text{I}/^{134}\text{Cs}$) at all locations. Figure 1 shows that the soil samples are arranged into 3 separate groups. Table 49 identifies the samples in each group and summarizes the ratios of all the major activities to ^{134}Cs . In this summary the results from the dry samples are presented. Wet sample data are used when dry sample data are not available. Also when only ^{140}La results were reported, the ^{140}Ba values were calculated assuming equilibrium.

Table 49 includes the estimated nuclide activity ratios in the Chernobyl core (PNL, 1986). These are initial estimates of the core composition based

on full power at 9.25 Mwd/kg burnup. The estimates will change for lower power and for power interruptions. However, they serve as a practical benchmark for comparison to our measurements. It is clear from a comparison of the reported values and the Chernobyl core value that ^{131}I , ^{132}Te and ^{137}Cs can be classified as volatile nuclides and ^{103}Ru , ^{140}Ba and ^{141}Ce as refractory nuclides.

Table 49 shows that not only are the relative depositions of ^{103}Ru and ^{131}I to ^{134}Cs unique in each of Groups 1, 2, and 3, but the relative depositions of ^{132}Te , ^{140}Ba and ^{141}Ce to ^{134}Cs also fit into distinctive ranges in Groups 1 and 2. There is much less consistency in the ^{132}Te , ^{140}Ba and ^{141}Ce ratios to ^{134}Cs in Group 3 perhaps due to low activity rates and high counting uncertainties and to an insufficient number of samples.

The $^{137}\text{Cs}/^{134}\text{Cs}$ ratios in Table 49 also show distinctive ranges between Groups 1 and 2, but some blurring between Groups 2 and 3. This range is impacted by the presence of earlier deposited weapons ^{137}Cs fallout and further consideration of the ratio is reserved for the discussion of the vegetation and air filter data.

The radiochemical composition of samples in Group 1 represents fallout from the upper portion of the Chernobyl cloud resulting from the initial explosion on April 26, 1986. The locations in Group 1 are north of Stockholm in Sweden where rain occurred on April 28 and 29. The burnup history of the fuel elements involved in this initial explosion and the fractionation occurring as a function of particle size combine to produce a composition which is minimal with respect to the refractory nuclides (^{103}Ru , ^{140}Ba and ^{141}Ce) and reasonable with respect to the volatiles ^{131}I and ^{132}Te .

The overlying vegetation at Soderfors and Tarnsjo generally reflects enhanced concentrations relative to ^{134}Cs of refractory nuclides (^{140}Ba and ^{141}Ce) and reduced concentrations relative to ^{134}Cs of volatile nuclides (^{131}I and ^{132}Te) as compared to the underlying soil. While the magnitude of these differences is not large, the trend is consistent with the concept of fractionation with particle size. According to this theory, the larger particles would be enriched in the refractory nuclides, and the vegetation would be more effective in collecting the larger particles than the smaller ones.

At Soderfors and Tarnsjo, the $^{103}\text{Ru}/^{134}\text{Cs}$ ratios like the $^{131}\text{I}/^{134}\text{Cs}$ and $^{132}\text{Te}/^{134}\text{Cs}$ ratios show lower values for the vegetation samples as compared to the ratios in the underlying soil (Tables 36, 41). This suggests that while only small amounts of ^{103}Ru escaped the reactor (refractory behavior), the ^{103}Ru that did escape behaved as a volatile. Perhaps there is some involvement of the volatile ruthenium tetroxide.

The vegetation samples are not impacted by earlier nuclear weapons fallout, so that the $^{137}\text{Cs}/^{134}\text{Cs}$ ratios in vegetation samples are representative of Chernobyl fallout in the area. For Group 1 the mean $^{137}\text{Cs}/^{134}\text{Cs}$ ratio of all the vegetation aliquots is $1.61 \pm .03$. The value is in good agreement with the mean of the soil data in Group 1, $1.67 \pm .16$, which indicates that the amount of Chernobyl ^{137}Cs fallout at these locations is large enough to overwhelm the weapons ^{137}Cs fallout residing within the 0 to 5 cm depth increment of soil.

The radiochemical composition of the samples in Group 2 represents emissions from the crippled Chernobyl reactor during the course of the fire and as a result of whatever actions were taken by the Russians to bring the accident under control. It is conceivable that fuel elements of a different burn-up history than those that contributed to the initial explosion were involved. Table 49 shows that all the reported nuclides in the soil samples, both refractory and volatile, were enhanced relative to ^{134}Cs in the samples in Group 2 as compared to Group 1 with ^{131}I and ^{132}Te values being close to the core values.

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We think that most of the radiochemical data in this report can be explained on the basis of the accident description thereby offering some corroboration of that description. But first it is useful to refer to the melting and boiling points in Table 48 to define the term volatile and refractory nuclides.

If we assign 2000°C as a reasonable maximum temperature of the core, then Table 48 easily identifies Cs, I, Te, Ba and Sr as volatiles, and Ce, La, Zr, Ru and Nb as refractories. If some oxidation of the nuclides is involved, then some of the Ru might react as a volatile, and Ba and Sr as a refractory.

To investigate the degree of fractionation of the Chernobyl fallout and any consistency of that fractionation, we plotted in Figure 1 the ratio of a refractory nuclide to a volatile nuclide ($^{103}\text{Ru}/^{134}\text{Cs}$) versus the ratio of a volatile nuclide to a volatile nuclide ($^{131}\text{I}/^{134}\text{Cs}$) at all locations. Figure 1 shows that the soil samples are arranged into 3 separate groups. Table 49 identifies the samples in each group and summarizes the ratios of all the major activities to ^{134}Cs . In this summary the results from the dry samples are presented. Wet sample data are used when dry sample data are not available. Also when only ^{140}La results were reported, the ^{140}Ba values were calculated assuming equilibrium.

Table 49 includes the estimated nuclide activity ratios in the Chernobyl core (PNL, 1986). These are initial estimates of the core composition based

on full power at 9.25 Mwd/kg burnup. The estimates will change for lower power and for power interruptions. However, they serve as a practical benchmark for comparison to our measurements. It is clear from a comparison of the reported values and the Chernobyl core value that ^{131}I , ^{132}Te and ^{137}Cs can be classified as volatile nuclides and ^{103}Ru , ^{140}Ba and ^{141}Ce as refractory nuclides.

Table 49 shows that not only are the relative depositions of ^{103}Ru and ^{131}I to ^{134}Cs unique in each of Groups 1, 2, and 3, but the relative depositions of ^{132}Te , ^{140}Ba and ^{141}Ce to ^{134}Cs also fit into distinctive ranges in Groups 1 and 2. There is much less consistency in the ^{132}Te , ^{140}Ba and ^{141}Ce ratios to ^{134}Cs in Group 3 perhaps due to low activity rates and high counting uncertainties and to an insufficient number of samples.

The $^{137}\text{Cs}/^{134}\text{Cs}$ ratios in Table 49 also show distinctive ranges between Groups 1 and 2, but some blurring between Groups 2 and 3. This range is impacted by the presence of earlier deposited weapons ^{137}Cs fallout and further consideration of the ratio is reserved for the discussion of the vegetation and air filter data.

The radiochemical composition of samples in Group 1 represents fallout from the upper portion of the Chernobyl cloud resulting from the initial explosion on April 26, 1986. The locations in Group 1 are north of Stockholm in Sweden where rain occurred on April 28 and 29. The burnup history of the fuel elements involved in this initial explosion and the fractionation occurring as a function of particle size combine to produce a composition which is minimal with respect to the refractory nuclides (^{103}Ru , ^{140}Ba and ^{141}Ce) and reasonable with respect to the volatiles ^{131}I and ^{132}Te .

The overlying vegetation at Soderfors and Tarnsjo generally reflects enhanced concentrations relative to ^{134}Cs of refractory nuclides (^{140}Ba and ^{141}Ce) and reduced concentrations relative to ^{134}Cs of volatile nuclides (^{131}I and ^{132}Te) as compared to the underlying soil. While the magnitude of these differences is not large, the trend is consistent with the concept of fractionation with particle size. According to this theory, the larger particles would be enriched in the refractory nuclides, and the vegetation would be more effective in collecting the larger particles than the smaller ones.

At Soderfors and Tarnsjo, the $^{103}\text{Ru}/^{134}\text{Cs}$ ratios like the $^{131}\text{I}/^{134}\text{Cs}$ and $^{132}\text{Te}/^{134}\text{Cs}$ ratios show lower values for the vegetation samples as compared to the ratios in the underlying soil (Tables 36, 41). This suggests that while only small amounts of ^{103}Ru escaped the reactor (refractory behavior), the ^{103}Ru that did escape behaved as a volatile. Perhaps there is some involvement of the volatile ruthenium tetroxide.

The vegetation samples are not impacted by earlier nuclear weapons fallout, so that the $^{137}\text{Cs}/^{134}\text{Cs}$ ratios in vegetation samples are representative of Chernobyl fallout in the area. For Group 1 the mean $^{137}\text{Cs}/^{134}\text{Cs}$ ratio of all the vegetation aliquots is $1.61 \pm .03$. The value is in good agreement with the mean of the soil data in Group 1, $1.67 \pm .16$, which indicates that the amount of Chernobyl ^{137}Cs fallout at these locations is large enough to overwhelm the weapons ^{137}Cs fallout residing within the 0 to 5 cm depth increment of soil.

The radiochemical composition of the samples in Group 2 represents emissions from the crippled Chernobyl reactor during the course of the fire and as a result of whatever actions were taken by the Russians to bring the accident under control. It is conceivable that fuel elements of a different burn-up history than those that contributed to the initial explosion were involved. Table 49 shows that all the reported nuclides in the soil samples, both refractory and volatile, were enhanced relative to ^{134}Cs in the samples in Group 2 as compared to Group 1 with ^{131}I and ^{132}Te values being close to the core values.

The Monaco air filter, vegetation and precipitation samples were collected at different times in early May. The mean activity ratios in Table 50 show that the $^{103}\text{Ru}/^{134}\text{Cs}$ values are constant among all samples, and that constancy extends even to the Monaco soil sample in Table 49. As in the case of the vegetation samples in Group 1, this suggests that the ^{103}Ru is paralleling the volatility of ^{134}Cs .

Shortly after collection, acid was inadvertently added to the Monaco precipitation raising the possibility of some evaporation of HI from the sample. Assuming that the ^{131}I value in the rain sample in Table 50 is low because of that evaporation, the ^{131}I , ^{132}Te and ^{140}Ba to ^{134}Cs ratios in rain (and consequently in the air above the planetary boundary layer) are high, those in the surface air are low and those in the vegetation samples are in between. This pattern is not unreasonable if we assume that the Monaco air filter, which was exposed from April 30 to May 1, sampled a preponderance of larger particles because of their greater settling velocities. If the smaller particles followed, the grass sample collected on May 2 would reflect a composition of the combined large and small particles. The precipitation occurred May 4 to May 5 so that the salad greens collected on May 5 reflect the effects of additional fallout plus the rain. The Monaco soil sample collected on May 14 (Table 49) exhibits the same composition as the Monaco vegetation.

The samples in Group 3 represent a radiochemical composition in transition from Group 1 to Group 2. Stockholm was just beyond the southern boundary of the precipitation that occurred in Sweden on April 28 and April 29, and Oland (south of Stockholm) received no precipitation between the time of the accident and the collection of the sample.

The Grindsjon filter sample represents an interesting case. It was collected south of Stockholm and should reflect the radiochemical composition of Group 3. It does compare reasonably well with the Oland soil sample except for a marked reduction in the ^{131}I and ^{132}Te ratios to ^{134}Cs as was similarly observed between the Monaco air filter and soil sample. Since the Grindsjon filter was exposed from April 28 to April 30 and the Oland soil sample was collected on May 7, this behavior suggests marked fractionation with particle size, time and altitude in the atmosphere.

Future Studies

Many of the samples described in this report are being analyzed for other radionuclides, including ^{89}Sr , ^{90}Sr , ^{238}Pu , $^{239}+^{240}\text{Pu}$. Pending the outcome of these results, analyses for ^{241}Am , Cm isotopes and ^{99}Tc will be considered.

The presence of large quantities of Zr cladding in the Chernobyl reactor suggests that experiments be conducted to demonstrate whether standard methods of sample dissolution solubilize all the radioactivities present. The formation of oxides of Zr could render some radioactive particles difficult to dissolve.

REFERENCES

- Beck, H. L. and P. W. Krey
'Radiation Exposure in Utah from Nevada Nuclear Tests'
Science, 220, 18-24 (1983)
- Hardy, E. P., P. W. Krey, C. S. Klusek, K. M. Miller, I. K. Helfer,
C. G. Sanderson and W. T. Rivera
'Observation and Sampling by EML in Sweden, with Preliminary Gamma-Ray
Spectrometric Data'
This report
- Livingston, H. D. and W. R. Clarke
'Chernobyl Related Studies in the Black Sea and Other Water Bodies'
This report
- PNL, Battelle Pacific Northwest Laboratory, Personal Communication
Hanford, WA, May 1986
- Volchok, H. L. and G. de Planque (editors)
EML Procedures Manual
USDOE Report HASL-300, 1983
- World Health Organization
'Chernobyl Reactor Accident; Report of a Consultation'
ICP/CEH 129,(Provisional) May 6, 1986

TABLE 1
SOIL AND VEGETATION SAMPLES

Site	Type	Collection Date (1986)	Net wt. (kg)		Area (cm ²)	Depth (cm)
			Wet	Dry		
Kutskar, Sweden	soil	5/5	1.83	1.48	750	2
Soderfors, Sweden	straw ^a	5/5	0.30	—	104	—
	soil	5/5	3.10	2.72	559	5
Uppsala, Sweden	soil	5/6	2.72	2.38	559	5
Stockholm, Sweden	grass	5/6	0.029	—	104	—
	soil	5/6	3.45	3.19	559	5
Oland, Sweden	grass	5/7	0.23	—	104	—
	soil	5/7	2.76	2.51	559	5
Gavle, Sweden	moss	5/8	0.037	—	252	—
Tarnsjo, Sweden	grass	5/9	0.03	—	104	
	grass	5/9	0.04	—	104	
	soil	5/9	2.62	2.32	435	5
Monaco	grass	5/2	0.18	—	—	—
	salad	5/5	0.06	—	—	—
	soil	5/14	3.11	2.82	620	5
Braunschweig, FRG	soil	5/13	4.73	3.81	620	5
Roskilde, Demark	soil	5/16	4.14	3.02	620	5
Klagenfurt, Austria	soil	5/17	5.10	3.82	620	5
Rome, Italy	soil	5/23	3.11	3.11	620	5
Neuherberg, FRG	soil	6/25	3.82		620	5

^a Old grass from previous year that had been scythed and left to cover the field over the winter.

TABLE 2
AIR FILTER AND PRECIPITATION SAMPLES

Site	Type	Collection Date (1986)	High Volume Air Samples (m³)	Deposition (L/m²)
Grindsjon, Sweden	Filter	4/28 - 4/30	22,715	-
Monaco	Filter	4/30 - 5/1	600	-
Monaco	Rain	5/4 - 5/5	-	11

TABLE 3

WET/HEATED ACTIVITY RATIOS IN SKUTSKAR SOIL

Nuclide	Aliquot A	Aliquot B
^{95}Zr	1.05 $\pm$ 0.22	1.05 $\pm$ 0.170
^{95}Nb	0.764 $\pm$ 0.088	0.842 $\pm$ 0.078
^{103}Ru	0.950 $\pm$ 0.036	0.995 $\pm$ 0.036
^{131}I	0.950 $\pm$ 0.009	0.968 $\pm$ 0.009
^{132}I	0.910 $\pm$ 0.026	1.01 $\pm$ 0.029
^{132}Te	0.958 $\pm$ 0.023	0.964 $\pm$ 0.0190
^{140}Ba	0.870 $\pm$ 0.057	0.995 $\pm$ 0.052
^{140}La	0.935 $\pm$ 0.030	0.986 $\pm$ 0.033
^{134}Cs	0.967 $\pm$ 0.031	1.01 $\pm$ 0.027
^{136}Cs	0.977 $\pm$ 0.090	1.07 $\pm$ 0.089
^{137}Cs	0.942 $\pm$ 0.018	0.975 $\pm$ 0.020
^{141}Ce	0.681 $\pm$ 0.160	0.611 $\pm$ 0.118

TABLE 4
DEPOSITION IN WET SOIL
Skutskar, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	0.37±0.05	0.56±0.07	14±2	21±3
¹⁰³ Ru	2.71±0.07	2.85±0.08	100±2	105±3
¹³¹ I	50.0 ±0.2	57.8 ±0.5	1850±7	2139±18
¹³² Te	50.0 ±0.7	56.6 ±0.7	1850±26	2094±26
¹³⁴ Cs	4.1 ±0.1	5.1 ±0.1	152±4	188±4
¹³⁶ Cs	1.8 ±0.1	2.4 ±0.1	66±4	87±5
¹³⁷ Cs	6.5 ±0.1	7.8 ±0.1	239±4	289±4
¹⁴⁰ Ba	7.8 ±0.3	9.8 ±0.4	290±12	362±14
¹⁴¹ Ce	0.34±0.06	0.37±0.06	12±2	14±2

TABLE 5
DEPOSITION IN DRY SOIL
Skutskar, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	0.148±0.006	0.102±0.005	5.5± 0.2	3.8± 0.2
¹⁰³ Ru	2.1 ±0.01	1.85 ±0.01	77.3± 0.7	68.4± 0.5
¹³¹ I	41.7 ±0.3	40.8 ±0.3	1543 ±10	1510 ±10
¹³⁴ Cs	3.18 ±0.01	3.18 ±0.01	117.7± 0.5	117.7± 0.5
¹³⁶ Cs	1.52 ±0.05	1.48 ±0.04	56 ± 2	55 ± 2
¹³⁷ Cs	5.08 ±0.01	5.07 ±0.01	188.0± 0.4	187.6± 0.4
¹⁴⁰ Ba	6.3 ±0.2	6.4 ±0.1	232 ± 6	235 ± 5
¹⁴¹ Ce	0.26 ±0.01	0.22 ±0.01	9.6± 0.4	8.0± 0.4

TABLE 6
DEPOSITION IN WET SOIL AND VEGETATION (Ci/km²±S.D.)
Soderfors, Sweden

Nuclide	Wet Soil		Vegetation	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	0.18±0.05	0.07±0.04	0.047±0.004	0.041±0.004
¹⁰³ Ru	1.92±0.08	1.73±0.08	0.254±0.005	0.244±0.004
¹³¹ I	40.7± 0.4	40.7± 0.4	2.81± 0.02	2.76± 0.02
¹³² Te	37.9± 0.9	40.6± 0.9	2.88± 0.04	2.84± 0.04
¹³⁴ Cs	2.21±0.09	2.38±0.09	0.647±0.008	0.513±0.006
¹³⁶ Cs	1.1± 0.1	1.3± 0.1	0.224±0.009	0.236±0.008
¹³⁷ Cs	3.8± 0.1	3.9± 0.1	0.823±0.006	0.826±0.007
¹⁴⁰ Ba	4.3± 0.4	4.0± 0.4	1.65± 0.03	1.59± 0.03
¹⁴¹ Ce	0.22±0.06	0.25±0.07	0.061±0.004	0.055±0.003

TABLE 7

DEPOSITION IN WET SOIL AND VEGETATION (kBq/m²+S.D.)
Soderfors, Sweden

Nuclide	Wet Soil		Vegetation	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	7± 2	3± 2	1.7±0.2	1.5±0.2
¹⁰³ Ru	71± 3	64± 3	9.4±0.2	9.0±0.1
¹³¹ I	1507±17	1507±15	104.1±0.6	102.1±0.6
¹³² Te	1402±32	1502±35	106 ±1	105 ±1
¹³⁴ Cs	82± 3	88± 3	23.9±0.3	19.0±0.2
¹³⁶ Cs	41± 4	47± 5	8.2±0.3	8.7±0.3
¹³⁷ Cs	142± 4	146± 4	30.4±0.2	30.6±0.2
¹⁴⁰ Ba	158±13	150±14	61 ±1	58 ±1
¹⁴¹ Ce	8± 2	9± 3	2.2±0.1	2.0±0.1

TABLE 8
DEPOSITION IN DRY SOIL
Soderfors, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	0.029±0.008	0.058±0.009	1.1± 0.3	2.1± 0.3
¹⁰³ Ru	1.92 ±0.01	2.02 ±0.03	71.0± 0.4	75 ± 1
¹³¹ I	44.4 ±0.5	43.7 ±0.7	1643 ±18	1617 ±26
¹³⁴ Cs	2.55 ±0.01	2.55 ±0.03	94.4± 0.4	95 ± 1
¹³⁶ Cs	1.47 ±0.08	1.3 ±0.1	54 ± 3	47 ± 4
¹³⁷ Cs	4.06 ±0.03	4.02 ±0.03	150 ± 1	149 ± 1
¹⁴⁰ Ba	3.8 ±0.2	4.3 ±0.3	141 ± 8	160 ±12
¹⁴¹ Ce	0.12 ±0.02	0.16 ±0.0	24.5± 0.6	6.0± 0.8

TABLE 9

DEPOSITION IN WET SOIL
Uppsala, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr ^a	0.03±0.01	0.07±0.02	1.0± 0.4	2.6± 0.6
¹⁰³ Ru	0.65±0.03	0.49±0.03	24 ± 1	18 ± 1
¹³¹ I	12.1 ±0.2	9.4 ±0.2	448 ± 7	349 ± 6
¹³² Te	12.0 ±0.4	9.4 ±0.3	444 ±15	347 ±12
¹³⁴ Cs	0.85±0.04	0.68±0.04	32 ± 1	25 ± 1
¹³⁶ Cs	0.34±0.05	0.27±0.04	13 ± 2	10 ± 2
¹³⁷ Cs	1.33±0.04	1.10±0.04	49 ± 2	41 ± 1
¹⁴⁰ Ba	1.3 ±0.1	1.1 ±0.2	47 ± 5	41 ± 6
¹⁴¹ Ce	—	0.03±0.02	—	1.1± 0.6

^a Calculated assuming equilibrium with its progeny.

TABLE 10
DEPOSITION IN DRY SOIL
Uppsala, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
¹⁰³ Ru	0.633±0.009	0.633±0.008	23.3± 0.3	23.3± 0.3
¹⁰⁶ Ru	0.17 ±0.02	0.16 ±0.02	6.3± 0.8	6.0± 0.6
¹³¹ I	13.0 ±0.3	13.3 ±0.3	481 ±10	492 ±10
¹³⁴ Cs	0.740±0.006	0.753±0.004	27.4± 0.2	27.9± 0.1
¹³⁶ Cs	0.59 ±0.07	0.53 ±0.06	22 ± 2	19 ± 2
¹³⁷ Cs	1.42 ±0.008	1.44 ±0.007	52.5± 0.3	53.3± 0.3
¹⁴⁰ Ba	1.4 ±0.2	1.6 ±0.2	50 ± 6	60 ± 6
¹⁴¹ Ce	0.035±0.007	0.046±0.006	1.3± 0.2	1.7± 0.2
¹⁴⁴ Ce	-	0.038±0.009	-	1.4± 0.3

TABLE 11

DEPOSITION IN WET SOIL AND VEGETATION (mCi/km²±S.D.)
Stockholm, Sweden

Nuclide	Wet Soil		Vegetation
	Aliquot A	Aliquot B	Aliquot A
⁹⁵ Zr	45±10	3± 6	2.0 ±0.1
¹⁰³ Ru	—	6± 5	1.04±0.06
¹³¹ I	346±25	338±32	20.4 ±0.4
¹³² Te	138±46	220±75	7 ±2
¹³⁴ Cs	10± 6	10± 7	0.43±0.04
¹³⁶ Cs	11± 8	—	0.16±0.06
¹³⁷ Cs	15± 4	16± 6	0.67±0.04
¹⁴⁰ Ba	73± 4	15±15	2.3 ±0.2
¹⁴¹ Ce	48± 7	7± 5	1.65±0.07

TABLE 12

DEPOSITION IN WET SOIL AND VEGETATION (kBq/m²+S.D.)
Stockholm, Sweden

Nuclide	Wet Soil		Vegetation
	Aliquot A	Aliquot B	Aliquot A
⁹⁴ Zr	1.7±0.4	0.1±0.2	0.074±0.004
¹⁰³ Ru	—	0.2±0.2	0.038±0.002
¹³¹ I	12.8±0.9	13 ±1	0.76 ±0.01
¹³² Te	5 ±2	8 ±3	0.276±0.008
¹³⁴ Cs	0.4±0.2	0.4±0.3	0.016±0.002
¹³⁶ Cs	0.4±0.3	—	0.006±0.002
¹³⁷ Cs	0.6±0.1	0.6±0.2	0.025±0.002
¹⁴⁰ Ba	2.7±0.8	0.6±0.6	0.085±0.008
¹⁴¹ Ce	1.8±0.3	0.3±0.2	0.061±0.003

TABLE 13

DEPOSITION IN DRY SOIL
Stockholm, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
¹⁰³ Ru	8 ± 1	12 ± 1	0.29±0.05	0.42±0.05
¹³¹ I	352 ±57	447 ±60	13 ±2	16 ±2
¹³⁴ Cs	5.1± 0.5	6.9± 0.6	0.19±0.02	0.25±0.02
¹³⁷ Cs	15.9± 0.7	15.8± 0.6	0.59±0.03	0.58±0.02
¹⁴⁰ Ba ^a	—	79 ±19	—	2.9 ±0.7
¹⁴¹ Ce	—	12 ± 2	—	0.42±0.09

^a Calculated assuming equilibrium with its progeny.

TABLE 14
DEPOSITION IN WET SOIL AND VEGETATION (mCi/km²±S.D.)
Oland, Sweden

Nuclide	Wet Soil	Vegetation	
	Aliquot A	Aliquot A	Aliquot B
⁹⁵ Zr	5.0± 2.0	0.85±0.05	0.44±0.05
¹⁰³ Ru	8.3± 1.9	1.63±0.05	0.78±0.05
¹³¹ I	568 ±16	89 ±5	93 ±7
¹³² Te	834 ±69	10.8 ±0.8	10 ±1
¹³⁴ Cs	13 ± 2	1.38±0.05	1.36±0.07
¹³⁶ Cs	9 ± 5	0.67±0.07	0.5 ±0.1
¹³⁷ Cs	52 ± 3	2.28±0.05	1.91±0.07
¹⁴⁰ Ba	14 ± 4 ^a	3.7 ±0.2	2.8 ±0.3
¹⁴¹ Ce	4 ± 2	0.97±0.06	0.51±0.08

^a Calculated assuming equilibrium with its progeny.

TABLE 15

DEPOSITION IN WET SOIL AND VEGETATION (kBq/m²+S.D.)
Oland, Sweden

Nuclide	Wet Soil	Vegetation	
	Aliquot A	Aliquot A	Aliquot B
⁹⁵ Zr	1.19±0.07	0.032±0.002	0.016±0.002
¹⁰³ Ru	0.31±0.07	0.060±0.002	0.029±0.002
¹³¹ I	21.0 ±0.6	3.3 ±0.2	3.4 ±0.3
¹³² Te	31 ±2	0.40 ±0.03	0.37 ±0.05
¹³⁴ Cs	0.48±0.07	0.051±0.002	0.050±0.003
¹³⁶ Cs	0.3 ±0.2	0.025±0.003	0.020±0.004
¹³⁷ Cs	1.9 ±0.1	0.084±0.002	0.071±0.003
¹⁴⁰ Ba	0.5 ±0.2 ^a	0.136±0.008	0.10 ±0.01
¹⁴¹ Ce	0.15±0.07	0.036±0.002	0.019±0.003

^a Calculated assuming equilibrium with its progeny.

TABLE 16
DEPOSITION IN DRY SOIL
Oland, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	1.2± 0.6	2.5±0.8 ^a	0.04±0.02	0.09±0.03 ^a
¹⁰³ Ru	4.9± 0.6	9 ± 1	0.18±0.02	0.32±0.05
¹³¹ I	474 ±10	456 ±21	17.5 ±0.4	16.9 ±0.8
¹³⁴ Cs	12.1± 0.6	11 ± 1	0.44±0.02	0.40±0.04
¹³⁷ Cs	48.0± 0.8	48 ± 2	1.77±0.03	1.76±0.06
¹⁴⁰ Ba	16 ± 6	38 ±14	0.6 ±0.2	1.4 ±0.5
¹⁴¹ Ce	-	2 ± 1	-	0.09±0.05

^a Calculated assuming equilibrium with its progeny.

TABLE 15

DEPOSITION IN WET SOIL AND VEGETATION (kBq/m²+S.D.)
Oland, Sweden

Nuclide	Wet Soil	Vegetation	
	Aliquot A	Aliquot A	Aliquot B
⁹⁵ Zr	1.19±0.07	0.032±0.002	0.016±0.002
¹⁰³ Ru	0.31±0.07	0.060±0.002	0.029±0.002
¹³¹ I	21.0 ±0.6	3.3 ±0.2	3.4 ±0.3
¹³² Te	31 ±2	0.40 ±0.03	0.37 ±0.05
¹³⁴ Cs	0.48±0.07	0.051±0.002	0.050±0.003
¹³⁶ Cs	0.3 ±0.2	0.025±0.003	0.020±0.004
¹³⁷ Cs	1.9 ±0.1	0.084±0.002	0.071±0.003
¹⁴⁰ Ba	0.5 ±0.2 ^a	0.136±0.008	0.10 ±0.01
¹⁴¹ Ce	0.15±0.07	0.036±0.002	0.019±0.003

^a Calculated assuming equilibrium with its progeny.

TABLE 16
DEPOSITION IN DRY SOIL
Oland, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	1.2± 0.6	2.5±0.8 ^a	0.04±0.02	0.09±0.03 ^a
¹⁰³ Ru	4.9± 0.6	9 ± 1	0.18±0.02	0.32±0.05
¹³¹ I	474 ±10	456 ±21	17.5 ±0.4	16.9 ±0.8
¹³⁴ Cs	12.1± 0.6	11 ± 1	0.44±0.02	0.40±0.04
¹³⁷ Cs	48.0± 0.8	48 ± 2	1.77±0.03	1.76±0.06
¹⁴⁰ Ba	16 ± 6	38 ±14	0.6 ±0.2	1.4 ±0.5
¹⁴¹ Ce	-	2 ± 1	-	0.09±0.05

^a Calculated assuming equilibrium with its progeny.

TABLE 17

DEPOSITION IN VEGETATION
Gavle, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	0.061±0.004	0.11±0.01	2.3±0.1	4.1± 0.4
¹⁰³ Ru	1.016±0.006	1.11±0.01	37.6±0.2	41.1± 0.5
¹³¹ I	25.97 ±0.05	26.2 ±0.1	961 ±2	970 ± 4
¹³² Te	16.0 ±0.2	15.2 ±0.4	594 ±6	564 ±14
¹³⁴ Cs	2.018±0.008	2.03±0.02	74.7±0.3	75.1± 0.8
¹³⁶ Cs	0.87 ±0.02	0.96±0.03	32.3±0.6	35 ± 1
¹³⁷ Cs	3.22 ±0.01	3.3 ±0.02	119.1±0.4	121.4± 0.7
¹⁴⁰ Ba	3.82 ±0.04	4.1 ±0.1	141 ±1	150 ± 4
¹⁴¹ Ce	0.121±0.005	0.16±0.01	4.5±0.2	5.9± 0.4

TABLE 18
DEPOSITION IN WET SOIL AND VEGETATION
Tarnsjo, Sweden

Nuclide	Wet Soil (Ci/km ²)		Vegetation (mCi/km ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	0.10± 0.01	0.08±0.01	0.14±0.01	0.006±0.004
¹⁰³ Ru	0.88± 0.02	0.86±0.02	0.44±0.02	0.286±0.009
¹³¹ I	15.5 ± 0.1	15.7 ±0.1	3.82±0.07	2.80 ±0.05
¹³² Te	17.5 ± 0.5	16.9 ±0.6	5.6 ±0.3	2.6 ±0.2
¹³⁴ Cs	1.16± 0.02	1.22±0.02	0.84±0.02	0.45 ±0.01
¹³⁶ Cs	0.53± 0.03	0.46±0.04	0.39±0.03	0.21 ±0.02
¹³⁷ Cs	1.86± 0.02	1.98±0.03	1.37±0.02	0.72 ±0.01
¹⁴⁰ Ba	1.94± 0.08	1.9 ±0.1	1.76±0.08	0.78 ±0.06
¹⁴¹ Ce	0.12± 0.02	0.09±0.02	0.14±0.01	0.015±0.005

Note: Vegetation aliquot A is 1-5 cm above the ground ± B is >5 cm above the ground.

TABLE 19

DEPOSITION IN WET SOIL AND VEGETATION
Tarnsjo, Sweden

Nuclide	Wet Soil (kBq/m ²)		Vegetation (Bq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	3.8± 0.4	2.9± 0.4	5.1± 0.5	0.4±0.3
¹⁰³ Ru	32.7± 0.6	31.8± 0.8	16.3± 0.6	3.1±0.3
¹³¹ I	574 ± 4	581 ± 4	141 ± 3	104 ±2
¹³² Te	648 ±18	625 ±20	207 ±10	97 ±7
¹³⁴ Cs	42.9± 0.7	45.1± 0.9	31.1± 0.7	16.7±0.5
¹³⁶ Cs	19 ± 1	17 ± 1	14 ± 1	7.8±0.7
¹³⁷ Cs	68.8± 0.7	73 ± 1	50.7± 0.8	26.6±0.5
¹⁴⁰ Ba	72 ± 3	69 ± 4	65 ± 3	29 ±2
¹⁴¹ Ce	4.6± 0.6	3.2± 0.6	5.1± 0.4	0.7±0.2

Note: Vegetation aliquot A is 1-5 cm above the ground± B is
>5 cm above the ground.

TABLE 20
DEPOSITION IN DRY SOIL
Tarnsjo, Sweden

Nuclide	Deposition (Ci/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	0.011± 0.005	0.010± 0.005	0.4± 0.2	0.4± 0.2
¹⁰³ Ru	0.78 ± 0.01	0.82 ± 0.02	29.0± 0.5	30.4± 0.6
¹³¹ I	16.5 ± 0.3	16.0 ± 0.3	610 ± 10	592 ± 11
¹³² Te	87 ±43	38 ±38	3224 ±1612	1404 ±1404
¹³⁴ Cs	1.30 ± 0.01	1.321± 0.02	48.1± 0.4	48.8± 0.7
¹³⁶ Cs	0.48 ± 0.05	0.59 ± 0.05	18 ± 2	22 ± 2
¹³⁷ Cs	2.05 ± 0.01	2.04 ± 0.02	75.8± 0.4	75.5± 0.7
¹⁴⁰ Ba	2.4 ± 0.2	2.0 ± 0.2	90 ± 6	75 ± 6
¹⁴¹ Ce	0.066± 0.008	0.032± 0.009	2.4± 0.3	1.2± 0.3

TABLE 21
DEPOSITION IN WET SOIL
Monaco

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	1± 1	4± 2 ^a	0.05± 0.05	0.15± 0.06 ^a
¹⁰³ Ru	214± 7	225± 7	7.9 ± 0.2	8.3 ± 0.2
¹³¹ I	901± 25	967± 30	33.3 ± 0.9	36 ± 1
¹³² Te	1850±260	1000±300	68 ±10	37 ±11
¹³⁴ Cs	51± 4	58± 4	1.9 ± 0.1	2.1 ± 0.1
¹³⁶ Cs	27± 9	26± 7	1.0 ± 0.3	1.0 ± 0.2
¹³⁷ Cs	97± 4	116± 4	3.6 ± 0.1	4.3 ± 0.2
¹⁴⁰ Ba	85± 20	110± 20	3.1 ± 0.8	4.1 ± 0.8
¹⁴¹ Ce	—	9± 4	—	0.3 ± 0.1

^a Calculated assuming equilibrium with its progeny.

TABLE 22
DEPOSITION IN DRY SOIL
Monaco

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
¹⁰³ Ru	186 ± 2	179 ± 1	6.88±0.08	6.6 ±0.05
¹⁰⁶ Ru	48 ± 4	41 ± 2	1.8 ±0.1	1.5 ±0.09
¹³¹ I	918 ±44	992 ±30	34 ±2	37 ±1
¹³⁴ Cs	36.2± 0.07	37.8± 0.4	1.34±0.02	1.40±0.01
¹³⁷ Cs	107 ± 1	110.0± 0.7	3.96±0.04	4.07±0.02
¹⁴⁰ Ba	129 ±25	109 ±14	4.8 ±0.9	4.0 ±0.5
¹⁴¹ Ce	11 ± 2	7.9± 0.9	0.41±0.06	0.29±0.03

TABLE 23
CONCENTRATION IN VEGETATION AND PRECIPITATION,
Monaco

Nuclide	Grass (pCi/g)		Salad (pCi/g)	Precip. (nCi/m ²)
	Aliquot A	Aliquot B		
¹⁰³ Ru	7.7±0.2	7.4±0.2	38.4±0.6	4.5±0.6
¹⁰⁶ Ru	—	6 ±1	13 ±2	12 ±2
¹³¹ I	121.9±0.5	116.1±0.5	229.6±0.8	318.4±0.9
¹³² Te	88.1±0.2	72.6±0.2	144.6±0.3	757.4±0.5
¹³⁴ Cs	2.0±0.1	1.9±0.1	11.0±0.3	10.1±0.3
¹³⁶ Cs	—	—	6.8±0.4	7.9±0.7
¹³⁷ Cs	3.6±0.2	3.5±0.2	21.9±0.6	19.5±0.5
¹⁴⁰ Ba	3.5±0.4	4.8±0.4	27 ±1	56 ±1

TABLE 24
CONCENTRATION IN VEGETATION AND PRECIPITATION
Monaco

Nuclide	Grass (Bq/kg)		Salad (Bq/kg)	Precip. (Bq/m ²)
	Aliquot A	Aliquot B		
¹⁰³ Ru	285± 7	274± 7	1421± 22	166±22
¹⁰⁶ Ru	-	222±37	481± 74	444±74
¹³¹ I	4510±18	4296±18	8495± 30	11781±33
¹³² Te	3260± 7	2686± 7	5350±111	28024±18
¹³⁴ Cs	74± 4	70± 4	407± 11	374±11
¹³⁶ Cs	-	-	252± 15	292±26
¹³⁷ Cs	133± 7	130± 7	810± 22	722±18
¹⁴⁰ Ba	130±15	178±15	999± 37	2072±37

TABLE 25

DEPOSITION IN WET SOIL
Braunschweig, FRG

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
¹⁰³ Ru	59± 6	180 ± 3	2.2 ±0.2	6.7 ±0.1
¹⁰⁶ Ru	41± 8	53 ± 7	1.5 ±0.3	2.0 ±0.2
¹³¹ I	854±25	839 ± 18	31.6 ±0.9	31.0 ±0.7
¹³² Te	—	2890 ±715	—	107 ±26
¹³⁴ Cs	41± 1	37.8± 0.8	1.52±0.04	1.40±0.03
¹³⁶ Cs	68±12	—	2.5 ±0.4	—
¹³⁷ Cs	88± 2	85 ± 2	32.56±0.07	3.14±0.06
¹⁴⁰ Ba	173±22	150 ± 14	6.4 ±0.8	5.6 ±0.5
¹⁴¹ Ce	10± 2	—	0.37±0.07	—

TABLE 26
DEPOSITION IN DRY SOIL
Braunschweig, FRG

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	-	4 ± 2	-	0.14±0.06
¹⁰³ Ru	187 ± 2	182 ± 2	6.92±0.06	6.73±0.07
¹⁰⁶ Ru	44 ± 3	44 ± 2	1.6 ±0.1	1.63±0.09
¹³¹ I	1150 ±135	971 ±191	43 ±5	36 ±7
¹³⁴ Cs	37.2± 0.4	36.8± 0.4	1.38±0.02	1.36±0.02
¹³⁷ Cs	90.4± 0.6	87.4± 0.6	3.34±0.02	3.23±0.02
¹⁴⁰ Ba ^a	213 ± 25	220 ± 28	8.0 ±0.9	8 ±1
¹⁴¹ Ce	10 ± 2	12 ± 2	0.38±0.06	0.45±0.06

^a Calculated assuming equilibrium with its progeny.

TABLE 27

DEPOSITION IN WET SOIL
Roskilde, Denmark

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	-	5 $\pm$ 1	-	0.20 $\pm$ 0.05
¹⁰³ Ru	83 $\pm$ 1	102 $\pm$ 2	3.06 $\pm$ 0.05	3.77 $\pm$ 0.07
¹⁰⁶ Ru	22 $\pm$ 3	33 $\pm$ 6	0.8 $\pm$ 0.1	1.2 $\pm$ 0.2
¹³¹ I	307 $\pm$ 8	389 $\pm$ 4	11.4 $\pm$ 0.3	14.4 $\pm$ 0.5
¹³⁴ Cs	10.7 $\pm$ 0.4	11.8 $\pm$ 0.7	0.40 $\pm$ 0.02	0.44 $\pm$ 0.03
¹³⁷ Cs	41.3 $\pm$ 0.8	45.7 $\pm$ 1.1	1.53 $\pm$ 0.03	1.69 $\pm$ 0.04
¹⁴⁰ Ba	38 $\pm$ 8	-	1.4 $\pm$ 0.3	-

TABLE 28

DEPOSITION IN DRY SOIL
Roskilde, Denmark

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
¹⁰³ Ru	92 ±2	98 ±2	3.38±0.06	3.62±0.06
¹⁰⁶ Ru	22 ±3	25 ±3	0.8 ±0.1	0.9 ±0.1
¹³⁴ Cs	12.1±0.4	12.2±0.3	0.45±0.01	0.45±0.01
¹³⁷ Cs	45.3±0.6	43.7±0.6	1.68±0.02	1.62±0.02
¹⁴¹ Ce	5 ±1	9 ±2	0.20±0.04	0.33±0.06

TABLE 29

DEPOSITION IN WET SOIL
Klagenfurt, Austria

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
¹⁰³ Ru	206± 4	218± 4	7.6 ±0.2	8.1 ±0.1
¹⁰⁶ Ru	52±12	55±10	1.9 ±0.5	2.0 ±0.4
¹³¹ I	1510±55	1400±45	56 ±2	52 ±2
¹³⁴ Cs	52± 1	45± 1	1.94±0.05	1.67±0.05
¹³⁷ Cs	123± 3	120± 2	4.6 ±0.1	4.44±0.09
¹⁴⁰ Ba ^a	144±20	117±11	5.3 ±0.8	4.3 ±0.4

^a Calculated assuming equilibrium with its progeny.

TABLE 30
DEPOSITION IN DRY SOIL
Klagenfurt, Austria

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	202 ± 3	22 ± 1	7.5 ±0.1	0.80±0.04
¹⁰³ Ru	197 ± 2	210 ± 2	7.3 ±0.1	7.8 ±0.1
¹⁰⁶ Ru	50 ± 5	47 ± 3	1.8 ±0.2	1.7 ±0.1
¹³¹ I	1413 ±92	1400 ±86	52 ±3	52 ±3
¹³⁴ Cs	41.8± 0.7	41.6± 0.4	1.54±0.02	1.55±0.02
¹³⁷ Cs	109 ± 1	111.5± 0.7	4.03±0.05	4.12±0.03
¹⁴⁰ Ba ^a	250 ±25	168 ±20	12 ±2	6.2 ±0.7
¹⁴¹ Ce	153 ± 3	27 ± 2	5.7 ±0.1	1.01±0.06
¹⁴⁴ Ce	73 ± 4	14 ± 1	2.7 ±0.1	0.52±0.06

^a Calculated assuming equilibrium with its progeny.

TABLE 31

DEPOSITION IN WET SOIL
Rome, Italy

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
⁹⁵ Zr	—	14 ± 2	—	0.52±0.07
¹⁰³ Ru	21 ± 1	25 ± 2	0.78±0.04	0.92±0.06
¹³¹ I	120 ±17	169 ±26	4.4 ±0.6	6.2 ±1.0
¹³⁴ Cs	3.9± 0.5	3.3± 0.7	0.15±0.02	0.11±0.02
¹³⁷ Cs	12.0± 0.7	9.2± 0.8	0.44±0.03	0.33±0.03
¹⁴⁰ Ba ^a	—	61 ±13	—	2.2 ±0.5

^a Calculated assuming equilibrium with its progeny.

TABLE 32
DEPOSITION IN DRY SOIL
Rome, Italy

Nuclide	Deposition (mCi/km ²)		Deposition (kBq/m ²)	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
¹⁰³ Ru	24 <u>+2</u>	27 <u>+2</u>	0.90 <u>+0.08</u>	1.00 <u>+0.08</u>
¹³⁴ Cs	4.4 <u>+0.7</u>	3.4 <u>+0.7</u>	0.16 <u>+0.02</u>	0.13 <u>+0.02</u>
¹³⁷ Cs	11.0 <u>+0.8</u>	10.9 <u>+0.7</u>	0.41 <u>+0.03</u>	0.40 <u>+0.03</u>

TABLE 33
AIR PARTICULATE CONCENTRATIONS (pCi/m³)

Site	Date	⁹⁵ Zr	⁹⁹ Mo	¹⁰³ Ru	¹⁰⁶ Ru	¹³¹ I	¹³² Te
Monaco							
	5/09/86	-	13.4±0.2	12.4 ±0.05	1.39±0.13	20.4±0.08	103 ±0.36
	5/13/86	-	13.5±0.16	12.0 ±0.02	1.41±0.037	19.3±0.035	100 ±0.22
	5/19/86	-	12.9±1.7	12.0 ±0.045	1.43±0.094	19.4±0.13	101 ± 1.4
	5/29/86	-	-	11.9 ±0.018	1.29±0.030	18.9±0.079	100 ± 3.1
Mean±Poisson Err		-	13.3±0.99	12.1 ±0.036	1.38±0.084	19.5±0.088	101 ± 1.7
Mean±1 σ		-	13.3±0.32	12.1 ±0.22	1.38±0.062	19.5±0.64	101 ± 1.4
Grindsjon							
	5/10/86	3.36±0.04	15.3±0.57	6.87±0.036	2.33±0.18	74.6±0.14	98.7± 0.42
	5/13/86	3.52±0.05	16.0±1.5	7.31±0.046	1.82±0.20	78.3±0.22	100 ± 0.87
	5/13/86	3.66±0.03	-	7.65±0.057	2.23±0.12	87.2±0.12	111 ± 0.44
	5/19/86	3.74±0.03	-	7.85±0.026	1.95±0.10	89.0±0.16	112 ± 1.2
	5/23/86	4.30±0.05	-	8.67±0.052	2.09±0.20	99.1±0.40	123 ± 4.4
Mean±Poisson Err		3.72±0.04	15.7±1.1	7.67±0.045	2.08±0.17	85.6±0.23	108 ± 2
Mean±1 σ		3.72±0.36	15.7±0.49	7.67±0.67	2.08±0.21	85.6±9.6	108 ±11
Site	Date	¹³⁴ Cs	¹³⁶ Cs	¹³⁷ Cs	¹⁴⁰ Ba	¹⁴¹ Ce	¹⁴⁴ Ce
Monaco							
	5/09/86	2.31±0.024	0.959±0.004	4.53±0.003	2.48±0.11	0.105 ±0.020	0.168±0.038
	5/13/86	2.28±0.008	0.773±0.035	4.44±0.010	2.42±0.083	0.0998±0.0056	0.070±0.012
	5/19/86	2.24±0.041	0.901±0.056	4.49±0.028	2.63±0.11	0.0818±0.0143	0.135±0.030
	5/29/86	2.27±0.009	0.666±0.030	4.46±0.010	2.46±0.064	0.0848±0.0041	0.100±0.010
Mean±Poisson Err		2.28±0.025	0.825±0.036	4.48±0.016	2.50±0.126	0.0929±0.0113	0.118±0.025
Mean±1 σ		2.28±0.029	0.825±0.131	4.48±0.039	2.50±0.0918	0.0929±0.0113	0.118±0.042
Grindsjon							
	5/10/86	11.2 ±0.028	4.70 ±0.075	22.0 ±0.052	13.6 ±0.18	3.05 ±0.030	2.19 ±0.097
	5/13/86	11.8 ±0.046	4.74 ±0.099	23.0 ±0.069	13.4 ±0.24	3.22 ±0.036	2.18 ±0.16
	5/13/86	13.1 ±0.057	5.59 ±0.057	24.8 ±0.038	14.4 ±0.15	3.52 ±0.018	2.50 ±0.048
	5/19/86	13.4 ±0.024	5.61 ±0.075	25.4 ±0.036	14.8 ±0.17	-	-
	5/23/86	14.8 ±0.048	6.01 ±0.16	28.2 ±0.071	16.4 ±0.38	4.17 ±0.034	2.81 ±0.075
Mean±Poisson Err		12.9 ±0.04	5.33 ±0.10	23.8 ±0.06	14.5 ±0.24	3.49 ±0.030	2.42 ±0.10
Mean±1 σ		12.9 ±1.4	5.33 ±0.58	23.8 ±1.6	14.5 ±1.2	3.49 ±0.49	2.42 ±0.30

TABLE 34
AIR PARTICULATE CONCENTRATIONS (mBq/m³)

Site	Date	⁹⁵ Zr	⁹⁹ Mo	¹⁰³ Ru	¹⁰⁶ Ru	¹³¹ I	¹³² Te
Monaco							
	5/09/86	-	496± 7	458± 2	51.4±4.8	755± 3	3810± 10
	5/13/86	-	500± 6	444± 1	52.2±1.4	714± 1	3700± 8
	5/19/86	-	477±63	444± 2	52.9±3.5	718± 5	3740± 50
	5/29/86	-	-	440± 1	47.7±1.1	699± 3	3700±110
Mean±Poisson Err		-	492±37	448± 1	51.1±3.1	722± 3	3740± 60
Mean± 1 σ		-	492±12	448± 8	51.1±2.3	722± 24	3740± 52
Grindsjon							
	5/10/86	124± 1	566±21	254± 1	86.2±6.6	2760± 10	3650± 20
	5/13/86	130± 2	592±56	270± 2	67.3±7.4	2900± 10	3700± 30
	5/13/86	135± 1	-	283± 2	82.5±4.4	3230± 10	4110± 20
	5/19/86	138± 1	-	290± 1	72.2±3.7	3290± 10	4140± 40
	5/23/86	159± 2	-	321± 2	77.3±7.4	3670± 10	4550±160
Mean±Poisson Err		138± 2	581±41	284± 2	77.0±6.3	3170± 10	4000± 70
Mean± 1 σ		138±13	581±18	284±25	77.0±7.8	3170±360	4000±410
Site	Date	¹³⁴ Cs	¹³⁶ Cs	¹³⁷ Cs	¹⁴⁰ Ba	¹⁴¹ Ce	¹⁴⁴ Ce
Monaco							
	5/09/86	85.5± 0.9	35.5± 0.2	168± 1	91.8± 4.1	3.89± 0.74	6.22± 1.41
	5/13/86	84.4± 0.3	28.6± 1.3	164± 1	89.5± 3.1	3.69± 0.21	2.60± 0.43
	5/19/86	82.9± 1.6	33.3± 2.1	166± 1	97.3± 4.1	3.03± 0.53	5.00± 1.11
	5/29/86	84.0± 0.3	24.7± 1.1	165± 1	91.0± 2.3	3.14± 0.15	3.70± 0.37
Mean±Poisson Err		84.4± 0.9	30.5± 1.3	166± 1	92.5± 4.7	3.44± 0.42	4.37± 0.93
Mean± 1 σ		84.4± 1.1	30.5± 4.8	166± 1	92.5± 3.4	3.44± 0.42	4.37± 1.55
Grindsjon							
	5/10/86	414 ± 1	174 ± 3	814± 2	503 ± 7	113 ± 1	81.0 ± 3.6
	5/13/86	437 ± 2	175 ± 4	851± 3	496 ± 9	119 ± 1	80.7 ± 5.9
	5/13/86	485 ± 2	207 ± 2	918± 1	533 ± 6	130 ± 1	92.5 ± 1.8
	5/19/86	496 ± 1	208 ± 3	940± 1	548 ± 6	-	-
	5/23/86	548 ± 2	222 ± 6	1040± 3	607 ±14	154 ± 1	104 ± 3
Mean±Poisson Err		477 ± 1	197 ± 4	881± 2	537 ± 9	129 ± 1	89.5 ± 3.7
Mean± 1 σ		477 ±52	197 ±21	881±59	537 ±44	129 ±18	89.5 ±11

TABLE 35

NUCLIDE RATIO TO ^{134}Cs
Skutskar, Sweden

Nuclide	Wet Soil ^a		Dry Soil ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	0.09 $\pm$ 15	0.11 $\pm$ 13	0.05 $\pm$ 4	0.03 $\pm$ 5
^{103}Ru	0.66 $\pm$ 4	0.56 $\pm$ 3	0.66 $\pm$ 0.8	0.59 $\pm$ 0.8
^{131}I	12.2 $\pm$ 3	11.5 $\pm$ 2	13.1 $\pm$ 0.8	13.2 $\pm$ 0.7
^{132}Te	12.0 $\pm$ 3	11.1 $\pm$ 2	-	-
^{136}Cs	0.43 $\pm$ 7	0.46 $\pm$ 6	0.48 $\pm$ 3	0.45 $\pm$ 3
^{137}Cs	1.57 $\pm$ 3	1.54 $\pm$ 3	1.6 $\pm$ 0.4	1.6 $\pm$ 0.4
^{140}Ba	1.38 $\pm$ 5	1.93 $\pm$ 4	1.96 $\pm$ 2	2.0 $\pm$ 2
^{141}Ce	0.08 $\pm$ 18	0.07 $\pm$ 16	0.08 $\pm$ 4	0.07 $\pm$ 5

^a Uncertainties are one std. dev. expressed in percent.

TABLE 36
NUCLIDE RATIO TO ^{134}Cs
Soderfors, Sweden

Nuclide	Wet Soil ^a		Dry Soil ^a		Vegetation ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	0.08 $\pm$ 28	0.03 $\pm$ 62	0.01 $\pm$ 28	0.02 $\pm$ 17	0.07 $\pm$ 9	0.08 $\pm$ 10
^{103}Ru	0.88 $\pm$ 6	0.72 $\pm$ 6	0.76 $\pm$ 1	0.81 $\pm$ 2	0.39 $\pm$ 2	0.47 $\pm$ 2
^{131}I	18.6 $\pm$ 4	17.3 $\pm$ 4	18.0 $\pm$ 1	17.8 $\pm$ 2	4.35 $\pm$ 1	5.38 $\pm$ 1
^{132}Te	17.1 $\pm$ 5	17.0 $\pm$ 4	-	-	4.44 $\pm$ 2	5.53 $\pm$ 2
^{136}Cs	0.51 $\pm$ 12	0.53 $\pm$ 11	0.57 $\pm$ 6	0.48 $\pm$ 8	0.35 $\pm$ 4	0.46 $\pm$ 4
^{137}Cs	1.75 $\pm$ 5	1.65 $\pm$ 5	1.60 $\pm$ 1	1.59 $\pm$ 1	1.27 $\pm$ 1	1.61 $\pm$ 1
^{140}Ba	1.9 $\pm$ 9	1.7 $\pm$ 10	1.5 $\pm$ 6	1.7 $\pm$ 8	2.56 $\pm$ 2	3.09 $\pm$ 2
^{141}Ce	0.10 $\pm$ 28	0.10 $\pm$ 29	0.05 $\pm$ 14	0.06 $\pm$ 13	0.09 $\pm$ 7	0.11 $\pm$ 6

^a Uncertainties are one std. dev. expressed in percent.

TABLE 37

NUCLIDE RATIO TO ^{134}Cs
Uppsala, Sweden

Nuclide	Wet Soil ^a		Dry Soil ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	0.03 $\pm$ 36	0.10 $\pm$ 24	—	—
^{103}Ru	0.72 $\pm$ 7	0.71 $\pm$ 8	0.77 $\pm$ 2	0.72 $\pm$ 2
^{106}Ru	—	—	0.23 $\pm$ 10	0.216 $\pm$ 2
^{131}I	13.9 $\pm$ 5	14.0 $\pm$ 5	17.3 $\pm$ 2	17.4 $\pm$ 2
^{132}Te	13.6 $\pm$ 6	13.7 $\pm$ 6	—	—
^{136}Cs	0.39 $\pm$ 15	0.4 $\pm$ 17	0.88 $\pm$ 12	0.78 $\pm$ 12
^{137}Cs	1.56 $\pm$ 6	1.64 $\pm$ 6	1.92 $\pm$ 1	1.91 $\pm$ 0.7
^{140}Ba	1.4 $\pm$ 11	1.6 $\pm$ 14	1.9 $\pm$ 12	2.2 $\pm$ 9
^{141}Ce	—	0.04 $\pm$ 49	0.05 $\pm$ 20	0.06 $\pm$ 12
^{144}Ce	—	—	—	0.05 $\pm$ 25

^a Uncertainties are one std. dev. expressed in percent.

TABLE 38
NUCLIDE RATIO TO ^{134}Cs
Stockholm, Sweden

Nuclide	Wet Soil ^a		Dry Soil ^a		Vegetation Aliquot A
	Aliquot A	Aliquot B	Aliquot A	Aliquot B	
^{95}Zr	4.3 $\pm$ 61	0.33 $\pm$ 211	-	-	4.6 $\pm$ 11
^{103}Ru	-	0.61 $\pm$ 103	1.6 $\pm$ 38	1.7 $\pm$ 20	2.4 $\pm$ 11
^{131}I	15 $\pm$ 56	31 $\pm$ 68	66 $\pm$ 19	64 $\pm$ 16	47 $\pm$ 10
^{132}Te	12 $\pm$ 67	21 $\pm$ 75	-	-	17.1 $\pm$ 11
^{136}Cs	1.1 $\pm$ 90	-	-	-	0.36 $\pm$ 41
^{137}Cs	1.3 $\pm$ 63	1.4 $\pm$ 77	3.0 $\pm$ 11	2.3 $\pm$ 1	1.5 $\pm$ 12
^{140}Ba	7.1 $\pm$ 65	1.4 $\pm$ 120	-	11 $\pm$ 25	5.3 $\pm$ 14
^{141}Ce	4.8 $\pm$ 62	0.7 $\pm$ 95	-	1.7 $\pm$ 24	3.8 $\pm$ 10

^a Uncertainties are one std. dev. expressed in percent.

TABLE 39
NUCLIDE RATIO TO ^{134}Cs
Oland, Sweden

Nuclide	Wet Soil ^a		Dry Soil ^a		Vegetation ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	0.37 $\pm$ 43		0.11 $\pm$ 53	0.24 $\pm$ 37	0.62 $\pm$ 10	0.32 $\pm$ 13
^{103}Ru	0.63 $\pm$ 27		0.41 $\pm$ 14	0.83 $\pm$ 18	1.18 $\pm$ 5	0.58 $\pm$ 9
^{131}I	44 $\pm$ 15		40 $\pm$ 6	44 $\pm$ 11	65 $\pm$ 4	68 $\pm$ 5
^{132}Te	63 $\pm$ 17		—	—	7.8 $\pm$ 9	7.5 $\pm$ 14
^{136}Cs	0.70 $\pm$ 53		—	—	0.48 $\pm$ 5	0.39 $\pm$ 20
^{137}Cs	3.9 $\pm$ 16		3.9 $\pm$ 6	4.4 $\pm$ 11	1.65 $\pm$ 4	1.41 $\pm$ 6
^{140}Ba	1.1 $\pm$ 34		1.3 $\pm$ 37	3.6 $\pm$ 37	2.7 $\pm$ 7	2.0 $\pm$ 12
^{141}Ce	0.30 $\pm$ 54		—	0.25 $\pm$ 57	0.70 $\pm$ 7	0.37 $\pm$ 16

^a Uncertainties are one std. dev. expressed in percent.

TABLE 40
NUCLIDE RATIO TO ^{134}Cs
Gavle, Sweden

Nuclide	Vegetation ^a	
	Aliquot A	Aliquot B
^{95}Zr	0.03 ± 6	0.05 ± 9
^{103}Ru	0.50 ± 0.7	0.55 ± 2
^{131}I	12.87 ± 0.4	12.9 ± 1
^{132}Te	7.9 ± 1	7.5 ± 3
^{136}Cs	0.43 ± 2	0.47 ± 4
^{137}Cs	1.59 ± 0.5	1.62 ± 1
^{140}Ba	1.89 ± 1	2.00 ± 3
^{141}Ce	0.06 ± 4	0.07 ± 2

^a Uncertainties are one std. dev. expressed in percent.

TABLE 41

NUCLIDE RATIO TO ^{134}Cs
Tarnsjo, Sweden

Nuclide	Wet Soil ^a		Dry Soil ^a		Vegetation ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	0.09 $\pm$ 11	0.06 $\pm$ 15	0.008 $\pm$ 50	0.007 $\pm$ 55	0.16 $\pm$ 10	0.02 $\pm$ 80
^{103}Ru	0.75 $\pm$ 3	0.69 $\pm$ 3	0.61 $\pm$ 2	0.63 $\pm$ 2	0.53 $\pm$ 4	0.63 $\pm$ 4
^{131}I	13.4 $\pm$ 2	12.8 $\pm$ 2	13.1 $\pm$ 2	11.4 $\pm$ 2	4.5 $\pm$ 3	6.2 $\pm$ 3
^{132}Te	14.8 $\pm$ 3	13.5 $\pm$ 4	67 $\pm$ 50	29 $\pm$ 100	6.7 $\pm$ 5	5.8 $\pm$ 7
^{136}Cs	0.45 $\pm$ 7	0.37 $\pm$ 8	0.37 $\pm$ 10	0.39 $\pm$ 10	0.46 $\pm$ 9	0.47 $\pm$ 10
^{137}Cs	1.53 $\pm$ 2	1.60 $\pm$ 2	1.58 $\pm$ 1	1.55 $\pm$ 1	1.6 $\pm$ 3	1.6 $\pm$ 3
^{140}Ba	1.6 $\pm$ 5	1.5 $\pm$ 6	1.9 $\pm$ 6	1.6 $\pm$ 8	2.1 $\pm$ 5	1.7 $\pm$ 8
^{141}Ce	0.11 $\pm$ 12	0.06 $\pm$ 19	0.05 $\pm$ 12	0.02 $\pm$ 29	0.16 $\pm$ 9	0.03 $\pm$ 30

^a Uncertainties are one std. dev. expressed in percent.

TABLE 42
NUCLIDE RATIO TO ^{134}Cs
Monaco

Nuclide	Wet Soil ^a		Dry Soil ^a		Vegetation ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	0.03 $\pm$ 100	0.06 $\pm$ 41	-	-	-	-
^{103}Ru	4.3 $\pm$ 8	3.9 $\pm$ 7	5.1 $\pm$ 2	4.8 $\pm$ 1	3.8 $\pm$ 7	3.9 $\pm$ 7
^{106}Ru	-	-	1.3 $\pm$ 8	1.1 $\pm$ 6	-	3.2 $\pm$ 18
^{131}I	18.1 $\pm$ 8	17 $\pm$ 7	25 $\pm$ 5	26 $\pm$ 3	60 $\pm$ 6	61 $\pm$ 6
^{132}Te	36 $\pm$ 16	17.2 $\pm$ 26	-	-	44 $\pm$ 6	38 $\pm$ 6
^{136}Cs	0.52 $\pm$ 34	0.46 $\pm$ 28	-	-	-	-
^{137}Cs	1.9 $\pm$ 8	2.0 $\pm$ 7	2.92 $\pm$ 2	2.91 $\pm$ 1	1.80 $\pm$ 8	1.84 $\pm$ 8
^{140}Ba	1.7 $\pm$ 27	1.9 $\pm$ 20	3.5 $\pm$ 19	2.9 $\pm$ 13	1.7 $\pm$ 13	2.5 $\pm$ 10
^{141}Ce	-	0.16 $\pm$ 37	0.30 $\pm$ 18	0.21 $\pm$ 11	-	-

^a Uncertainties are one std. dev. expressed in percent.

TABLE 43
NUCLIDE RATIO TO ^{134}Cs
Braunschweig, FRG

Nuclide	Wet Soil ^a		Dry Soil ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	—	—	—	0.10 $\pm$ 39
^{103}Ru	1.4 $\pm$ 10	4.7 $\pm$ 3	5.1 $\pm$ 3	4.9 $\pm$ 3
^{106}Ru	1.0 $\pm$ 3	1.4 $\pm$ 13	1.2 $\pm$ 12	1.2 $\pm$ 11
^{131}I	24.3 $\pm$ 4	21.4 $\pm$ 3	31 $\pm$ 23	26 $\pm$ 38
^{132}Te	—	69 $\pm$ 25	—	—
^{136}Cs	1.8 $\pm$ 18	—	—	—
^{137}Cs	2.13 $\pm$ 4	2.22 $\pm$ 3	2.44 $\pm$ 3	2.36 $\pm$ 3
^{140}Ba	4.2 $\pm$ 12	3.9 $\pm$ 9	5.8 $\pm$ 24	5.9 $\pm$ 25
^{141}Ce	0.24 $\pm$ 24	—	0.28 $\pm$ 30	0.33 $\pm$ 28

^a Uncertainties are one std. dev. expressed in percent.

TABLE 44
NUCLIDE RATIO TO ^{134}Cs
Roskilde, Denmark

Nuclide	Wet Soil ^a		Dry Soil ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	—	0.45 ± 26	—	—
^{103}Ru	7.7 ± 4	8.5 ± 7	7.7 ± 4	7.9 ± 3
^{106}Ru	2.1 ± 15	2.7 ± 19	1.8 ± 12	2.0 ± 13
^{131}I	28 ± 5	31 ± 7	—	—
^{137}Cs	3.9 ± 4	3.8 ± 7	3.7 ± 4	3.6 ± 3
^{140}Ba	3.4 ± 21	—	—	—
^{141}Ce	—	—	0.44 ± 21	0.69 ± 18

^a Uncertainties are one std. dev. expressed in percent.

TABLE 45

NUCLIDE RATIO TO ^{134}Cs
Klagenfurt, Austria

Nuclide	Wet Soil ^a		Dry Soil ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	—	—	4.9 ± 2	0.51 ± 6
^{103}Ru	3.9 ± 4	4.8 ± 4	4.7 ± 2	—
^{106}Ru	1.0 ± 24	1.2 ± 17	1.2 ± 10	1.1 ± 6
^{131}I	28 ± 5	30 ± 5	34 ± 7	3.3 ± 6
^{132}Te	—	—	—	34 ± 7
^{137}Cs	2.34 ± 4	2.65 ± 4	2.63 ± 2	2.66 ± 12
^{140}Ba	2.7 ± 14	2.6 ± 9	7.8 ± 5	4.0 ± 23
^{141}Ce	—	—	3.7 ± 2	0.66 ± 6
^{144}Ce	—	—	1.8 ± 6	0.34 ± 12

^a Uncertainties are one std. dev. expressed in percent.

TABLE 46
NUCLIDE RATIO TO ^{134}Cs
Rome, Italy

Nuclide	Wet Soil ^a		Dry Soil ^a	
	Aliquot A	Aliquot B	Aliquot A	Aliquot B
^{95}Zr	—	4.3 $\pm$ 26	—	—
^{103}Ru	5.5 $\pm$ 13	7.7 $\pm$ 21	5.5 $\pm$ 17	7.9 $\pm$ 21
^{131}I	31 $\pm$ 18	52 $\pm$ 26	—	—
^{137}Cs	3.1 $\pm$ 14	2.8 $\pm$ 22	2.5 $\pm$ 17	3.2 $\pm$ 22
^{140}Ba	—	19 $\pm$ 30	—	—

^a Uncertainties are one std. dev. expressed in percent.

TABLE 47
WET/DRY RATIOS

Location	^{95}Zr	^{95}Nb	^{103}Ru	^{106}Ru	^{131}I
Skutskar, Sweden	3.71 ± 0.77	1.98 ± 0.24	1.41 ± 0.13	—	1.31 ± 0.13
Soderfors, Sweden	2.9 ± 1.7	—	0.93 ± 0.06	—	0.92 ± 0.02
Uppsala, Sweden	—	—	0.90 ± 0.07	—	0.82 ± 0.15
Stockholm, Sweden	—	—	0.65 ± 0.55	—	0.86 ± 0.21
Oland, Sweden	4.2 ± 2.8	2.0 ± 1.01	1.22 ± 0.32	—	1.22 ± 0.07
Tarnsjo, Sweden	8.9 ± 6.8	—	1.06 ± 0.04	—	0.88 ± 0.09
Monaco	—	—	1.20 ± 0.06	—	0.98 ± 0.07
Braunschweig, FRG	—	—	0.64 ± 0.46	1.07 ± 0.26	0.80 ± 0.18
Roskilde, Denmark	—	—	0.98 ± 0.04	1.18 ± 0.36	—
Klagenfurt, Austria	—	—	1.04 ± 0.03	1.10 ± 0.36	1.04 ± 0.11
Rome, Italy	—	—	0.90 ± 0.15	—	—
Weighted mean, σ	3.7 ± 0.7	2.0 ± 1.0	1.03 ± 0.02	1.11 ± 0.18	0.95 ± 0.02

Location	^{134}Cs	^{136}Cs	^{137}Cs	^{140}Ba	^{140}La	^{141}Ce
Skutskar, Sweden	1.45 ± 0.05	1.39 ± 0.13	1.41 ± 0.19	1.40 ± 0.09	1.43 ± 0.20	1.46 ± 0.36
Soderfors, Sweden	0.90 ± 0.05	0.58 ± 0.16	0.96 ± 0.04	1.02 ± 0.16	0.94 ± 0.07	1.65 ± 0.7
Uppsala, Sweden	1.02 ± 0.07	0.56 ± 0.15	0.85 ± 0.04	0.79 ± 0.18	0.81 ± 0.09	0.74 ± 0.41
Stockholm, Sweden	1.7 ± 1.5	—	1.0 ± 0.44	—	0.65 ± 0.25	2.4 ± 2.5
Oland, Sweden	1.16 ± 0.22	—	1.10 ± 0.07	—	0.76 ± 0.31	1.65 ± 1.26
Tarnsjo, Sweden	0.91 ± 0.03	0.92 ± 0.15	0.94 ± 0.02	0.82 ± 0.10	0.88 ± 0.05	2.12 ± 0.67
Monaco	1.46 ± 0.14	—	0.97 ± 0.06	0.82 ± 0.31	1.11 ± 0.17	0.94 ± 0.41
Braunschweig, FRG	1.07 ± 0.04	—	0.97 ± 0.03	—	0.70 ± 0.28	0.89 ± 0.28
Roskilde, Denmark	0.93 ± 0.08	—	0.98 ± 0.04	—	—	—
Klagenfurt, Austria	1.17 ± 0.05	—	1.10 ± 0.04	—	0.63 ± 0.15	—
Rome, Italy	0.81 ± 0.27	—	0.97 ± 0.21	—	—	—
Weighted mean, σ	1.05 ± 0.02	0.91 ± 0.07	0.97 ± 0.01	1.12 ± 0.06	0.89 ± 0.03	1.12 ± 0.16

TABLE 48
MELTING AND BOILING POINTS (°C)

Elements or Oxide	Melting Point	Boiling Point
RuO_4	25	108
Cs	28.6	670
I_2	114	184
Te	452	1390
Pu	640	3235
Ba	725	1640
TeO_2	733	1245
Sr	769	1384
Ce	799	3426
La	921	3457
Ce_2O_3	1692	-
Zr	1857	4377
BaO	1918	2000
Ru	2310	3900
SrO	2430	3000
Nb	2468	4742
ZrO_2	2700	5000

TABLE 49
SUMMARY OF SOIL ACTIVITY RATIOS TO ^{134}Cs

Location	^{103}Ru	^{131}I	^{132}Te	^{140}Ba	^{141}Ce	^{137}Cs
<u>Group 1</u>						
Skutskar, Sweden	0.62 $\pm$ 0.05	13.0 $\pm$ 0.1	11.6 $\pm$ 0.4	1.98 $\pm$ 0.07	0.076 $\pm$ 0.005	1.60 $\pm$ 0.01
Soderfors, Sweden	0.77 $\pm$ 0.01	17.3 $\pm$ 0.4	17 $\pm$ 1	1.60 $\pm$ 0.15	0.056 $\pm$ 0.011	1.59 $\pm$ 0.02
Uppsala, Sweden	0.85 $\pm$ 0.02	17.7 $\pm$ 0.6	14.0 $\pm$ 2.5	2.02 $\pm$ 0.31	0.052 $\pm$ 0.012	1.91 $\pm$ 0.04
Tarnsjo, Sweden	0.61 $\pm$ 0.02	12.4 $\pm$ 0.4	14.5 $\pm$ 0.8	1.69 $\pm$ 0.19	0.037 $\pm$ 0.009	1.56 $\pm$ 0.03
Wtd. Mean $\pm$ Std. Dev.	0.75 $\pm$ 0.01	13.3 $\pm$ 0.1	12.7 $\pm$ 0.3	1.89 $\pm$ 0.06	0.064 $\pm$ 0.004	1.61 $\pm$ 0.01
<u>Group 2</u>						
Monaco	5.0 $\pm$ 0.1	26 $\pm$ 2	26 $\pm$ 9	3.2 $\pm$ 0.8	0.26 $\pm$ 0.05	2.9 $\pm$ 0.1
Braunschweig, FRG	5.0 $\pm$ 0.1	29 $\pm$ 7	73 $\pm$ 37	5.9 $\pm$ 1.0	0.30 $\pm$ 0.06	2.4 $\pm$ 0.1
Roskilde, Denmark	7.8 $\pm$ 0.3	31 $\pm$ 3	-	3.4 $\pm$ 1.5	0.56 $\pm$ 0.15	3.6 $\pm$ 0.1
Klagenfurt, Austria	4.9 $\pm$ 0.1	34 $\pm$ 6	-	5.0 $\pm$ 0.7	2.2 $\pm$ 2.2 ^a	2.6 $\pm$ 0.1
Rome, Italy	6.6 $\pm$ 1.8	40 $\pm$ 14	-	17 $\pm$ 5	-	2.8 $\pm$ 1.5
Wtd. Mean $\pm$ Std. Dev.	5.1 $\pm$ 0.1	28 $\pm$ 1	29 $\pm$ 9	4.6 $\pm$ 0.5	0.29 $\pm$ 0.04	2.9 $\pm$ 0.1
<u>Group 3</u>						
Stockholm, Sweden	1.6 $\pm$ 0.4	67 $\pm$ 16	17 $\pm$ 18	13 $\pm$ 3	1.9 $\pm$ 0.5	2.7 $\pm$ 0.4
Oland, Sweden	0.60 $\pm$ 0.14	41 $\pm$ 5	63 $\pm$ 11	1.5 $\pm$ 0.4	0.2 $\pm$ 0.1	4.2 $\pm$ 0.5
Wtd. Mean $\pm$ Std. Dev.	0.71 $\pm$ 0.13	43 $\pm$ 5	50 $\pm$ 9	1.7 $\pm$ 0.4	0.27 $\pm$ 0.10	3.3 $\pm$ 0.3
Chernobyl core	35	23	32	4	39	1.51

^a 2.2 value omitted from calculation of the mean.

TABLE 50
SUMMARY OF ACTIVITY RATIOS TO ^{134}Cs IN AIR FILTERS,
PRECIPITATION AND MONACO VEGETATION

Sample	^{106}Ru	^{131}I	^{132}Te	^{137}Cs	^{140}Ba	^{141}Ce
Air Filter						
Grindsjon	0.6 ± 0.02	6.7 ± 0.05	8.5 ± 0.3	1.92 ± 0.04	1.1 ± 0.04	0.27 ± 0.02
Monaco	4.9 ± 0.04	6.0 ± 2.9	4.4 ± 0.2	1.90 ± 0.12	0.87 ± 0.32	0.037 ± 0.010
Precipitation						
Monaco	4.9 ± 0.3	32 ± 2^a	82 ± 5	1.92 ± 0.15	5.7 ± 0.7	—
Vegetation						
Monaco Grass	3.8 ± 0.6	64 ± 8	45 ± 7	1.81 ± 0.33	2.2 ± 1.0	—
Monaco Salad	3.6 ± 0.2	22 ± 12	15 ± 1	2.0 ± 0.14	2.6 ± 0.4	0.17 ± 0.7

^a Probable low value due to distillation of HI resulting from inadvertent addition of acid to the sample.

Figure 1. Correlation of the activity ratio $^{103}\text{Ru}/^{134}\text{Cs}$ to the ratio of $^{131}\text{I}/^{134}\text{Cs}$.

CHERNOBYL FALLOUT STUDIES IN THE BLACK SEA AND OTHER OCEAN AREAS

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INTRODUCTION

The release of massive quantities of radionuclides to the lower atmosphere from the Chernobyl nuclear power station accident on April 26, 1986 has environmental radioecological implications that extend into the future. It is premature at present to make a comprehensive assessment of the oceanic impact of the release and the possible consequent potential marine radiotracer applications. Clearly, the Baltic Sea, is one area where fallout from Chernobyl was high enough to be used to conduct an extensive range of experiments. The Black Sea, Norwegian/Greenland/Barents Seas and Arctic Ocean are also likely to have received substantial amounts of Chernobyl fallout. In addition to direct fallout, the Arctic Ocean can be expected to receive an advective input from the south as Atlantic water flows relatively rapidly into it. Likewise, the Norwegian Sea will receive water exported from the Baltic Sea outflow. The Black Sea receives large amounts of river input in the northwest - mostly from the Danube and Dnper Rivers. Both these rivers drain watersheds heavily impacted by Chernobyl fallout - the latter including the freshwater environment directly around the Chernobyl site itself.

Dr. H. D. Livingston's laboratory at the Woods Hole Oceanographic Institution started to collect samples this summer that can be used to assess the geographical impact of Chernobyl fallout in the areas noted above. This information will permit an assessment of what radio-tracer experiments are possible and will establish a partial data base against which temporal changes may be noted.

THE BLACK SEA

Sampling

We participated in a cruise to the southwestern Black Sea aboard the Dokuz Eylul Universitesi Rektörlüğü research vessel K. PIRI REIS, set and recovered sediment trap moorings and occupied a number of stations for water and plankton sampling.

The stations at which samples were collected for radionuclide analysis by Woods Hole Oceanographic Institution are listed in Table 1 and plotted in Figure 1. They include four stations in the Black Sea, one in the Bosphorus where Black Sea surface waters flows toward the Mediterranean, one in the Sea of Marmara, and one in the Aegean Sea. Water sampling at each station consisted of two operations.

1. Filtration/Chemisorption

Relatively large volumes of water were pumped through a series of filters and chemisorbers in series. Water passed sequentially through a prefilter, two filters impregnated with manganese dioxide and two filters impregnated with cupric ferrocyanide. All filters were cotton fiber cartridges (AMC Cuno, Microwynd II) and were mounted in filter housings. Volume was measured using a flow meter. The effective pore size of the filters was 1 μm . The prefilter collected particulate material $> 1 \mu\text{m}$ from the water to determine the partition of the radionuclides present between dissolved and particulate phases. The manganese dioxide filters collect dissolved phase reactive elements or radionuclides from the filtered stream. These filters are especially effective for higher valence metals such as lanthanides and actinides. The cupric ferrocyanide filters are effective for radio-caesium absorption. In both cases collection efficiencies are generally quite high ($> 80-90\%$), but can be calculated from the amounts collected on each cartridge (Mann et al., 1984). From these series of samples we can expect to collect a spectrum of different nuclides present in the Chernobyl fallout:

Prefilter: particle associated nuclides.

Manganese dioxide: fission product lanthanides, higher valent cations and transuranics

Cupric ferrocyanide: ^{134}Cs and ^{137}Cs

Typically 500 to 1000 L of water were processed - all surface samples. Attempts to collect subsurface samples by pumping were not successful due to technical problems.

2. Discrete Samples

At each station we collected a 10 L water sample in a plastic Jerry jug. The primary purpose of this sample was to be able to measure ^{90}Sr . This measurement should provide a measure of the new Chernobyl ^{90}Sr delivered to the Black Sea by direct fallout (in addition to the nuclear bomb fallout already present in surface water - derived chiefly from the Black Sea river input). These data would represent baseline data against which to measure ^{90}Sr fallout delivered to the Black Sea by drainage from the watershed, especially from the heavily contaminated region around the Chernobyl reactor site. These discrete samples will also serve as back-up to the filter samples and as samples in which nuclides not collected by the filters can be measured. In addition to the 10 L samples, a small sample for salinity determination was also collected.

Plankton

At three stations, net tows for plankton were made. Only one, at station 10, was a large sample and it was collected by a vertical tow with a large plankton net.

Sediment Traps

At station 10 (41°48'N, 30°25'E), one of Dr. S. Honjo's sediment trap moorings was set. Two Mark 5 sediment traps (1.2 m² receiving areas) were deployed at depths of 250 m (60 m below the local chemocline) and 1,250 m (about 650 m above the seafloor). Each trap is equipped with 12 sampling cups set to collect a time-series of settling large particles at 12-day intervals. Present plans call for this mooring to be retrieved on a cruise in September of this year. These trap samples will provide a record of the transport of large particle of Chernobyl radionuclides that were deposited into the Black Sea sediments. Radionuclides likely to be involved in labelling large particle transport include ¹⁴⁴Ce, ¹⁵⁵Eu (possible ²⁴²Cm), ¹⁰⁶Ru and ⁹⁰Sr. The latter isotope will be incorporated into the carbonate fraction of the large particle flux, especially in the large coccolith blooms prevalent in the Black Sea. The size of this signal could very well be sharply increased as ⁹⁰Sr fallout is delivered to heavily contaminated areas in and around the Ukraine and is mobilized and flushed into the northwestern Black Sea.

Soil Sampling

While the K. PIRI REIS was in port in Amasra, on the northern Turkish coast, a soil sample was collected from the grounds of the NATO facility there. This sample was collected on behalf of the Environmental Measurements Laboratory and it will be a part of his soil sampling program to assess the depositional pattern and inventory of Chernobyl fallout. From the point of view of Black Sea deposition, the measurement of fallout delivered to the coastal region of the southeastern Black Sea will be useful in setting a lower limit of detection to the assessment of direct Chernobyl fallout to the western Black Sea.

PRELIMINARY DATA

The only measurements completed at present are from direct gamma spectrometry (coaxial Ge(Li)) on filter cartridges and absorbers (either directly or after dry ashing) and on plankton samples. The data are considered preliminary since we do not have unequivocal evidence of the uniformity of the nuclide distribution within the cartridges, although we feel reasonably confident of a homogeneous distribution. In addition, the calibration is untested (it was achieved by loading standard amounts of ¹³⁴Cs and ¹³⁷Cs on a Cs filter cartridge). Finally, the sample counting geometry resulting from placing a filter cartridge "end-on" to a detector is most inefficient, so counting uncertainties have not been minimized.

A separate uncertainty in the absolute Cs isotope concentrations obtained is derived from our discovery that Cs collection efficiencies were variable, instead of high and consistent. Several collection efficiencies were around 50% instead of the typical > 90% we expected. We think the reason for this problem lies in incomplete drying during cartridge impregnation. Because of this problem we cannot be certain that the derived efficiencies are reliable.

Instead we report Cs isotope concentrations by summing the amounts found on each cartridge. This should provide a minimum isotope concentration. The actual concentration will be only slightly higher when the collection efficiency is high. Reliable, absolute measurements of Cs isotope concentrations will be obtained after analysis of the 10 L samples collected. The preliminary data indicate that there will be no difficulty in measurement at the concentrations present.

The preliminary Cs isotope data are given in Tables 2 and 3. The levels in the Black Sea are quite remarkable. Typical North Atlantic surface water concentrations containing only bomb fallout ^{137}Cs have recently been around 18 dpm/100 L (3 Bq/m³). Black Sea values have probably been even lower because of low Cs river run-off. The values in the Sea of Marmara and the Aegean Sea are lower because of lower deposition there. It is important to note that these high concentrations were in surface water collected nearly two months after deposition. Considerable mixing and dilution are likely to have occurred during this period. Since we were not successful in collecting subsurface samples on the June cruise, we will make every effort to collect them on a later cruise - hopefully on a planned sediment trap-recovery cruise in September 1986.

The ^{134}Cs concentrations are such that the $^{134}\text{Cs}/^{137}\text{Cs}$ ratios are about as expected for Chernobyl fallout. At the higher concentrations the ratios average a little below 0.5, as has been widely reported for Chernobyl fallout. At the lower concentrations, the ratios are a little lower as the Chernobyl fallout is diluted by mixing with water containing bomb-derived ^{137}Cs (i.e., free of any ^{134}Cs). Again, the precision of the ratios is not as good as could be achieved by using more favorable counting geometry.

The concentrations of other Chernobyl-derived nuclides in Black Sea surface waters are derivable by relating these observed ^{137}Cs concentrations to the amounts of other isotopes found relative to ^{137}Cs in Chernobyl fallout. There will be many reports on the fallout composition. One early one by the Finnish Centre for Radiation and Nuclear Safety, describes the composition in fallout delivered to Finland in early May (Helsinki, 1986). Our preliminary observations on Chernobyl isotopes (other than ^{137}Cs and ^{134}Cs) in Black Sea surface waters, particles and plankton are consistent with the relative abundances described in the above report. Our data are only qualitative as the samples need to be recounted after ashing to obtain a better calibrated and more efficient counting geometry. Major peaks in the gamma spectra from the manganese dioxide cartridges, filtered particulates and plankton include: ^{141}Ce , ^{144}Ce , ^{103}Ru , ^{106}Ru , ^{140}La , ^{140}Ba , ^{95}Nb and $^{129\text{m}}\text{Te}$.

NORWEGIAN AND BARENTS SEA

It is probable that the Nordic Seas and Arctic Seas will receive significant amounts of Chernobyl fallout, either directly or from advective transport from regions such as the Baltic Sea which were heavily contaminated. The assessment of these inputs is important in connection with their use in Arctic tracer oceanography.

To this end, we have arranged for the collection of some 30 L seawater samples on a cruise of the Norwegian ship R/V LANCE. Dr. Bert Rudels of the Norwegian Polar Research Institute in Oslo will be working in the northeastern Norwegian Sea, Barents Sea and Arctic Ocean (north of Spitsbergen) this summer, and he is planning to collect samples and ship them to Woods Hole for analysis. These samples should serve to indicate the scale of the Chernobyl fallout input to these ocean areas in a manner similar to the Black Sea data shown above.

ACKNOWLEDGEMENTS

We are grateful to the Government of Turkey for allowing us to make these measurements. The officers and crew of the K. PIRI REIS were extremely helpful and cooperative and made the sampling effort go smoothly. The techniques for collection of cesium radionuclides from seawater using impregnated filter cartridge absorbers have been recently developed through the efforts of D. L. Schneider and P. Hernes. Our thanks to them for their efforts and skill.

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REFERENCES

Mann, B. R., L. D. Surpernant and S. A. Casso
'In Situ Chemisorption of Transuranics from Sea Water'
Nucl. Inst. Meth. Phys. Res., 223, 235-238 (1984)

Finnish Centre for Radiation and Nuclear Safety
'Radiation Situation in Finland from 5 to 16 May 1986'
Second Interim Report, STUK-B-VALO 45, Helsinki, May (1986)

TABLE 1

K. PIRI REIS CRUISE, JUNE 1986: STATION LOCATIONS

Station no.	Date 1986	Position	Location
3	June 14	39°14.2'N, 25°20.0'E	Aegean Sea
7	June 15	40°45.5'N, 28°09.2'E	Sea of Marmara
9	June 17	41°16'N, 29°11'E	Black Sea - mouth of Bosporus
9A	June 17	41°09'E, 29°05'E	Bosporus
10	June 18	41°47.6'N, 30°24.9'E	Southern Black Sea - sediment trap site
13	June 19	42°15.7'N, 32°33.5'E	Southern Black Sea - former trap site
15	June 18	41°14.3'N, 30°23.4'E	Southern coastal

TABLE 2

¹³⁷Cs CONCENTRATIONS IN SURFACE WATER COLLECTED
BY THE R/V K. PIRI REIS CRUISE

Location	Station No.	Concentrations (dpm/100 L)	Concentrations (bq/m ³)
Black Sea	10	852 $\pm$ 69	142 $\pm$ 12
Black Sea	15	359 $\pm$ 21	60 $\pm$ 4
Black Sea	13	212 $\pm$ 30	35 $\pm$ 5
Bosporus Mouth	9	438 $\pm$ 16	73 $\pm$ 3
Bosporus	9A	394 $\pm$ 19	66 $\pm$ 3
Sea of Marmara	7	196 $\pm$ 34	33 $\pm$ 6
Aegean Sea	3	85 $\pm$ 9	14 $\pm$ 1.5

TABLE 3

^{134}Cs CONCENTRATIONS AND $^{134}\text{Cs}/^{137}\text{Cs}$ RATIOS IN
SURFACE WATER: R/V K. PIRI REIS

Location	Station No.	^{134}Cs Concentration		$^{134}\text{Cs}/^{137}\text{Cs}$
		dpm/100 L	Bq/m ³	
Black Sea	10	400 $\pm$ 17	67 $\pm$ 3	0.47 $\pm$ 0.02
Black Sea	15	180 $\pm$ 18	30 $\pm$ 3	0.50 $\pm$ 0.05
Black Sea	13	89 $\pm$ 5	15 $\pm$ 1	0.42 $\pm$ 0.06
Bosporus Mouth	9	210 $\pm$ 18	35 $\pm$ 3	0.48 $\pm$ 0.04
Bosporus	9A	181 $\pm$ 16	30 $\pm$ 3	0.46 $\pm$ 0.04
Sea of Marmara	7	80 $\pm$ 10	13 $\pm$ 2	0.41 $\pm$ 0.05
Aegean Sea	3	32 $\pm$ 6	5.3 $\pm$ 1.0	0.38 $\pm$ 0.07

Figure 1. Water sampling station positions from the K. PIRI REIS cruise - Black Sea, June 1986.

OBSERVATIONS AND SAMPLING BY EML IN SWEDEN, WITH PRELIMINARY GAMMA-RAY SPECTROMETRIC DATA

Edward Hardy, Philip Krey, Catherine Klusek
Kevin Miller, Irene Helfer, Colin Sanderson
and William Rivera

INTRODUCTION

Following the first news reports of the reactor accident at Chernobyl, the Associate Director of the Office of Health and Environmental Research (U. S. Department of Energy) recommended that first-hand observations and measurements be made in Europe. It was felt that information on the radionuclide composition of the initial fallout debris was critical to understanding the nature of the Chernobyl accident and in predicting the magnitude and characteristics of the fallout expected in the United States.

Through Dr. William Bair of Battelle Pacific Northwest Laboratory a request was made to Dr. Gunnar Bengtsson, Director General of the National Institute of Radiation Protection (NIRP), to permit three Americans to visit NIRP in Stockholm. Edward Hardy of the Environmental Measurements Laboratory (EML) and David Robertson and William Rickard of Battelle Pacific Northwest Laboratory subsequently spent one week in Sweden. Some radiation measurements were made and samples of soil and vegetation were collected in a number of areas in the southeastern part of the country. This report summarizes the activities carried out during this trip and also presents gamma spectrometric data for the samples analyzed at EML.

OBSERVATIONS AND SAMPLING

By the time of our arrival on May 4th, a considerable amount of data had already been generated by Swedish scientists and NIRP was receiving information from many other centers in Europe. It was apparent that all of the necessary measurements were being made to assess the radiation exposures and radionuclide doses received by people from the Chernobyl accident.

Dr. Curt Bergman of NIRP explained that at the time of the accident, the pasture season had not begun in Sweden and subsequently farmers had been warned to keep their cows indoors until notified otherwise. The NIRP action level in milk was established at 200 Bq ^{131}I /L, but all pooled supplies were considerably lower so no milk was being withheld from distribution.

Based upon field measurements being reported to the NIRP, Uppsala (population ~ 142,000; located about 60 km north of Stockholm) had air exposure rates ~ 190 $\mu\text{R/hr}$. An area 160 km northwest of Stockholm had reached 470 $\mu\text{R/hr}$ (near the city of Gavle, population ~ 88,000). Air exposure rates in the Stockholm area (population ~ 1,400,000) were 20 to 30 $\mu\text{R/hr}$ (~ 2 to 3 times background assuming a pre-Chernobyl air exposure rate of 10 $\mu\text{R/hr}$). The map, on p. 243, shows the locations of these areas as well as other places where we subsequently made measurements and collected samples. Robertson brought a Ludlum scintillation exposure rate meter and a Geiger-Mueller (GM) survey meter and we were prepared to collect grass and soil samples should the opportunity arise.

On Monday, May 5, we met Dr. Bergman on the eastern side of Uppsala. (In the car the exposure rate was 100 $\mu\text{R/hr}$ and at 1 m above the lawn in Bergman's yard, it was 130 $\mu\text{R/hr}$.) Bergman directed us to the Gavle area where heavy rain had intercepted the initial wave of fallout. Near the village of Skutskar, about 10 km east of Gavle, the air exposure rate was 900 $\mu\text{R/hr}$ at 1 m in a clearing near the main road. The ground cover was mostly moss, lichen and dead grass. Samples of the top soil and vegetation cover were taken. About 100 m away over a wet patch of dirt road, the air exposure rate was 1400 $\mu\text{R/hr}$ at 1 m.

Then we drove to Soderfors which was in the same rain pattern as the Gavle area but some 30 km south. Here the air exposure rate was 700 $\mu\text{R/hr}$ at 1 m above a field that was not used for either grazing or cultivation. The grass had been scythed and left, representing last year's growth. The new grass was barely visible. We collected the dead and new grass from a 1 m² area, clipping to about 1 cm above the soil surface. Within the clipped grass area, soil cores were taken to 5 cm. It was assumed that none of the radionuclides comprising the Chernobyl fallout would have penetrated below this depth. The GM survey meter recorded 7000 cpm on the surface of the dead vegetation and 5000 cpm after clipping to 1 cm above the soil surface. The permanent moss cover had entrapped some radioactivity, but most had been washed through the dead grass to the soil surface by the rain.

The next day, May 6, we returned to Uppsala and took readings near the University in the western part of the city. In a public park, the scintillation detector read 220 $\mu\text{R/hr}$ at 1 m. In a farming area about 10 km south of Uppsala, the reading was 210 $\mu\text{R/hr}$ at 1 m. Here, we again collected vegetation and surface soil samples. New grass was beginning to sprout but was still very sparse.

In the afternoon of May 6, we returned to NIRP where we met Dr. Kay Edvarson, who showed us a map of airborne radiation measurements that had been made at 150 m over the southern half of Sweden by the National Defense Research Institute (NDRI). The fallout distribution pattern was primarily dictated by the amounts of rainfall which occurred during the passage of the initial air mass containing radioactive debris particles from Chernobyl.

At the Stockholm offices and laboratories of the NDRI, Dr. Lars-Erik DeGeer and Dr. Edvarson briefed us on their activities and findings up to that point in time. Among the salient points made by these Swedish scientists were that air filters contained about one "very hot particle" per 10³ m³, enriched in the refractory radionuclides. The degree of fractionation between ¹³¹I and ¹³²I depended on whether rainfall scavenging had occurred and the intensity. Eighty-five percent of the ¹³¹I passed through the particle collecting air filter. The ¹³⁷Cs to ¹³⁴Cs ratio in air filters is consistently about 2, indicating high burn-up.

We requested and received from Dr. DeGeer, a hi-vol air filter collected April 28-30 at Grindsjon about 20 km south of Stockholm. One half of this filter was sent to EML and the other half to Pacific Northwest Laboratories.

We then returned to NIRP and received permission to sample grass and soil from the east lawn of the Institute. The new grass, which stood only about 3 cm high down to 1 cm, was clipped and surface soil cores were taken within this area. The air exposure rate at 1 m was 30 $\mu\text{R/hr}$. With the GM counter we observed the presence of randomly dispersed very hot particles. Small samples of grass-covered soil containing these hot particles were collected. There were about 5 or 6 hot particles per m² of ground surface.

Dr. Edvarson had pointed out that the southwest coast of Sweden had received no rain, but that air concentrations and in situ gamma spectrometric measurements had shown high radiation levels. Based on this informa-

tion and curious about the hot particles found in Stockholm, we drove south on May 7. Stopping in Nyköping, Gusum and Västervik to make GM survey measurements, we found that the number of hot particles per m^2 dropped off as we headed south until there was only about $1/\text{m}^2$ at Oskarshamn, 250 km south of Stockholm. (The scintillation detector was not available this day as it was being calibrated by the NIRP.)

Crossing to Oland Island at Kalmar, 300 km due south of Stockholm, we headed north about 10 km and selected an area for sampling. Relatively few hot particles were detected here - considerably $< 1/\text{m}^2$. We then clipped new grass, which was about 5 cm high, down to 1 cm then took surface soil cores in the 1 m^2 clipped area.

The next day, May 8, on returning to NIRP, Birgitta Svahn showed us time trends of radionuclide concentrations in air. ^{131}I concentrations in Stockholm had dropped from a high of $270 \text{ pCi}/\text{m}^3$ (3 days following the accident) to $0.5 \text{ pCi}/\text{m}^3$ (8 days after the accident) and then had risen to $10 \text{ pCi}/\text{m}^3$ (12 days after the accident). Air concentrations of ^{137}Cs , about one-fifth of the ^{131}I concentrations, were showing a similar pattern. The delayed increases were first suspected as being due to resuspension from the dry areas, but the continued increases suggested new pulses.

Dr. Rickard, a radioecologist, wanted to take advantage of this unique fallout event by comparing fallout over a forest canopy to an open area. We returned to the heavily rain-scavenged Gavle area, 160 km northwest of Stockholm, where individual "hot" particles observed on the ground further south could not be distinguished above the radiation flux attributable to the relatively heavy fallout in this area. Rickard sampled biota in the forested areas on either side of a transmission line swath. A dramatic indication that winter was in this area just the previous week, was Rickard's finding of a frozen layer of peat just 3 cm below the peat surface. Hardy cut a section of moss covering a rock standing about 1 m high; the bare rock underneath showed very little radioactivity compared to the moss surface. Robertson could distinguish hot particles with the GM survey meter on picnic tables at the Alvkärleby hydroelectric dam nearby. The particles appeared to be imbedded in grooves of the wood surface.

On the last sampling day, May 9, we decided to search out a dairy farm in the highly rain-scavenged fallout area south of Gavle, where, under normal conditions, milk cows would be grazing. The Salja farm, 10 km north of the village of Tärnsjö (120 km northwest of Stockholm) was comprised of 35 cows. The air exposure rate at the dairy farm was $220 \mu\text{R}/\text{hr}$ at 1 m. There was a well-established pasture where the new grass was about 7 cm high in spots. The grass was clipped in two sections: from the top to 5 cm above the ground and from 5 to 1 cm above the ground. Surface soil cores were then taken in the clipped area. In all probability, this grass was not present when the initial radioactive air mass passed over and particles were brought down to the ground by rain.

We were provided with printouts of the Swedish data base as it had developed by May 9 and were allowed to copy data from other countries. In addition to those NIRP scientists already mentioned, Mikael Jensen, John-Christer Lindhe and Sture Nordlinder graciously took time to answer questions and provide us with the latest available information.

DISCUSSION OF RESULTS

The samples we collected in Sweden were shipped to EML and Pacific Northwest Laboratories by air freight. At EML, the samples were prepared for gamma-ray spectrometric analysis and the initial counting took place within two to four days after sampling. The sample preparation and counting procedures for these and other samples are described in Krey et al. (1986). The gamma-ray spectrometric data are presented in this article from the standpoint of characterizing the radionuclide composition of the nuclear debris that was deposited not only in Sweden during the first week after the accident, but also at other places in Europe where EML subsequently obtained samples.

Aliquots of these samples are in the process of being analyzed radiochemically for ^{90}Sr , ^{89}Sr , ^{238}Pu and $^{239,240}\text{Pu}$. Decisions will subsequently be made as to whether it would be useful to analyze the samples for ^{241}Am and ^{99}Tc as well.

The EML data for the samples collected in Sweden are presented as averages of the available radionuclide measurements made by gamma-ray spectrometry, expressed in units of aerial deposition decay-corrected to the sampling period. The progeny isotopes, ^{95}Nb and ^{140}La , were decay-corrected based on the parent half-life. The tables for vegetation and soil samples also contain the corresponding exposure rates at 1 m above the ground for each measured radionuclide. These values were calculated from the deposition data using conversion factors developed at EML for an infinite half-space source geometry and typical soil composition (Beck, 1980). The source distribution in the soil was assumed to be a decreasing exponential function with depth having a relaxation length of 0.1 cm. This relaxation length was chosen based on past experiences with measurements of freshly deposited fission products (HASL, 1976) and represents, in effect, a slightly buried plane source at the soil surface. To some extent, the assumed source distribution somewhat underestimates the exposure rate that would be produced by radionuclides in the vegetation while possibly overestimating the exposure rate for radionuclides in the soil component if the ground is uneven or if heavy precipitation has driven the fallout more deeply into the soil.

The comparison between the in situ survey meter readings and the calculated air exposure rates based on the gamma spectrometric measurements of soil and vegetation is summarized in the following table:

<u>Site</u>	Air Exposure Rate ($\mu\text{R/hr}$)	
	<u>in situ</u>	<u>calculated</u>
Skutskar	900	857
Soderfors	700	708
Tarnsjo	220	187
Uppsala	210	178
Stockholm	30	<3

Despite the limitations in the accuracy of these inferred exposure rates, the totals for all the radionuclides at each site (adding vegetation values to soil values) agrees remarkably well with the survey meter readings where available, with the exception of Stockholm. At the sites where the data are in agreement, we can conclude that representative samples were taken. At Stockholm, even if a natural background contribution is taken into account in the survey meter reading, the inferred exposure rate from the soil and grass sample seems low, which suggests a non-representative sample. As mentioned before, scattered 'hot' particles were observed on the ground at this site and it is possible that none may have been included in the limited amount of soil collected.

It should be noted that for Stockholm and Oland Island, the deposition values for ^{137}Cs probably include a substantial contribution from global weapons test fallout and should, therefore, neither be used in dose estimates nor as a basis of computing isotope ratios.

ACKNOWLEDGEMENT

David Robertson and William Rickard of Battelle Pacific Northwest Laboratories provide the in situ radiation exposure measurements in Sweden and occasionally helped in collecting samples for EML. Their cooperation is gratefully acknowledged.

REFERENCES

Beck, H. L.

'Exposure Rate Conversion Factors for Radionuclides Deposited on the Ground'
USDOE Report EML-378 (1980)

'HASL Measurements of Fallout Following the September 26, 1976 Chinese Nuclear
Test'

USDOE Report HASL-314, October (1976)

Krey, P. W., C. S. Klusek, C. Sanderson, K. Miller and I. Helfer

'Radiochemical Characterization of Chernobyl Fallout in Europe'
This Report

TABLE 1

Location: Skutskar, Sweden
 Site: 10 km east of Gavle
 Type sample: Top soil and moss cover
 single template, 750 cm², 0-2 cm
 Sampling day: May 5, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	380± 110	14000± 4000	4.6	0.33
⁹⁵ Nb	380± 110	14000± 4000	4.7	0.34
¹⁰³ Ru	2100± 600	78000± 22000	16.5	1.18
¹³¹ I	24000±7000	890000±250000	152.0	10.9
¹³² Te, ¹³² I	7000±2100	260000± 78000	280.0	20.1
¹³⁴ Cs	4000±1200	150000± 44000	101.0	7.24
¹³⁶ Cs	1200± 400	44000± 15000	41.0	2.94
¹³⁷ Cs ^b	6400±1900	240000± 70000	59.4	4.26
¹⁴⁰ Ba	4900±1500	180000± 56000	11.8	0.85
¹⁴⁰ La	5600±1700	210000± 63000	186.0	13.3
¹⁴¹ Ce	260± 80	10000± 3000	0.3	0.02
			Σ 857.0	61.4

Air exposure rate measured in situ 900.0

^a Decay-corrected to sampling day.

^b Estimate 40 nCi/m² or 1500 Bq/m² prior to Chernobyl, based on 1983 depth distributions observed in U. S. soils.

TABLE 2

Location: Soderfors, Sweden
 Site: Field between main road and water body
 Type sample: Scythed grass (1 m²)
 Sampling day: May 5, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	40± 4	1500± 100	0.5	0.03
⁹⁵ Nb	51± 3	1900± 100	0.6	0.05
¹⁰³ Ru	214± 8	7900± 200	1.7	0.12
¹³¹ I	1320±80	48800±3000	8.3	0.60
¹³² Te, ¹³² I	429± 8	15900± 300	17.2	1.23
¹³⁴ Cs	512± 8	18900± 300	13.6	0.98
¹³⁶ Cs	140± 8	5200± 300	4.8	0.34
¹³⁷ Cs	825± 8	30500± 300	7.7	0.55
¹⁴⁰ Ba	990±80	36600±3000	2.4	0.17
¹⁴⁰ La	1150±80	42500±3000	38.3	2.74
¹⁴¹ Ce	50± 4	1800± 100	0.05	0.004
			Σ 95.0	6.8

^a Decay-corrected to sampling day.

TABLE 3

Location: Soderfors, Sweden

Site: Field between main road and water body

Type sample: Moss-covered soil underneath scythed grass
9 cores, 558 cm², 0-5 cm

Sampling day: May 5, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	120± 80	4400± 3000	1.4	0.10
⁹⁵ Nb	200± 40	7400± 1500	2.5	0.18
¹⁰³ Ru	1600±160	59200± 5900	12.6	0.90
¹³¹ I	20000±800	740000±30000	126.0	9.06
¹³² Te, ¹³² I	6000±400	220000±15000	240.0	17.2
¹³⁴ Cs	2400±100	89000± 4000	61.0	4.37
¹³⁶ Cs	800± 80	30000± 3000	27.4	1.96
¹³⁷ Cs ^b	4000±120	150000± 4000	37.1	2.66
¹⁴⁰ Ba	2560±120	95000± 4000	6.2	0.44
¹⁴⁰ La	2960± 80	110000± 3000	98.6	7.06
¹⁴¹ Ce	160± 40	5900± 1500	0.2	0.01
			Σ	613.0
			Plus Table 2	708.0
			Air exposure rate measured <u>in situ</u>	700.0

^a Decay-corrected to sampling day.

^b Estimate 40 nCi/m² or 1500(Bq/m²) prior to Chernobyl based on 1983 depth distributions observed in U. S. soils.

TABLE 4

Location: Uppsala, Sweden
 Site: 10 km southeast of the city
 Type sample: Moss-covered soil
 9 cores, 558 cm², 0-5 cm
 Sampling day: May 6, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	11± 1	410± 40	0.1	0.01
⁹⁵ Nb	40± 25	1500± 920	0.5	0.03
¹⁰³ Ru	510± 70	19000±3000	4.0	0.29
¹⁰⁶ Ru	170± 10	6300± 400	0.6	0.04
¹³¹ I	5430±140	200000±5000	34.3	2.46
¹³² Te, ¹³² I	1570±140	58000±5000	62.8	4.50
¹³⁴ Cs	740± 20	27000±1000	18.8	1.35
¹³⁶ Cs	370± 30	14000±1000	12.7	0.91
¹³⁷ Csb	1430± 20	53000±1000	13.3	0.95
¹⁴⁰ Ba	820± 80	30000±3000	2.0	0.14
¹⁴⁰ La	880± 80	32000±3000	29.3	2.10
¹⁴¹ Ce	40± 10	1500± 400	0.04	0.003
Σ			178.0	12.8

Air exposure rate measured in situ 210.0

^a Decay-corrected to sampling day.

^b Estimate 40 nCi/m² or 1500/Bq/m² prior to Chernobyl based on 1983 depth distributions observed in U. S. soils.

TABLE 5

Location: Stockholm, Sweden
 Site: East lawn of National Institute of Radiation Protection
 Type sample: Clipped new grass (1 m²)
 Sampling day: May 6, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	1.8 ±0.2	67± 7	0.022	0.0016
⁹⁵ Nb	2.0 ±0.2	74± 7	0.025	0.0018
¹⁰³ Ru	0.87±0.07	32± 2	0.007	0.0005
¹³¹ I	8.0 ±0.7	300±25	0.051	0.0036
¹³² Te, ¹³² I	0.87±0.07	32± 2	0.035	0.0025
¹³⁴ Cs	0.42±0.05	16± 2	0.011	0.0008
¹³⁶ Cs	0.09±0.05	3± 2	0.003	0.0002
¹³⁷ Cs	0.67±0.05	25± 2	0.006	0.0004
¹⁴⁰ Ba	1.3 ±0.1	48± 4	0.003	0.0002
¹⁴⁰ La	1.3 ±0.1	48± 4	0.043	0.0031
¹⁴¹ Ce	1.3 ±0.1	48± 4	0.001	0.0001
			Σ 0.22	0.015

^a Decay-corrected to sampling day.

TABLE 6

Location: Stockholm, Sweden

Site: East lawn of National Institute of Radiation Protection

Type sample: Soil with about 1 cm new grass cover
9 cores, 558 cm², 0-5 cm

Sampling day: May 6, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
¹⁰³ Ru	8± 3	300±110	0.063	0.0045
¹³¹ I	150±10	5600±370	0.948	0.0679
¹³² Te, ¹³² I	22± 8	815±300	0.880	0.0631
¹³⁴ Cs	6± 1	220± 37	0.163	0.0117
¹³⁷ Cs ^b	16± 1	590± 37	0.148	0.0106
			Σ 2.20	0.158
			Plus Table 5	2.42
			Air exposure rate measured <u>in situ</u>	30.0

^a Decay-corrected to sampling day.

^b Estimate 4 nCi/m² or 150(Bq/m²) prior to Chernobyl based on
¹³⁴Cs to ¹³⁷Cs ratio in Stockholm air, Apr. 28-30, 1986

TABLE 7

Location: Oland Island, Sweden
 Site: 10 km north of Farjestaden
 Type sample: Clipped new grass (1 m²)
 Sampling day: May 6, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	0.6±0.3	20± 10	0.007	0.0005
⁹⁵ Nb	0.8±0.2	30± 7	0.010	0.0007
¹⁰³ Ru	0.8±0.4	30± 15	0.006	0.0005
¹³¹ I	36.0±6.0	1300±220	0.228	0.0163
¹³² Te, ¹³² I	1.0±0.2	37± 7	0.040	0.0029
¹³⁴ Cs	1.4±0.1	52± 4	0.036	0.0026
¹³⁶ Cs	0.4±0.1	15± 4	0.014	0.0010
¹³⁷ Cs	2.1±0.3	78± 11	0.020	0.0014
¹⁴⁰ Ba	1.8±0.4	67± 15	0.004	0.0003
¹⁴⁰ La	2.0±0.4	74± 15	0.067	0.0048
¹⁴¹ Ce	0.6±0.3	22± 11	0.0007	0.00005
			Σ	
			0.40	0.031

^a Decay-corrected to sampling day.

TABLE 8

Location: Oland Island, Sweden
 Site: 10 km north of Farjestaden
 Type sample: Soil with about 1 cm new grass cover
 9 cores, 558 cm², 0-5 cm
 Sampling day: May 7, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	3 ± 2	110± 75	0.036	0.0026
⁹⁵ Nb	3.0± 1.5	110± 55	0.037	0.0027
¹⁰³ Ru	6.5± 1.0	240± 40	0.051	0.0037
¹³¹ I	200 ±10	7400±370	1.264	0.0906
¹³² Te, ¹³² I	75 ±10	2800±370	3.000	0.2150
¹³⁴ Cs	12 ± 1	440± 40	0.305	0.0219
¹³⁶ Cs	5 ± 2	185± 75	0.171	0.0123
¹³⁷ Cs ^b	50 ± 3	1850±110	0.464	0.0333
¹⁴⁰ La	9 ± 2	330± 75	0.300	0.0215
¹⁴¹ Ce	2.5± 1.0	90± 40	0.003	0.0002
			Σ 5.63	0.404

Plus Table 7 6.03

Air exposure rate in situ was not measured

^a Decay-corrected to sampling day.

^b Estimate 26 nCi/m² or 960(Bq/m²) prior to Chernobyl based on
¹³⁴Cs to ¹³⁷Cs ratio in Stockholm air April 28-30, 1986

TABLE 9

Location: Gavle, Sweden
 Site: 8 km east of the city in a transmission line swath
 Type sample: Moss cut from a rock
 single template, 240 cm², to bare rock
 Sampling day: May 8, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	70± 30	2600±1100	0.8	0.06
⁹⁵ Nb	140± 40	5200±1500	1.7	0.12
¹⁰³ Ru	880± 60	32000±2000	6.9	0.50
¹³¹ I	9520±100	352000±4000	60.2	4.31
¹³² Te, ¹³² I	1290± 40	47700±1500	51.6	3.70
¹³⁴ Cs	2110± 20	78100± 700	53.6	3.84
¹³⁶ Cs	510± 40	18800±1500	17.4	1.25
¹³⁷ Cs	3400± 40	126000±2000	31.6	2.26
¹⁴⁰ Ba	2170±100	80300±3700	5.2	0.37
¹⁴⁰ La	2440± 20	90200± 700	81.3	5.92
¹⁴¹ Ce	100± 20	3700± 700	0.1	0.01
			Σ 310.0	22.2

^a Decay-corrected to sampling day.

TABLE 10

Location: Tarnsjo, Sweden

Site: Salja dairy farm, 10 km north of village

Type sample: New grass, clipped from top to 5 cm
above ground, 1 m²

Sampling day: May 9, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
¹⁰³ Ru	0.36±0.02	13 ±1	0.003	0.0002
¹³¹ I	1.48±0.11	55 ±4	0.009	0.0007
¹³² Te, ¹³² I	0.27±0.03	10 ±1	0.011	0.0008
¹³⁴ Cs	0.72±0.03	27 ±1	0.018	0.0013
¹³⁶ Cs	0.17±0.02	6.2±0.7	0.006	0.0004
¹³⁷ Cs	1.14±0.02	42.2±0.7	0.011	0.0008
¹⁴⁰ Ba	0.62±0.06	23 ±2	0.001	0.0001
¹⁴⁰ La	0.73±0.06	27 ±2	0.024	0.0017
¹⁴¹ Ce	0.02±0.01	0.7±0.4	0.00002	0.000002
			Σ 0.083	0.0059

^a Decay-corrected to sampling day.

TABLE 11

Location: Tarnsjo, Sweden
 Site: Salja dairy farm, 10 km north of village
 Type sample: New grass, clipped from 5 to 1 cm
 above ground, 1 m²
 Sampling day: May 9, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	0.12±0.02	4.4±0.7	0.001	0.0001
⁹⁵ Nb	0.14±0.02	5.2±0.7	0.002	0.0001
¹⁰³ Ru	0.38±0.02	14.1±0.7	0.003	0.0002
¹³¹ I	1.37±0.06	51 ±2	0.009	0.0006
¹³² Te, ¹³² I	0.38±0.03	14 ±1	0.015	0.0011
¹³⁴ Cs	0.92±0.06	34 ±2	0.023	0.0017
¹³⁶ Cs	0.22±0.02	8.1±0.7	0.007	0.0005
¹³⁷ Cs	1.54±0.06	57 ±2	0.014	0.0010
¹⁴⁰ Ba	0.95±0.06	35 ±2	0.002	0.0002
¹⁴⁰ La	1.10±0.10	41 ±4	0.037	0.0026
¹⁴¹ Ce	0.12±0.03	4 ±1	0.0001	0.000009
			Σ 0.113	0.0081

^a Decay-corrected to sampling day.

TABLE 12

Location: Tarnsjo, Sweden
 Site: Salja dairy farm, 10 km north of village
 Type sample: Soil with about 1 cm of new grass cover
 7 cores, 434 cm², 0-5 cm
 Sampling day: May 9, 1986

Nuclide	Deposition ^a		Air Exposure Rate (Calculated)	
	(nCi/m ²)	(Bq/m ²)	(μR/hr)	(pA/kg)
⁹⁵ Zr	80± 20	3000± 700	1.0	0.07
⁹⁵ Nb	120± 20	4400± 700	1.5	0.11
¹⁰³ Ru	670± 80	24800±3000	5.3	0.38
¹³¹ I	5350±200	198000± 800	33.8	2.42
¹³² Te, ¹³² I	1100± 40	40700±1500	44.0	3.15
¹³⁴ Cs	1250± 20	46200± 700	32.3	2.31
¹³⁶ Cs	260± 20	9600± 700	8.9	0.64
¹³⁷ Csb	1980± 80	73000±3000	18.4	1.32
¹⁴⁰ Ba	1030± 80	38000±3000	2.5	0.18
¹⁴⁰ La	1190± 80	44000±3000	39.6	2.84
¹⁴¹ Ce	60± 40	2200±1500	0.1	0.004
			Σ 187.0	13.4

Plus Tables 10 and 11 187.0

Air exposure rate measured in situ 220.0

^a Decay-corrected to sampling day.

^b Estimate 40 nCi/m² or 1500/Bq.m² prior to Chernobyl based on 1983 depth distributions observed in U. S. soils.

TABLE 13

Location: Grindsjon, Sweden
 Site: ~20 km south of Stockholm
 Type sample: Air filter
 Sampling day: April 28 to 30, 1986

Nuclide	Concentration (pCi/m ³) ^a	Concentration (mBq/m ³) ^a
⁹⁵ Zr	3.6±0.4	130± 15
⁹⁹ Mo	6.4±0.6	240± 22
¹⁰³ Ru	7.2±0.7	270± 26
¹⁰⁶ Ru	2.1±0.2	78± 7
¹³¹ I	64 ±6	2400±220
¹³² Te, ¹³² I	52 ±4	1900±150
¹³⁴ Cs	12.8±1.4	470± 52
¹³⁶ Cs	4.7±0.6	170± 22
¹³⁷ Csb	24.7±2.4	910± 90
¹⁴⁰ Ba	12 ±1	440± 40
¹⁴⁰ La	10 ±3	370±110
¹⁴¹ Ce	3.8±1.3	140± 50
¹⁴⁴ Ce	2.5±0.3	92± 10

^a Decay-corrected to midpoint of sampling.

^b Estimate ≤ 0.0001 pCi/m³ or ≤ 0.004 mBq/m³ prior to Chernobyl based on New York City air data.

Figure 1. Map of Sweden showing the areas where radiation measurements were made and samples were collected for analyses at EML.

OBSERVATIONS OF CHERNOBYL FALLOUT IN GERMANY
BY IN SITU GAMMA-RAY SPECTROMETRY

C. V. Gogolak, I. Winkelmann, S. Weimer, S. Wolff and P. Klopfer

INTRODUCTION

Since 1980, the Environmental Measurements Laboratory (EML) has been involved in a cooperative research program on the application of in situ gamma-ray spectrometry to the measurement of environmental contamination with the Institute for Radiation Hygiene (Institut fuer Strahlenhygiene, ISH) of the Federal Health Office (Bundesgesundheitsamt, BGA) of the Federal Republic of Germany in Neuherberg near Munich. Following the accident at the Chernobyl power plant, ISH undertook a comprehensive program of environmental measurements, including an extensive survey of the state of Bavaria with portable germanium spectrometers. EML was invited to participate in some of these measurements during the period of June 3 to 19. This report will discuss some of the early results of that collaboration, focussing on some of the technical aspects of the application of in situ spectrometry to this contamination problem.

INTERPRETATION OF IN SITU MEASUREMENTS NEAR MUNICH

Several considerations are involved in the interpretation of in situ gamma spectral measurements, the most important of which is the assumed depth distribution of the deposited activity. This is indexed by a relaxation depth, which is the depth at which the activity falls to $1/e$ (37%) of its value at the soil surface. For freshly deposited fallout, this can usually be assumed to be small, i.e., the activity is almost a plane source and the relaxation depth is close to zero. An in situ spectrum contains peaks whose area is proportional to the primary (unscattered) gamma ray flux from individual radionuclides in the soil. For a given peak area, the inferred deposited activity will increase with the assumed relaxation depth. The primary flux per unit absorbed dose rate in air due to a particular radionuclide at 1 m above the ground is a less sensitive function of the exact depth distribution than is the primary flux per unit deposition of that radionuclide. The estimated deposition and absorbed dose rate due to the major fallout radionuclides detected in an in situ spectrum taken by ISH on May 1 are given in Table 1 for two assumed depth distributions, corresponding to two different relaxation depths, 0 cm (plane source) and 1 cm.

The differences in these values shows that the question of the depth distribution is an important one. The difference in estimated deposition is greater than the difference in estimated absorbed dose rate. Nevertheless, it is usually the case that when the assumed source geometry is correct, the total absorbed dose rate inferred from an in situ measurement will agree with an independent measurement of the total absorbed dose rate to within about 10%. In order to make this comparison, the contribution from the ^{238}U and ^{232}Th series, ^{40}K and cosmic radiation must be taken into account. The background from terrestrial gamma sources is relatively low at the Neuherberg laboratory: 13, 7, and 5 nGy/h (1.3, 0.7 and 0.5 $\mu\text{rad/h}$), respectively, for U,

Th and K as inferred from a spectrum taken on June 1 at the same location. These results are similar to those found in 1980 at a nearby location [viz., 17, 10, and 5 nGy/h (1.7, 1.0 and 0.5 μ rad/h)] (Gogolak, 1981). The average cosmic ray absorbed dose rate at 520 m altitude is $\sim$ 36 nGy/h (3.6 μ rad/h). Therefore, the total absorbed dose rate at this site on May 1, inferred from the in situ spectrum, assuming the activity is a plane source, is 817 nGy/h (81.7 μ rad/h), while that obtained assuming a 1 cm relaxation depth is 955 nGy/h (95.5 μ rad/h). The value of $\sim$ 886 nGy/h (88.6 μ rad/h) obtained with a plastic scintillometer by ISH (corrected for its 55% cosmic-ray response) at the site of the measurement, falls between these two values. The Gesellschaft fuer Strahlen- und Umweltforschung, Association for Radiation and Environmental Research (GSF, 1986), using a monitoring ionization chamber, measured a maximum of 956 nGy/h (95.6 μ rad/h) in the early morning of May 1 at a nearby site with similar background. This value is closer to that obtained from the spectrum using a 1 cm relaxation depth. These data, while not conclusive, indicate that the relaxation depth was most probably greater than zero, and are not inconsistent with a value close to 1 cm. That the fallout should penetrate relatively deeply so quickly is rather surprising given previous experience with other fallout episodes, such as that from some weapons tests conducted by the People's Republic of China in the 1970's, and merits further study.

Also shown in Table 1 are the total deposited activities obtained independently from wet and dry deposition collectors over the period April 30 to May 8 by GSF in Neuherberg (GSF, 1986). The GSF estimates that $\sim$ 80% of the fallout occurred during a rainfall on the afternoon of April 30. The time dependence of the dose rate recorded by both the BGA and the GSF confirm that the majority of the fallout was deposited in Neuherberg by May 1. A comparison of 80% of the GSF deposition values to those inferred from the in situ spectrum also indicates that the relaxation depth was close to 1 cm in Neuherberg. It is possible that since most of the fallout was deposited during a heavy rainfall in a short period of time, that this primarily wet deposition caused the activity to penetrate the soil more deeply than if the deposition were dry fallout.

Some questions naturally arise. Given that the initial relaxation depth is $\sim$ 1 cm near Munich, how much might it have changed with time in the weeks following deposition? Given that the initial soil penetration was associated with heavy rainfall, how might this vary among locations that experienced different rainfall? How might the behavior of individual radionuclides differ? Several different methods are available to study this.

INVESTIGATION OF SPACIAL AND TEMPORAL VARIATIONS IN FALLOUT DEPTH DISTRIBUTION

One means for detecting any changes in depth profile is to examine the change in primary flux at 1 m above the ground at a given location as a function of time. A series of measurements were made by ISH at the laboratory site. As most of the fallout was deposited in a relatively short time, the primary flux should decay with the half-life of the emitting radionuclide, unless that radionuclide's depth distribution were changing. Then the decay would be faster due to increased attenuation by the soil as the radionuclide penetrated deeper. An examination of this data shows that this has not occurred. For the relatively long lived cesium isotopes the primary flux at the lines 662 keV for ^{137}Cs and 604 keV for ^{134}Cs show virtually no change from May 1 to June 1. The primary flux at 364 keV for ^{131}I , 228 keV for ^{132}Te , and 668 keV for ^{132}I also appear to decay with the half-life of these radionuclides over this time period. There was evidently very little further penetration of the fallout following the initial deposition on April 30.

A comparison of the total deposition measured in a soil sample to that inferred from the in situ spectra was also made. Soil sampling, preparation and analysis is somewhat time consuming, and can be subject to errors introduced by local inhomogeneities in the fallout pattern. Nevertheless, it provides a means for verification of the value for the relaxation length chosen. On June 18, a set of three-5.5 cm diameter soil cores were taken at the ISH laboratory site and were counted at EML on June 30. In Table 2, the decay-corrected EML analysis is compared to the in situ results obtained by ISH on June 1. Overall, the agreement is quite good when a 1 cm relaxation depth is assumed. A possible exception is ^{103}Ru . The discrepancy for this nuclide could be due to the fact that ruthenium has been associated with hot particles in the Chernobyl fallout (Devell et al., 1986) so the soil sample result may only reflect local inhomogeneities in deposition which are averaged out by the in situ spectrum.

Additional confirmation of the value of the relaxation depth can be obtained from soil sample profiles. This, of course, multiplies the effort necessary in soil sampling by the number of depth fractions taken. One such profile was taken by the GSF on May 12 in Munich. The cumulative inventory below depth for ^{131}I , ^{134}Cs and ^{137}Cs (Bunzl, 1986) were fit by least squares to an exponential function to find the relaxation depths according to the method of Miller and Helfer (1985). The results, shown in Figure 1, were near 1 cm for all three radionuclides. Note that in these curves, the steeper the slope, the smaller the relaxation depth. It is interesting to note that, averaged down to 4 cm, the relaxation depth for ^{131}I does not appear significantly different from that of the cesium isotopes, and also that there does not seem to be a significant perturbation of the ^{137}Cs profile by the residual levels of this radionuclide from atmospheric weapons test fallout. However, if attention is restricted to the top 2 cm, where most of the activity lies, there is some indication that the iodine has penetrated more deeply than the cesium.

A method that can be used to check the internal consistency of an in situ spectrum with respect to an assumed depth distribution is to compare the count rates from different energy lines of the same radionuclide. If the assumed depth distribution is deeper than that which actually exists, the lower energy peak will contain more than the expected number of counts relative to those in the higher energy peak. Conversely, if the assumed depth distribution is too shallow, the lower energy peak will contain too few counts. For this technique to work well, the two gamma ray lines should be as widely spaced as possible. For the Chernobyl fallout, the possibility exists to compare the 328.8, 487.0 and 1596.5 keV lines of ^{140}La whose intensities are 20.7%, 45.9% and 95.4%, respectively. It is necessary to correct the 328.8 keV count rate for any contribution from the 328 keV (3.3%) line of ^{228}Ac , and the 487 keV count rate for the 487.5 keV (.2%) line of ^{132}I . ^{228}Ac is a member of the naturally occurring ^{232}Th series, and should be uniformly distributed in the soil. In correcting for ^{132}I , a depth distribution must be assumed. This was taken to be a constant at 1 cm. Since the corrections are relatively small, this should not introduce too large an error in the ratio. The ^{132}I areal concentrations were obtained using the 668 keV line. The ^{232}Th series concentrations were inferred from the 583 keV ^{208}Tl line assuming equilibrium. The expected ratio of the counting rates of the ^{140}La lines for various depth distributions is given in Table 3. Since the detector efficiency enters into the calculation of these ratios, these values apply only for the detector used by ISH for the in situ measurements.

The ratios observed at Neuherberg in the weeks following the major fallout deposition are shown in Figure 2. The error bars are 1 σ for the

ratio of the counting errors for the full energy absorption peak counting rates, and do not include the error introduced in correcting for the interfering lines. Despite the scatter, both sets of ratios appear to support the conclusion that the depth distribution did not change significantly during this period. The correlation coefficients between the 329/1597 and 487/1597 count rate ratios and time are .4 and .5, respectively. This weak correlation, if at all significant, would imply a decrease in relaxation depth, and might only reflect the drying of the soil after the rain. The average ratio of the 329 keV line to the 1597 keV line is 0.66, which corresponds exactly to a relaxation depth of 1 cm. The 487/1597 ratio, however, is systematically higher than one would expect. The reason for this is not clear, but it may be due to an incomplete correction for the ^{132}I interference. Given the weight of the other evidence for a 1 cm relaxation depth, it is not unreasonable to assume that the 329/1597 ratio is correct.

Beginning on May 12, a survey of the state of Bavaria using in situ spectrometry was undertaken by the ISH. ^{137}Cs depositions ranging from below 6 kB/m² (162 nCi/m²) to 44 kBq/m² (1188 nCi/m²) were observed, using a 1 cm relaxation depth to analyze the data. The higher levels appear to have been associated with heavy rainfall on April 29 to May 1. The heavy rainfall also appears to be responsible for driving the fallout into the soil relatively quickly. Thus it is possible that at sites with low fallout levels, which may be primarily due to dry deposition, the relaxation depth is < 1 cm. Conversely, at locations with substantially higher deposition values, possibly due to greater amounts of rainfall, the relaxation depth may be more than 1 cm. To test this conjecture, the 329/1597 and 487/1597 ^{140}La count rate ratios were computed for the data obtained at 29 locations between May 12 and May 16. These are plotted against ^{134}Cs deposition in Figure 3. The ratios of the intensities of the La lines both indicate that there may be some slight correlation between depth distribution and the level of fallout. The correlation coefficients between these ratios and ^{134}Cs deposition were -.7 and -.5 for the 487 and 329 lines, respectively. As more data are analyzed, it should be possible to determine if this trend is significant.

The ^{137}Cs deposition was not used to index the total amount of fallout, because of the uncertainty in the pre-existing levels of this radionuclide at different locations. The level of ^{137}Cs in Germany remaining from atmospheric weapons tests is estimated to be 2 to 5 kBq/m² (54 to 135 nCi/m²) at totally undisturbed locations. At many sites the surface contamination levels could be much lower due to grading, plowing, or other disturbances. To see to what extent the remaining ^{137}Cs from atmospheric weapons tests may be contributing to the totals observed in Bavaria, one may examine the $^{134}\text{Cs}/^{137}\text{Cs}$ ratio as a function of observed ^{134}Cs deposition. In most measurements of Chernobyl fallout this ratio is 0.5 to 0.55. If there is a substantial "background level" of ^{137}Cs at any location, it should be more apparent when the Chernobyl fallout levels are low and be evidenced by a depressed $^{134}\text{Cs}/^{137}\text{Cs}$ activity ratio. Figure 4 indicates that there is little, if any, effect of residual ^{137}Cs on these ratios. The correlation of the $^{134}\text{Cs}/^{137}\text{Cs}$ activity ratio with ^{134}Cs deposition is only .5. The observed ratios all fall within the expected range. The average ratio was .55, the value observed in most media at Neuherberg.

DEVELOPMENT AND TESTING OF RAPID FIELD SURVEY METHODS

During the period of June 6 to 11, EML participated in field surveys of Kelheim, Chieming, Berchtesgaden-Engedey and Bad Reichenhall. The latter two locations had some of the highest fallout levels measured in Bavaria. These

surveys afforded us the opportunity to test some new data analysis equipment that was under development at EML at the time. In field surveys, it is important to be able to analyze data as quickly as possible, particularly in an emergency, because the results at one site can help to determine those areas that will be most profitable to study, and unusual circumstances can be investigated immediately. Manual analysis for a few radionuclides is always possible, but for a complete analysis of a spectrum, to obtain the total artificial and natural gamma dose rate, for example, access to a computer is desirable. A small battery operated computer was programmed with an adaptation of the EML spectral analysis software, which was enhanced to automatically seek, identify and analyze unusual (i.e., other than natural or ^{137}Cs) peaks in the spectrum. The objective was to determine if a relatively simple approach could provide the required results rapidly in the field even when the spectrum was rather complicated. The program was modified in Neuherberg to incorporate the calibration factors for the detector in use for these surveys. The spectra were also analyzed by ISH on the laboratory computer following normal procedures. The results of these analyses, together with the total absorbed dose rates measured with a scintillation dosimeter, are shown in Table 4.

A comparison of the two sets of results indicates that the new system worked reasonably well. In some cases, gamma-ray lines close together in energy were not resolved by the software, and manual adjustments were necessary. There appear to be some differences for ^{134}Cs depositions at the locations with high fallout levels. Neighboring peaks in the spectrum may have interfered with the background subtraction subroutine, causing these peak areas to be underestimated. The analysis for natural radionuclides uses fixed energy boundaries in determining the background for the peaks involved. In the presence of the large number of gamma-ray lines from the Chernobyl fallout, the background could have been overestimated and so the contribution of natural radionuclides could also have been underestimated. Previous surveys conducted by ISH (Bundesminister des Innern, 1978) have found that the terrestrial gamma background in these areas is 35 to 50 nGy/h (3.5-5.0 $\mu\text{rad/h}$). The results for the natural radionuclides using the normal analysis procedure are not yet complete.

Normally, one does not rely on a completely automated analysis of spectral data, but supplements this with option for interactive analysis and verification by a knowledgeable operator. Such an option is built into spectral analysis programs in routine use at EML and ISH. Because of time constraints, it was not possible to incorporate an interactive section to the code used by the portable system before these surveys. When this addition is completed, the above analyses will be re-examined in detail. Six other spectra from the survey of Bavaria covering a range of deposition values were also recorded on microdisk to aid in developing the new software, but have not yet been examined.

Overall, the agreement between the absorbed dose rates determined from the spectra and those determined using a scintillation dose rate meter is reasonably good. The totals from the standard analysis, using the values from the automated analysis for the contribution of natural radionuclides, are somewhat closer to the dosimeter totals, primarily because of the differences in the estimated ^{134}Cs contributions.

CONCLUSIONS

During the brief period of time available for these studies, several interesting phenomena involving the application of in situ spectrometry to the measurement of the environmental contamination from this accident have been examined, and a number of questions of scientific importance have emerged. As with all such occurrences, the opportunity must be used to increase the base of knowledge for the future. In this regard, it is clear that much research has already begun to improve our understanding of the movement of radioactivity in the environment, but more remains to be done.

REFERENCES

Bundesminister des Innern

'Die Strahlenexposition von aussen in der Bundesrepublik Deutschland durch natuerliche radioaktive Stoffe im Freien und in Wohnungen'
Report of the Ministry of the Interior, Federal Republic of Germany (1978)

Bunzl, K.

Gesellschaft fuer Strahlen- und Umweltforschung (GSF), Private Communication (1986)

Devell, L., H. Tovedal, U. Bergstrom, A. Appelgren, J. Chyssler, and L. Andersson

'Initial Observations of Fallout from the Reactor Accident at Chernobyl'
Nature, 321, 192-193 (1986)

Gogolak, C. V.

'Calibration of a Ge(Li) Spectrometer for In Situ Measurements'
ISH-Bericht 6, Bundesgesundheitsamt, Neuherberg, Federal Republic of Germany (1981)

GSF, Gesellschaft fuer Strahlen- und Umweltforschung

'Umweltradioaktivitaet und Strahlenexposition in Suedbayern durch den Tschernobyl-Unfall'

GSF Bericht 16/86, Neuherberg, Federal Republic of Germany (1986)

Miller, K. M. and I. K. Helfer

'In Situ Measurements of ^{137}Cs in Natural Terrain'

'Proceedings of the Eighteenth Midyear Topical Symposium of the Health Physics Society' Colorado Springs, Colorado, pp. 243-250 (1985)

TABLE 1
DEPOSITION AND ABSORBED DOSE RATE AT NEUHERBERG, MAY 1

Nuclide	Deposition						Absorbed Dose Rate in Air			
	0 cm		1 cm		Cum. ^a		0 cm		1 cm	
	(kBq/m ²)	(nCi/m ²)	(kBq/m ²)	(nCi/m ²)	(kBq/m ²)	(nCi/m ²)	(nGy/h)	(μrad/h)	(nGy/h)	(μrad/h)
^{99m} Tc	3	81	6	162	-	-	1	0.1	2	0.2
¹³² Te	45	1216	100	2703	120	3243	41	4.1	54	5.4
¹³⁶ Cs	1	27	3	81	4	114	13	1.3	13	1.3
¹³¹ I	34	919	72	1946	92	2486	58	5.8	73	7.3
¹⁰³ Ru	9	243	18	486	27	730	19	1.9	23	2.3
¹⁴⁰ Ba	6	162	12	324	12	324	4	0.4	4	0.4
¹³⁴ Cs	5	135	10	270	10	270	30	3.0	39	3.9
¹³⁷ Cs	9	243	18	486	19	514	23	2.3	26	2.6
¹³² I	53	1432	107	2892	-	-	523	52.3	610	61.0
¹⁴⁰ La	5	135	9	243	-	-	44	4.4	50	5.0
Total	170	4595	355	9595	-	-	756	75.6	894	89.4

^a Cumulative wet and dry deposition 4/30-5/8 (GSF, 1986).

TABLE 2
CHERNOBYL FALLOUT NEAR MUNICH ON JUNE 1

Nuclide	<u>In Situ Spectrum</u>		<u>Soil Sample</u>	
	1 cm relax. depth (kBq/m ²)	(nCi/m ²)	(3 5.5 cm cores) (kBq/m ²)	(nCi/m ²)
¹⁴¹ Ce	-	-	0.3±0.1	8± 3
¹³¹ I	5	135	5.4±0.4	146±11
¹⁰³ Ru	11	297	14.8±0.1	400± 3
¹⁴⁰ Ba	1.7	46	2.2±0.5	59±14
¹³⁷ Cs	15.9	430	16.1±0.1	435± 3
⁹⁵ Nb	-	-	0.3±0.04	8± 1
¹³⁴ Cs	9.7	262	8.8±0.1	238± 3
¹³⁶ Cs	0.6	16	1.0±0.2 ^a	27± 5 ^a
¹⁴⁰ La	2.2	59	2.0±0.2	54± 5

^a Includes ¹⁰⁶Rh.

TABLE 3

EXPECTED RATIO OF COUNTING RATES AS A FUNCTION OF RELAXATION DEPTH

Relaxation depth (cm):	0.0	0.1	1.0	2.0	3.0
329 keV/1597 keV:	0.77	0.73	0.66	0.62	0.60
487 keV/1597 keV:	1.24	1.18	1.11	1.05	1.02

TABLE 4
 ABSORBED DOSE RATES IN AIR AND DEPOSITIONS IN BAVARIA^a
 (1 cm RELAXATION DEPTH)

Nuclide		Location															
		Kelheim				Chieming				Berchtesgaden				Bad Reichenhall			
		(nGy/h)	(kBq/m ²)	(μrad/h)	(nCi/m ²)	(nGy/h)	(kBq/m ²)	(μrad/h)	(nCi/m ²)	(nGy/h)	(kBq/m ²)	(μrad/h)	(nCi/m ²)	(nGy/h)	(kBq/m ²)	(μrad/h)	(nCi/m ²)
¹³¹ I	A:	4	(3.0)	0.4	(81)	2	(1.8)	0.2	(49)	5	(5.2)	0.5	(141)	5	(4.8)	0.5	(130)
	B:	3	(3.0)	0.3	(81)	2	(2.2)	0.2	(59)	5	(5.3)	0.5	(143)	5	(4.7)	0.5	(127)
¹⁰⁶ Ru	A:	12	(10.0)	1.2	(270)	10	(7.6)	1.0	(205)	33	(26.8)	3.3	(72.4)	27	(21.5)	2.7	(581)
	B:	13	(10)	1.3	(270)	10	(7.5)	1.0	(203)	33	(26)	3.3	(89)	27	(21)	2.7	(568)
¹⁰⁶ Rh	A:	2	(3.7)	0.2	(100)	2	(3.6)	0.2	(97)	5	(10.0)	0.5	(270)	4	(8.9)	0.4	(241)
¹³⁴ Cs	A:	29	(7.4)	2.9	(200)	30	(7.5)	3.0	(203)	98	(24.8)	9.8	(670)	68	(17.1)	6.8	(462)
	B:	37	(8.3)	3.7	(224)	35	(7.7)	3.5	(208)	122	(26)	12.2	(703)	96	(21)	9.6	(568)
¹³⁶ Cs	A:	4	(0.7)	0.4	(19)	3	(0.6)	0.3	(16)	6	(1.1)	0.6	(30)	3	(0.6)	0.3	(16)
¹³⁷ Cs	A:	19	(13.0)	1.9	(351)	19	(13.1)	1.9	(354)	63	(43.2)	6.3	(1168)	52	(35.9)	5.2	(970)
	B:	17	(13)	1.7	(351)	19	(14)	1.9	(378)	60	(44)	6.0	(1189)	50	(37)	5.0	(1000)
¹⁴⁰ La	A:	8	(1.4)	0.8	(38)	4	(0.8)	0.4	(22)	16	(3.0)	1.6	(81)	12	(2.3)	1.2	(62)
	B:	8	(1.4)	0.8	(38)	4	(0.7)	0.4	(19)	16	(2.9)	1.6	(78)	12	(2.3)	1.2	(62)
¹⁴⁰ Ba	A:	0.3	(0.9)	0.03	(24)	0.2	(0.5)	0.02	(14)	1	(2.2)	0.1	(59)	1	(3.0)	0.1	(81)
	B:	0.3	(0.85)	0.03	(23)	0.3	(0.8)	0.03	(22)	1	(2.0)	0.1	(54)	1	(2.0)	0.1	(54)
²³⁸ U		4		0.4		17		1.7		8		0.8		10		1.0	
²³² Th		7		0.7		12		1.2		7		0.7		11		1.1	
⁴⁰ K		8		0.8		10		1.0		6		0.6		10		1.0	
Cosmic (est.)		36		3.6		36		3.6		36		3.6		36		3.6	
Total	A:	133		13.3		145		14.5		284		28.4		239		23.9	
	B:	139		13.9		150		15.0		305		30.5		265		26.5	
Dosimeter total ^b		148		14.8		156		15.6		295		29.5		261		26.1	

^a Depositions shown in parentheses.

^b 17 nGy/h added to reading to account for incomplete cosmic ray response.

Note:

A: Automated portable computer analysis.

B: standard analysis procedure.

Figure 1. Depth profiles of Chernobyl fallout in Munich on May 12. Profiles are given for ^{134}Cs (x), ^{137}Cs (o) and ^{131}I (+).

Figure 2. Time dependence of the peak area ratios for ^{140}La lines: x denotes the peak area ratio of the 329 keV line to the 1597 keV line; and o denotes the peak area ratio of the 487 line to the 1597 keV line.

Figure 3. Spatial dependence of the peak area ratios for ^{140}La lines, with total ^{134}Cs deposition used to index the total amount of fallout: x denotes the peak area ratio of the 329 keV line to the 1597 keV line; and o denotes the peak area ratio of the 487 line to the 1597 keV line.

Figure 4. ^{134}Cs to ^{137}Cs activity ratios as a function of total ^{134}Cs deposition.

INTERNATIONAL DATA EXCHANGE AND COOPERATIVE RESEARCH

Philip W. Krey

INTRODUCTION

During the Chernobyl nuclear crisis, scientists in Europe and all over the world were fully engaged in measurements of Chernobyl fallout in environmental samples and food to assess the potential hazards to the general population, and, if necessary, to recommend remedial action. With the crisis over, the international scientific community must begin the process of: accumulating this large data base; interpreting the trends in nuclide behavior; providing additional data to explore or verify such trends; and communicating information among researchers on the work in progress and future plans so that a complete description of the accident and its effects can be reconstructed.

This report describes the Environmental Measurements Laboratory's (EML) involvement in this process during my visit to Europe from June 7 to June 22, 1986. The purpose of the trip was to chair a session and deliver a paper at an international meeting on actinides and long lived fission products, and also to visit several European environmental research laboratories. For ease of presentation and economy of space, I have simply listed in statement form the most important issues concerning Chernobyl that arose during my visit and the cooperative research projects that EML agreed to participate in with some of our European colleagues.

The Lund Conference

The International Conference on the Low Level Measurements of the Actinides and Long Lived Fission Products in Environmental and Biological Samples was held in Lund, Sweden, June 7-11, 1986. The conference provided a week-long opportunity for the participants to discuss the Chernobyl accident. The last day of the conference was devoted to a discussion of the Chernobyl fallout results accumulated by the conferees. I presented a summary of the results of EML's investigations of Chernobyl fallout in North America that were available at that time. Those results were a brief distillation of the data presentation in the other reports of this compendium. Some of the major comments and observations made at the Conference are:

- * The dose and subsequent health risk to the population of western Europe are minimal.
- * Although fallout levels in Russia and eastern Europe are not well known, circumstances would have been much worse had there been rain immediately following the accident.

- * In an attempt to salvage some usefulness from tragic circumstances, the Chernobyl accident provides an opportunity for research with emphasis on comparison of reactor accident fallout with nuclear weapons fallout.
- * Fractionation (variation in the relative radioactive composition) of the Chernobyl fallout occurred with time and location for both fission products and the actinides.
- * There was evidence of several pulses of Chernobyl fallout in western Europe.
- * The relative amount of gaseous ^{131}I was large and variable. Dr. K. Bunzl of the Gesellschaft für Strahlen- und Umweltforschung München reported that deposited ^{131}I was distilled out of the soil back into atmosphere during daylight hours.
- * There were no reported measurements in Europe of the distribution of Chernobyl fallout with particle size.
- * The zirconium cladding of the fuel elements may have produced some fallout particles that resist standard dissolution methods for radiochemical analysis and may require special procedures.

Subsequent to the Lund conference, I visited several of Europe's leading institutions in environmental radioactivity research. While other matters of mutual interest were discussed, Chernobyl fallout received considerable attention.

National Institute of Radiation Protection and the National Research Defense Institute of Sweden

Dr. Kay Edvardson of the National Institute of Radiation Protection and Dr. Lars-Erik de Geer of the National Research Defense Institute hosted my visit. The major issues in the discussions included:

- * EML's results of analysis of samples collected in Sweden after the Chernobyl accident (Krey et al., 1986) agreed reasonably well with the Swedish results of comparable samples.
- * There was evidence of 3 plumes of Chernobyl fallout reaching Stockholm through May 10, 1986: the initial plume, another on May 5 and the last on May 9. The first two generally had similar radiochemical compositions, while the last was enriched in ^{99}Mo , ^{103}Ru , ^{106}Ru and ^{140}Ba , but was depleted in ^{141}Ce , all in relation to ^{137}Cs . An examination of the $^{103}\text{Ru}/^{106}\text{Ru}$ and $^{141}\text{Ce}/^{144}\text{Ce}$ ratios during these intervals show reasonable constancy indicating that the variability in the other nuclide ratios must be due primarily to their individual chemical and physical characteristics.
- * The gaseous/particulate ratio of ^{131}I in surface air at Stockholm increased with time offering corroborative evidence that K. Bunzl's theory on the

distillation of ^{131}I out of soil did occur at Stockholm.

- * Plutonium mass isotopic analyses of an air filter sample and a vegetation sample collected in Sweden showed that the particles in the air filter sample reflected higher uranium fuel burn-up. Assuming that the air filter sample presents a particle size distribution of Chernobyl fallout smaller than that collected in the vegetation sample, these initial Pu measurements suggest an inverse relationship between fuel burn-up and particle size. Since plutonium isotopes do not fractionate with respect to each other, a relationship with particle size would indicate that uranium fuel elements with different histories were involved in the accident.

In estimating external exposures of fallout in urban settings, allowances are usually made for shielding of the gamma-ray flux by buildings and for the composite decay of the radionuclides present. However, appropriate corrections are not made for the removal of the fallout nuclides from the building, street and road surfaces by the action of subsequent wind and rain. Exposure rate readings are being made in Sweden to estimate the magnitude of these corrections.

As part of a cooperative research effort, EML has agreed to analyze a number of the Stockholm air filter samples for plutonium, and to arrange for the mass isotopic analysis of the isolated plutonium activities. Because the plutonium mass isotopic composition is a good indicator of the uranium fuel burn-up, these data should provide unequivocal evidence about the history of the fuel elements producing the fallout during the course of the accident.

Riso National Laboratory Roskilde, Denmark

My host at the Riso National Laboratory was Dr. Asker Aarkrog. Dr. Aarkrog made a presentation of the Danish data at the Chernobyl session of the Lund Conference, which served as the basis for much of our discussion. Some of the important matters discussed included:

- * EML's analysis of a soil sample collected at Roskilde, Denmark (Krey et al., 1986) agreed reasonably well with Riso's analysis of Chernobyl fallout in the area.
- * An analysis of Chernobyl fallout collected on board ship in the Baltic Sea and of dust recovered from a truck in east Poland showed higher ^{241}Am , ^{242}Cm and ^{243}Cm ratios to $^{239+240}\text{Pu}$ at the more distant location in the Baltic Sea. This trend is reversed for the $^{239+240}\text{Pu}/^{137}\text{Cs}$ ratio.

The activity ratio of ^{90}Sr (considered a refractory nuclide) to ^{137}Cs (considered a volatile) was higher in the truck dust from east Poland than in the Baltic Sea sample.

The $^{89}\text{Sr}/^{90}\text{Sr}$ activity ratio in grass at the Riso National Laboratory was about 10 times higher than the ratio found in air filter samples in Finland (Finnish Centre for Radiation and Nuclear Safety, 1986).

These results are in general agreement with the hypothesis developed in another report in this compendium (Krey et al., 1986), which suggests that small particles and volatile radionuclides are enhanced in the upper altitudes

of the initial Chernobyl plume and large particles and refractory nuclides are enhanced at lower altitudes. The data also suggests that fuel elements with higher burn-up produced the fallout at greater distances (smaller particles) from Chernobyl and fuel elements with less burn-up produced the fallout (larger particles) closer to Chernobyl.

The average population dose for Denmark during the year following the Chernobyl accident is estimated to be about $200 \mu S^*$ or about 10% of background radiation. About one half of this dose is from external exposure and one half from internal exposure, ~ 75% of the latter being contributed by ^{137}Cs .

Atomic Energy Research Establishment, Harwell, England

Roger Cambray of the Environmental and Medical Sciences Division arranged for my visit to Harwell. In discussions with Mr. Cambray and his colleagues the following points were especially important:

- * Air filter samples at Chilton showed that the first Chernobyl fallout plume that reached England peaked on May 2, and a second peak, two orders of magnitude lower in concentration occurred on May 7. The $^{137}Cs/^{134}Cs$ ratios of the two peaks were 1.5 and 1.7, respectively.
- * On May 8 the $^{137}Cs/^{134}Cs$ ratio abruptly changed and with a few exceptions it remained at 1.8 or above through May 30, indicating a change in the history of fuel elements producing the fallout.
- * From May 11 the daily air concentration generally increased and reached a maximum on May 25 when it approximated the value of the second peak of May 8. The ^{103}Ru concentrations relative to ^{134}Cs were enriched from May 18 on as compared to earlier Chernobyl debris. Some consideration was given to the possibility that this gradually increasing air concentration may reflect the rearrival of the upper altitude cloud from the initial explosion at Chernobyl after its first circumnavigation of the globe. However, the $^{137}Cs/^{134}Cs$ and $^{103}Ru/^{134}Cs$ ratios do not completely support that possibility.
- * R. Cambray enlisted the cooperation of the British Foreign Service to collect soil samples at the Embassies and Consulates around the world including eastern Europe.
- * Dr. John Garland is using the Chernobyl fallout as an opportunity to study and model the process of dry deposition to building surfaces.
- * R. Cambray is attempting to estimate the global deposit of ^{137}Cs from the Chernobyl accident from the ^{134}Cs and ^{137}Cs analysis of soil samples. EML agreed to cooperate in this study by providing soil samples reasonably spaced across the North American continent, 12 of these samples have already been sent to Dr. Cambray.

All of these locations are sites where ion exchange columns or total precipitation collectors are exposed in EML's global fallout monitoring

network. At sites with total precipitation collectors, direct comparisons between EML's ^{137}Cs measurements in the rain samples with AERE's ^{137}Cs measurements in the soil samples will be possible. At sites with ion exchange columns, indirect comparisons will be possible between EML's measurements of ^{89}Sr and ^{90}Sr in the columns and AERE's ^{137}Cs measurements in the soil, provided that characteristic $^{89}\text{Sr}/^{137}\text{Cs}$ and $^{90}\text{Sr}/^{137}\text{Cs}$ activity ratios of Chernobyl debris can be established.

REFERENCES

- Finnish Centre for Radiation and Nuclear Safety
'Radiation Situation in Finland from 5 to 16 May 1986'
Second Interim Report, STUK-B-VALO 45, Helsinki, May (1986) .
- Krey, P. W., C. S. Klusek, C. G. Sanderson, K. M. Miller and I. K. Helfer
'Radiochemical Characterization of Chernobyl Fallout in Europe' .
This report

MEASUREMENT OF CHERNOBYL FALLOUT ACTIVITY IN GRASS AND SOIL AT CHESTER, NEW JERSEY

Mona Dreicer,* Irene K. Helfer, and Kevin M. Miller

INTRODUCTION

In assessing the exposure to man from radionuclides in the environment, it is important to determine how much of the material is inhaled and ingested by the population. For ^{131}I , in most cases, the principle pathway of exposure is from the consumption of milk. The concentration of the ^{131}I in milk is dependent on the concentration of fallout in the pasture grass that milk producing cows consume. The fraction of fallout that is intercepted and ultimately retained by the pasture grass is affected by the physical and chemical makeup of the fallout, the weather conditions, and the biomass density of the pasture. In attempts to further characterize how ^{131}I is intercepted and retained by natural pasture under wet and dry deposition conditions, samples were taken at the Environmental Measurements Laboratory's (EML) monitoring site at Chester, NJ in May and June of 1986 when the radioactive air mass resulting from the Chernobyl accident was over the north-eastern area of the United States. Results of dry and wet deposition measurements taken at Chester during this time period are presented in Larsen et al. (1986) and Juzdan et al. (1986).

Indigenous grass samples were taken in an area near to a local New Jersey dairy farm. It can be assumed that the activity found on these grass samples is similar to what would be on the grass that the cows would consume. Under normal pasture conditions, cows graze the grass down to about 5 cm above the soil surface, therefore, the samples that were collected were cut in two height strata so the concentration of ^{131}I on the portion of the grass that the cows ingest could be determined. The activity found in milk from a nearby farm is discussed by Klusek et al. (1986).

METHODS

The grass samples were taken in the area around EML's Chester site. In this area, the grass had not been cut during the 1986 growing season and was not mowed until after these samples were taken.

* Mona Dreicer is an employee of Lawrence Livermore National Laboratory, temporarily assigned to EML.

Twenty-three 30.5 cm by 30.5 cm plots were sampled from May 5 to June 24, 1986. The first samples, May 5 and 6, are not reported because no activity was detected. Two samples were taken from each plot: (a) from the ground surface to 5 cm above the ground (bottom), and (b) from 5 cm above the ground to the top of the grass (top). The 5 cm cut-off was chosen to approximate the level to which cows eat grass under normal pasture conditions (Morrison, 1958). The grass samples were transported back to the Laboratory in plastic bags and the wet weight was measured as soon as possible. In some cases, the grass was oven-dried at $\sim 100^{\circ}\text{C}$ and re-weighed. The average ratio of wet to dry weight was used to estimate the dry weight of the samples where no dry weight was available.

Before the grass samples were counted, they were mixed thoroughly and placed into 600 cm³ reentrant beakers. The grass was analyzed prior to oven drying, which would have volatilized the ^{131}I in the sample. The counting occurred 1 to 7 days after sampling. Depending on the counting statistics of the sample, the counting time varied from 2 to 24 hours using a 22% efficient germanium lithium (GeLi) gamma-ray spectrometer. The detectors are attached to a 4000 channel analyzer and the peak analysis was performed using a Hewlett Packard 9825 computer (Gogolak and Miller, 1977). There is an estimated systematic uncertainty of 5% in the measured concentration for ^{131}I , ^{137}Cs and ^{103}Ru ; and 10% for ^{134}Cs . For radionuclides with no discernable peak, a lower limit of detection was determined from 4.7 N, where N is the number of counts in the continuum in a 3 keV bank around the peak energy channel (Volchok and de Planque, 1983).

To measure total deposition, four 62 cm² cores of soil were taken to a depth of 5 cm in the plot after the grass was sampled in the plot. The cores were broken up and mixed before being packed into 600 cm³ reentrant beakers and then counted for ~ 72 hours.

RESULTS AND DISCUSSION

The activity per unit area for ^{131}I , ^{137}Cs , ^{134}Cs and ^{103}Ru are presented in Tables 1 through 4. The data are decay corrected to the day of sampling. Table 5 presents the wet, dry and calculated dry weights of the grass samples. To calculate the dry weight for samples for which an actual measurement was not made, the ratio of dry to wet weight for the samples dried was averaged and used as a conversion factor [top: 0.2752 ± 0.0702 dry/wet; bottom: 0.3993 ± 0.1294 dry/wet]. We assumed that the biomass density of the pasture has an effect on the fraction of fallout that is intercepted. It was expected that the biomass would increase during the growing season and that the biomass on the top would become consistently greater than that of the bottom sample as the grass continued to grow. However, there appears to be no trends in biomass through time or between top and bottom samples. This is probably due to the variability in natural pasture and the limited number of samples taken.

Grass-to-milk transfer models sometimes require the activity as a function of biomass of the forage. For convenience, the data is presented in activity/kg of dry grass in Tables 6 through 9.

In general, the activity per kg of grass for the four radionuclides was higher on the top of the grass until about May 20, after which the activity on the lower portion usually surpassed the top. This shows that the activity on the two strata does vary and that the height of the grass that the cows consume could be an important consideration in the pathway analysis. However, in many cases there is no significant differences between the two strata. This could be due to the large counting errors or it would indicate that the activity distributes evenly on the grass.

The activity of ^{131}I /kg dry grass is plotted versus the sampling day in Figure 1 (for the top) and Figure 2 (for the bottom). The error bars are $\pm 1 \sigma$ standard deviation, which is reported as percent error on Table 1. The first peak of activity is seen on the top of the grass on May 12 and 13. After a small drop in the activity on the 14th, it remained high until the 19th. The bottom grass activity rises gradually until a peak on May 19. There is a drop again after a rainstorm on June 6th. In most cases, the activity on the bottom grass sample stays higher than the top for the rest of the monitoring time period. The drop in activity on the 14th of May may be influenced by the biomass of the sample being somewhat greater and the deposition per unit area being slightly lower. The larger rainstorms that occurred on May 20 and June 6 probably washed the activity that had accumulated on the top into the bottom of the grass. This accumulated activity and additional activity deposited after this point, probably kept the ^{131}I level in the bottom part higher than on the top. Detailed rainfall data is presented elsewhere in this compendium (Juzdan, 1986).

The data for ^{137}Cs , ^{134}Cs , and ^{106}Ru follow similar trends as those described for ^{131}I . The ^{137}Cs activity found on the top and bottom of the grass is presented on Figures 3 and 4.

Table 10 presents the total inventory of ^{131}I , ^{106}Ru and ^{134}Cs found in the grass and the soil samples taken from the same plot on May 23 and June 3. From this data, the total deposition estimate can be inferred. ^{137}Cs is not included in the table because it includes the activity deposited due to global weapons fallout. The other radionuclides are only a result of the deposited fallout that had occurred during May and June. The fraction of the deposited fallout that the grass retained on the two days the soil was sampled is between 0.28 and 0.34 for ^{131}I and ^{134}Cs , respectively. For ^{106}Ru the fraction is as high as 0.47. These values have large errors due to small amounts of activity present and the small number of samples taken.

In general, the variability of the data presented here could be due to the variation in deposition, differences in biomass density, error introduced by calculating dry weights for some samples, counting errors, low levels of activity, small sample size, or variation in chemical and physical form of the deposited activity through time. Replicate samples would have helped to quantify the variability, however, it was not possible to process the optimum number of samples.

SUMMARY

In an attempt to gather more data on the interception and retention of ^{131}I in natural pasture grasses, the activity deposited from the contaminated air mass resulting from the Chernobyl accident in May and June of 1986 was measured on pasture grass in Chester, New Jersey. In some cases, the activity differed between the top and bottom strata of the grass, which indicates that it is important to take into account these differences when estimating the amount of ^{131}I consumed by the milk-producing cows. Rainfall appears to have some effect on the amount and distribution of the activity of the grass.

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REFERENCES

- Gogolak, C. V., and K. M. Miller
'New Developments in Field Gamma-Ray Spectrometry'
USDOE Report EML-332 (1977)
- Morrison, F. B.
'Feeds and Feeding'
Morrison Publishing Company, Ontario, Canada (1958)
- Volchok, H. L. and G. de Planque
'Environmental Measurements Laboratory Procedures Manual'
USDOE Report EML-300, 26th Edition (1983)

TABLE 1

¹³¹I ACTIVITY ON GRASS SAMPLES COLLECTED AT CHESTER, NEW JERSEY
DURING MAY AND JUNE OF 1986

Date	Top			Bottom		
	(mCi/km ²)	(MBq/km ²)	% error	(mCi/km ²)	(MBq/km ²)	% error
5/09	0.067	2.48	45	0.011	0.41	18
5/10	0.120	4.44	30	0.187	6.92	33
5/12	0.496	18.35	11	0.225	8.32	08
5/13	0.253	9.36	13	0.251	9.29	06
5/14	0.482	17.83	13	0.166	6.14	43
5/15	0.353	13.06	16	0.287	10.62	16
5/16	0.557	20.61	15	0.337	12.47	18
5/17	0.219	8.10	18	0.616	22.79	10
5/19	0.487	18.02	17	0.411	15.21	26
5/21	0.185	6.85	25	0.292	10.80	17
5/22	0.127	4.70	05	0.191	7.07	20
5/23	0.226	8.36	24	0.341	12.62	26
5/26	0.321	11.88	24	0.302	11.17	19
5/28	0.141	5.22	41	0.145	5.36	34
5/29	0.076	2.81	29	0.134	4.96	22
5/30	0.128	4.74	29	0.047	1.74	55
6/03	0.109	4.03	29	0.209	7.73	24
6/09	<0.076	<2.81 ^a	-	<0.142	<5.25	*
6/13	<0.064	<2.37	-	0.065	2.41	62
6/18	<0.133	<4.92	-	0.033	1.22	67
6/24	<0.074	<2.74	-	<0.091	<3.37	*

^a For nuclides with no discernable peak, a lower limit of detection was determined from $4.7 N$, where N is the number of counts in continuum in a 3 keV band at a peak energy (Volchok and de Planque, 1983).

TABLE 2

¹³⁷Cs ACTIVITY ON GRASS SAMPLES COLLECTED AT CHESTER, NEW JERSEY
DURING MAY AND JUNE OF 1986

Date	Top			Bottom		
	(mCi/km ²)	(MBq/km ²)	% error	(mCi/km ²)	(MBq/km ²)	% error
5/09	<0.028	<1.04 ^a	*	<0.030	<1.11	*
5/10	<0.060	<2.22	*	<0.002	<0.074	*
5/12	0.020	0.74	95	0.048	1.78	77
5/13	0.061	2.26	44	0.043	1.59	30
5/14	<0.103	<3.99	*	<0.108	<4.00	*
5/15	0.091	3.37	42	0.140	5.18	31
5/16	0.191	7.07	36	0.077	2.85	48
5/17	0.072	2.66	39	0.254	9.40	17
5/19	0.195	7.21	35	0.060	2.22	70
5/21	0.100	3.70	32	0.123	4.55	23
5/22	0.097	3.59	37	0.107	3.96	29
5/23	0.162	5.99	23	0.112	4.14	36
5/26	0.082	3.03	45	0.175	6.48	19
5/28	0.092	3.40	47	0.090	3.33	39
5/29	0.085	3.14	31	0.144	5.33	24
5/30	0.052	1.92	42	0.123	4.55	29
6/03	0.080	2.96	45	0.223	8.25	23
6/09	0.038	1.41	26	0.085	3.14	28
6/13	0.037	1.37	46	0.057	2.11	68
6/18	<0.068	<2.52	*	0.077	2.85	22
6/24	0.071	2.63	76	0.061	2.26	31

^a For nuclides with no discernable peak, a lower limit of detection was determined from 4.7 N, where N is the number of counts in continuum in a 3 keV band at a peak energy (Volchok and de Planque, 1983).

TABLE 3

¹³⁴Cs ACTIVITY ON GRASS SAMPLES COLLECTED AT CHESTER, NEW JERSEY
DURING MAY AND JUNE OF 1986

Date	Top			Bottom		
	(mCi/km ²)	(MBq/km ²)	% error	(mCi/km ²)	(MBq/km ²)	% error
5/09	0.034	1.25	59	<0.030	1.12	*
5/10	<0.005	<0.19	*	<0.040	1.48	50
5/12	<0.087	<3.22 ^a	*	<0.082	<3.03	*
5/13	0.038	1.41	68	0.010	0.37	60
5/14	<0.102	<3.79	*	<0.108	<4.00	*
5/15	0.056	2.07	64	<0.082	3.03	*
5/16	0.080	2.96	41	0.092	3.40	41
5/17	0.048	1.78	54	0.100	3.70	43
5/19	0.061	2.26	48	0.060	2.22	70
5/21	0.083	3.07	34	0.071	2.63	31
5/22	0.061	2.26	56	0.071	2.63	42
5/23	0.044	1.63	66	0.079	2.92	32
5/26	0.043	1.59	42	0.084	3.11	37
5/28	<0.090	<3.14	*	0.093	3.44	28
5/29	0.026	0.96	38	0.098	3.63	24
5/30	0.051	1.89	43	0.065	2.40	46
6/03	0.051	1.89	55	0.098	3.63	31
6/09	0.048	1.78	85	0.075	2.78	41
6/13	<0.060	<2.22	*	0.072	2.66	42
6/18	0.069	2.55	39	0.024	0.89	29
6/24	0.025	0.93	60	0.036	1.33	47

^a For nuclides with no discernable peak, a lower limit of detection was determined from $4.7 N$, where N is the number of counts in continuum in a 3 keV band at a peak energy (Volchok and de Planque, 1983).

TABLE 4

^{106}Ru IN GRASS SAMPLES COLLECTED IN CHESTER, NEW JERSEY DURING
MAY AND JUNE 1986

Date	Top			Bottom		
	(mCi/km ²)	(MBq/km ²)	% error	(mCi/km ²)	(MBq/km ²)	% error
5/09	<0.058 ^a	<2.15	*	<0.018	<0.66	*
5/10	<0.019	<0.70	*	<0.02	<0.74	84
5/12	<0.087	<3.22	*	<0.082	<3.03	*
5/13	0.034	1.26	62	0.030	1.11	30
5/14	0.067	2.48	57	0.069	2.55	58
5/15	0.046	1.70	65	0.064	2.37	52
5/16	0.083	3.07	66	0.038	1.41	79
5/17	0.038	1.41	58	0.109	4.03	32
5/19	0.066	2.44	55	<0.115	<4.26	*
5/21	0.046	1.70	46	0.087	3.22	28
5/22	0.064	2.37	55	0.082	3.03	34
5/23	0.145	5.36	28	0.131	4.85	35
5/26	0.058	2.15	57	0.129	4.77	27
5/28	0.061	2.26	69	0.061	2.26	46
5/29	0.058	2.15	47	0.147	5.44	28
5/30	0.066	2.44	39	0.161	5.96	29
6/03	0.069	2.55	45	0.183	6.77	22
6/09	0.040	1.48	28	0.131	4.85	23
6/13	<0.060	<2.22	*	0.063	2.33	43
6/18	0.075	2.76	27	0.048	1.78	27
6/24	0.042	1.55	88	0.073	2.70	27

^a For nuclides with no discernable peak, a lower limit of detection was determined from $4.7 N$, where N is the number of counts in continuum in a 3 keV band at a peak energy (Volchok and de Planque, 1983).

TABLE 5
WEIGHT OF GRASS SAMPLES COLLECTED AT THE CHESTER, NEW JERSEY
DURING MAY AND JUNE 1986^a

Date	Top (g)		Bottom (g)	
	Wet	Dry	Wet	Dry
5/09	56.62	15.6 ^b	65.3	11.3
5/10	36.56	10.1 ^b	64.4	25.7 ^b
5/12	60.71	16.7 ^b	40.1	16.2
5/13	31.30	8.6 ^b	43.3	17.3 ^b
5/14	89.51	24.6 ^b	47.5	19.0 ^b
5/15	49.55	13.6 ^b	42.0	16.8 ^b
5/16	86.19	23.7 ^b	50.7	20.2 ^b
5/17	29.25	8.1 ^b	91.0	36.3 ^b
5/19	113.67	31.3 ^b	40.5	16.1
5/21	132.62	36.5 ^b	145.2	58.0 ^b
5/22	39.13	10.8 ^b	49.1	9.1
5/23	106.48	29.3 ^b	74.5	29.7 ^b
5/26	91.56	25.2 ^b	31.8	15.4
5/28	69.43	15.5	25.7	11.8
5/29	37.82	10.4 ^b	22.6	13.1
5/30	57.18	14.3	28.2	14.0
6/03	36.19	9.4	33.7	14.1
6/09	49.70	13.7 ^b	26.3	10.5 ^b
6/13	32.10	8.8 ^b	33.3	13.3 ^b
6/18	50.00	15.5	19.8	6.7
6/24	70.30	21.0	26.3	11.0

^a The grass was sampled above 5 cm off the ground (Top) and from the ground surface to 5 cm (Bottom).

^b Calculated by multiplying the wet weight by the average dry to wet weight ratio of samples where the weight data was available; top = 0.2752 ± 0.0702 ; bottom = 0.3993 ± 0.1294 .

TABLE 6

¹³¹I ACTIVITY/g OF DRY GRASS COLLECTED DURING
MAY AND JUNE 1986 AT CHESTER, NEW JERSEY^a

Date	Dry Grass			
	Top		Bottom	
	(pCi/g)	(Bq/kg)	(pCi/g)	(Bq/kg)
5/09	0.40	14.8	0.09	3.3
5/10	1.10	70.7	0.68	25.0
5/12	2.76	102.0	1.29	47.7
5/13	2.73	101.0	1.35	49.9
5/14	1.82	67.3	0.81	30.1
5/15	2.40	89.0	1.59	58.8
5/16	2.18	80.7	1.55	57.2
5/17	2.53	93.5	1.57	58.3
5/19	1.45	53.5	2.37	87.7
5/21	0.47	17.4	0.47	17.3
5/22	1.10	40.5	1.95	72.1
5/23	0.72	26.5	1.07	39.4
5/26	1.18	43.8	1.82	67.4
5/28	0.85	31.3	1.14	42.2
5/29	0.68	25.1	0.95	35.2
5/30	0.83	30.8	0.31	11.5
6/03	1.08	39.9	1.38	50.9
6/09	<0.52	<19.1	<1.26	<46.5
6/13	<0.67	<24.9	0.45	16.8
6/18	<0.80	<29.5	0.46	17.0
6/24	<0.33	<12.1	<0.77	<28.4

^a % error values for this data is shown on Table 1.

TABLE 7

¹³⁷Cs ACTIVITY/g OF GRASS COLLECTED AT CHESTER, NEW JERSEY
IN MAY AND JUNE OF 1986^a

Date	Dry Grass			
	Top		Bottom	
	(pCi/g)	(Bq/kg)	(pCi/g)	(Bq/kg)
5/09	<0.17	<6.2	<0.25	<9.1
5/10	<0.55	<20.4	<0.01	<0.3
5/12	0.11	4.1	0.28	10.2
5/13	0.66	24.3	0.23	8.5
5/14	<0.39	<14.4	<0.53	<19.6
5/15	0.62	22.9	0.78	28.7
5/16	0.75	27.7	0.35	13.1
5/17	0.83	30.7	0.65	24.0
5/19	0.58	21.4	0.35	12.8
5/21	0.25	9.4	0.20	7.3
5/22	0.84	31.0	1.09	40.4
5/23	0.51	19.0	0.35	12.9
5/26	0.30	11.2	1.10	39.1
5/28	0.55	20.4	0.71	26.2
5/29	0.76	28.1	1.02	37.8
5/30	0.34	12.5	0.82	30.2
6/03	0.79	29.3	1.47	54.4
6/09	0.26	9.5	0.75	27.8
6/13	0.39	14.4	0.40	14.7
6/18	<0.41	<15.1	1.07	39.5
6/24	0.31	11.6	0.52	19.1

^a % error values for this data is shown on Table 2.

TABLE 8

¹³⁴Cs ACTIVITY/g OF GRASS SAMPLES TAKEN
AT CHESTER, NEW JERSEY IN MAY AND JUNE OF 1986^a

Date	Dry Grass			
	Top		Bottom	
	(pCi/g)	(Bq/kg)	(pCi/g)	(Bq/kg)
5/09	<0.20	<7.5	<0.25	<9.2
5/10	<0.05	<1.7	0.15	5.4
5/12	<0.48	<17.9	<0.47	<17.4
5/13	0.41	15.2	0.05	1.99
5/14	<0.39	<14.3	<0.53	<19.6
5/15	0.38	14.1	<0.45	<16.8
5/16	0.31	11.6	0.42	15.4
5/17	0.55	20.5	0.26	9.5
5/19	0.18	6.7	0.35	12.8
5/21	0.21	7.8	0.11	4.2
5/22	0.53	19.5	0.72	26.8
5/23	0.14	5.2	0.25	9.1
5/26	0.16	5.9	0.51	18.7
5/28	<0.54	<20.0	0.73	27.1
5/29	0.23	8.6	0.69	25.7
5/30	0.33	12.3	0.43	16.0
6/03	0.50	18.6	0.65	23.9
6/09	0.33	12.1	0.66	24.5
6/13	0.63	23.4	0.41	15.0
6/18	0.41	15.3	0.33	12.3
6/24	0.11	4.11	0.30	11.3

^a % error values for this data is shown on Table 3.

TABLE 9

¹³⁴Ru ACTIVITY/g OF GRASS SAMPLES TAKEN
AT CHESTER, NEW JERSEY IN MAY AND JUNE OF 1986^a

Date	Dry Grass			
	Top		Bottom	
	(pCi/g)	(Bq/kg)	(pCi/g)	(Bq/kg)
5/09	<0.34	<12.8	<0.15	<5.5
5/10	0.18	6.5	<0.07	<2.6
5/12	<0.48	<17.9	<0.47	<17.4
5/13	0.37	13.6	0.16	6.0
5/14	0.25	9.3	0.34	12.5
5/15	0.31	11.6	0.35	13.1
5/16	0.33	12.0	<0.17	<6.5
5/17	0.44	16.2	0.28	10.3
5/19	0.20	7.3	<0.66	<24.6
5/21	0.12	4.3	0.14	5.2
5/22	0.55	20.4	0.84	31.0
5/23	0.46	17.0	0.41	15.1
5/26	0.21	7.9	0.78	28.8
5/28	0.37	13.5	0.48	17.8
5/29	0.52	19.2	1.04	38.6
5/30	0.43	15.9	1.07	39.5
6/03	0.68	25.2	1.21	44.6
6/09	0.27	10.1	1.16	42.9
6/13	<0.63	<23.4	0.44	16.3
6/18	0.45	16.7	0.67	24.6
6/24	0.19	6.87	0.62	22.8

^a % error values for this data is shown on Table 4.

TABLE 10

ACTIVITY IN SOIL UNDER GRASS SAMPLES AND ON GRASS SAMPLES
COLLECTED AT CHESTER, NEW JERSEY

Date	Nuclide	Grass Total		% Error	Soil		% Error
		(mCi/km ²)	(MBq/km ²)		(mCi/km ²)	(MBq/km ²)	
5/23	¹³¹ I	0.567	20.979	18	1.276	47.212	44
	¹⁰³ Ru	0.276	10.212	22	0.307	11.359	56
	¹³⁴ Cs	0.176	6.512	30	0.451	16.687	85
6/03	¹³¹ I	0.318	11.766	19	0.631	23.347	27
	¹⁰³ Ru	0.252	9.324	20	0.499	18.463	25
	¹³⁴ Cs	0.149	5.513	28	0.367	13.592	25

Figure 1. ^{131}I in top of grass from Chester, NJ.

Figure 2. ^{131}I in bottom 5 cm of grass from Chester, NJ.

Figure 3. ^{137}Cs in top of grass from Chester, NJ.

Figure 4. ^{137}Cs in bottom 5 cm of grass from Chester, NJ.

MEASUREMENTS OF THE EXTERNAL RADIATION FIELD IN THE NEW YORK METROPOLITAN AREA

Kevin M. Miller and Jonas Geduldig

INTRODUCTION

In keeping with the tradition of applying its expertise in the measurement of low-level radiation during events that may be of some radiological significance, the Environmental Measurements Laboratory (EML) used its specialized instrumentation and techniques for the purpose of assessing the impact of the Chernobyl nuclear power plant accident on the New York metropolitan area. The specific purpose of the study described here was to measure any increase in the external radiation levels that occurred from the deposition of gamma-emitting isotopes associated with the accident.

METHODS

The external exposure rate due to gamma emitters in the outdoor environment was monitored using continuous recording high pressure ionization chambers (HPIC). The monitors were located at our three stations that we routinely use for background studies: Chester, NJ, EML's roof and Shoreham, NY. In addition, two extra units were placed in the field at Marlboro, NJ and Briarcliff Manor, NY shortly after the start of the accident for better geographical coverage. A map showing these five locations is presented in Figure 1.

The HPIC system is fully described in the EML Procedures Manual (Volchok and de Planque, 1983). In summary, the ion current from a 25 cm diameter, 25 atmosphere argon chamber is amplified through a temperature compensated MOSFET electrometer, digitized, and recorded every 10 s on a magnetic tape cassette. An automated computerized analysis of the cassette data provides average exposure rates over 5 min, hourly and daily time intervals. In service, the ion chamber sits atop its recorder box 60 cm above the ground and is positioned in a reasonably flat area with no obstructions within a radius of several meters. It thus provides a true measure of the open field exposure rate. The wall thickness and fill pressure of this HPIC provides a fairly flat energy response. Calibrations are performed with a certified National Bureau of Standards ^{226}Ra source and correction factors on the order of a few percent are applied depending upon the energy spectrum encountered.

Gamma ray spectral measurements were carried out in situ using a 22% efficient Ge detector and portable 4000 channel pulse height analyzer. The detector was positioned at a height of 1 m above the ground and standard EML techniques were used for calibration and data analysis (Volchok and de Planque, 1983). In order to convert the measured uncollided photon flux to a deposition estimate, we assumed a source distribution that exponentially decreased as a function of depth in the soil with a relaxation length of 0.1 cm. This corresponds to a near surface source that has only slightly diffused into the soil. This type of distribution has been used successfully in the past for estimates of fresh fission product deposition (HASL, 1976).

RESULTS AND DISCUSSION

Figure 2 shows a histogram of the mean daily exposure rates at the five locations along with daily precipitation data at two of the sites. The exposure rate includes the cosmic-ray equivalent, which at these locations is estimated to currently range between 3.7 and 4.0 $\mu\text{R/h}$ (0.27 to 0.29 pA/kg). Since the first traces of fallout in the New York area were not picked up until May 8 (see other sections of this report), we were able to acquire several days of natural background levels at the two extra locations, Marlboro and Briarcliff Manor, where we had no previous data.

It is apparent from the data in Figure 2 that no appreciable increase in gamma-ray levels can be seen at any of the locations during the first few weeks following the accident when most of the radioisotopes would have settled out or been scavenged from the troposphere. The small changes in the levels can be attributed to variations in natural background that result mainly from soil moisture, which acts as an attenuating medium to the terrestrial component of the radiation field, and which varies over time. The variations are most prominent at the Chester site because the gamma component from natural radionuclides in the soil there is two to three times higher than at any of the other sites. At Chester, there was the additional effect of snowmelt and runoff in late April that produced a pronounced rise in background from a depressed level to what would normally be expected in the early spring, based on 10 yr of monitoring data from this site.

The precipitation data shown at the bottom of Figure 2 for Chester and New York City can be taken as an indicator of when significant fallout might have occurred if the debris bearing cloud was present. The signature of a fresh fission product deposition is a rise in the exposure rate during the precipitation event followed by an exponential decay to normal background levels over the course of a few weeks. The Chinese nuclear weapons test fallout in October 1976 produced a pronounced increase in the open field exposure rate in the New York area that measured up to 4 $\mu\text{R/h}$ (0.3 pA/kg) at some locations (HASL, 1976). The only significant rise that can be seen in the exposure levels in Figure 2 occurred during dry spells. This effect is seen routinely this time of year and is caused by evaporation of water from the soil. (With the exception of evaporation of standing water, this effect is not seen on the gravel and tar base of EML's roof.) The precipitation events cause a leveling off or an actual decrease in exposure levels as the soil is recharged with water.

The fact that no exposure rate increase could be detected in this data set is consistent with the small amounts of deposition that were measured in precipitation collectors, grass and soil samples in the area (see other sections of this report). As an independent check, several in situ gamma-ray spectra were taken at various times during this period on the EML roof and at Chester. These spectra, accumulated over periods of 30 to 160 min each, did not show any evidence of fresh fission products until late May. Table 1 presents the results of a final pair of spectra taken at these two sites that show some small amount of deposition. Taking into account other isotopes that were detected in small quantities in rainwater and on grass, the total exposure rate from all Chernobyl fallout products in the New York area is estimated to have totaled $< 0.1 \mu\text{R/h}$ (7 fA/kg) at its maximum. Since this fallout was spread out in time in the form of several precipitation events and episodes of dry deposition, it would not be discernible in the ion chamber data.

ACKNOWLEDGEMENTS

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REFERENCES

'HASL Measurements of Fallout Following the September 26, 1976 Chinese Nuclear Test'

USERDA Report HASL-314 (1976)

Volchok, H. L. and G. de Planque (Editors)

'EML Procedures Manual'

USDOE Report EML-300, 26th Edition (1983)

TABLE 1

DEPOSTION ESTIMATES FROM in situ SPECTRA

Location	Date	^{131}I		1 σ Error (%)	^{103}Ru		1 σ Error (%)
		(mCi/km ²)	(Bq/m ²)		(mCi/km ²)	(Bq/m ²)	
EML Roof	May 20	0.84	30	<u>+36</u>	0.16	5.9	<u>+100</u>
Chester	May 23	0.84	30	<u>+45</u>	0.40	15.0	<u>+43</u>

Figure 1. Map of Greater New York Area showing location of five ion chamber exposure rate monitors.

Figure 2. Average daily exposure rates recorded at five monitoring sites and daily precipitation data from two sites.

PARTICLE SIZE DISTRIBUTION OF CHERNOBYL RELATED AEROSOLS IN NEW YORK CITY

Ronald H. Knuth and Colin G. Sanderson

INTRODUCTION

The accident at the nuclear power plant near Chernobyl, U.S.S.R. on April 26, 1986 released large amounts of radioactive aerosols and gases into the atmosphere. The atmospheric transport of this radioactive release was predicted to impact on the east coast of the United States sometime in early May.

The Aerosol Studies Division of the Environmental Measurements Laboratory (EML) is currently studying the size distribution and deposition characteristics of nonradioactive contaminants in the Northeast aerosol through the use of hi-volume impactors. On May 9th, a Sierra impactor was set up on the roof of EML in an attempt to sample the radioactive aerosols released during the accident at the Chernobyl power plant. From May 9-12 we collected an integrated impactor sample of the first detectable activity from the Chernobyl accident during the period of maximum concentration in the New York City area. This is substantiated by the daily concentration values reported by Larsen et al. (1986) and Leifer et al. (1986) who collected total air and gaseous ^{131}I samples, respectively, during the same time period at the same New York City sampling site.

This paper presents the particle size distribution characteristics of the ^{131}I , ^{134}Cs and ^{137}Cs nuclides that were determined from this single impactor sample.

SAMPLING PROCEDURES AND ANALYSIS

The Sierra Model 235 five stage slotted impactor with a Microsorban back-up filter was housed in a General Metal Works GMW-8500 aluminum shelter. The impactor air flow rate was set at $0.85 \text{ m}^3/\text{min}$, and maintained constant by a Sierra Model 310 flow controller. At this flow rate, the individual stage 50% cut-off diameters for unit density particles were: S-1, $8.3 \mu\text{m}$; S-2, $3.45 \mu\text{m}$; S-3, $1.73 \mu\text{m}$; S-4, $1.07 \mu\text{m}$; S-5, $0.58 \mu\text{m}$; and the back-up filter collected all particles $<0.58 \mu\text{m}$ (Knuth, 1979a).

The impaction substrates used for this experiment were slotted Whatman #41 filter papers treated with mineral oil. The oiled filter minimizes particle rebound and reentrainment, which has been found in previous impactor evaluations to bias impactor size distribution measurements towards smaller sizes (Knuth, 1979b). The impaction substrates were removed from the impactor and cut in half for analysis. One quarter of the back-up filter was used for analysis. The samples were compressed into plastic tubes and analyzed with a high resolution gamma-ray spectrometer. The gamma-ray detector used was a 86 cm^3 HPGe detector with a 1.5 cm diameter well.

RESULTS AND DISCUSSION

Table 1 contains the results of the impactor analyses. The concentrations reported are the decay corrected values taking into account the nuclide half-life. They have been calculated from the mid-point of counting time to the mid-point of the sample collection. The concentrations are given in mBq/m³ and fCi/m³ and the error in %. The larger counting errors associated with the concentrations of ¹³⁴Cs and ¹³⁷Cs in the upper impactor stages (larger particle cut-off) should be noted. The counting error values that range from 6 to 50% are dependant on concentration and sample counting times. The larger error values associated with the upper impactor stages are not considered significant as a change in these low concentrations does not affect the activity distributions.

Figures 1, 2 and 3 depict the plotted size distribution of ¹³¹I, ¹³⁴Cs and ¹³⁷Cs, respectively, which were generated from the data in Table 1. The particle diameter, d_p , represents the size of a unit density sphere with aerodynamic characteristics that are identical to a sampled particle. The normalized activity distribution function $\Delta A / \Delta \log d_p$ is plotted as the ordinate value; where ΔA is the activity concentration of the nuclide in a given size range (d_p min to d_p max) and $\Delta \log d_p$ is the difference ($\log d_p$ max minus $\log d_p$ min) of the particle size interval.

In the histogram plots, the area under the curve between any two particle diameters is proportional to the fraction of the sampled particulate activity in that defined size interval. These block type histograms are only approximations of the actual smooth curve distributions and assume the particles are uniformly distributed in $\log d_p$ in each size range. The lower and upper particle diameter limits have been set to 0.05 and 40.0 μ m, respectively, although the true distribution would have contained some particles above and below these values (Davidson, 1977; Milford and Davidson, 1985).

An iteration method (Twomey, 1975) was used to develop smooth curve estimations of the distributions of the three nuclides and they are plotted over the histogram distributions shown in Figures 1 to 3. We have also calculated the geometric mean (GMD) and activity median aerodynamic (AMAD) diameters for the three nuclides (Table 2).

DISCUSSION OF RESULTS

The values given in Table 1 show that >88% of the ¹³¹I, >93% of the ¹³⁴Cs, and >92% of the ¹³⁷Cs activity was associated with particles equal to or smaller than 0.58 μ m the 50% cut-off size of the 5th impactor stage. The activity median aerodynamic diameter (AMAD) for each of the nuclides falls somewhere below the 50% cut-off diameter of 0.58 μ m for the fifth and final impactor stage. For this reason, it is difficult to determine the true AMAD of this data. Also, the distributions are not truly log-normal and use of the graphical method of plotting the data on log-probability paper to determine the particle diameter at the 50% intercept is highly dependent on the fit of the data points to a straight line.

In Table 2 we have listed the AMAD and GMD values calculated for our data using two different particle size limits (0.05 to 40 μ m) and (0.2 to 40 μ m). We have also listed the values recently published by Bondietti and Brantly (1986) who ran similar impactor measurements during approximately the same time period at Oak Ridge Tennessee. Bondietti and Brantly list the 5th stage cut-off diameter at 0.41 μ m, which is consistent with the Sierra impactor operating at ~ 1.13 m³/min. However, no reference is given for the method they used to determine the value for the AMAD.

It is interesting to note that for our data the change in our assumed limits does affect the AMAD and GMD values that are calculated and our values at the 0.20 to 40 μm limits are somewhat lower than the values reported by Bondietti and Brantly. They also estimate that $\sim 40\%$ of the airborne ^{131}I was aerosol associated if they assume that their gaseous ^{131}I measurements were 100% efficient. If we take the average gaseous ^{131}I reported by Leifer et al. for May 9-12 (590 fCi/ m^3), and assume that our ^{131}I aerosol value for this time period of (375 fCi/ m^3) is entirely particulate, we find approximately the same value (39%) for our New York City measurements.

SUMMARY

Using a Hi-volume impactor, we sampled radioactive particulates in New York City that were released by the Chernobyl accident. These measurements showed that $\sim 90\%$ of the ^{131}I , ^{134}Cs and ^{137}Cs particulates were equal to or less than 0.58 μm in diameter. The activity associated with the three nuclides agreed closely with measurements of other investigators who did total air measurements over the same time interval at the same location.

REFERENCES

Bondietti, E. A. and J. N. Brantly

'Characteristics of Chernobyl Radioactivity in Tennessee'

Nature, 322, 313 (1986)

Davidson, C. I.

'The Deposition of Trace Metal-Containing Particles in the Los Angeles Area'

Powder Technology, 18, 117 (1977)

Knuth, R. H.

'Calibration of a Modified Sierra Model 235 Slotted Cascade Impactor'

USDOE Report EML-360 (1979a)

Knuth, R. H.

'Comments on Inertial Impactor Calibration and Use'

in: Aerosol Measurement Lundgren, Harris, Marlow, Lippmann, Clark

and Durham (Editors), University of Florida Press, Gainesville (1979b)

Larsen, R., C. G. Sanderson, W. T. Rivera and M. Zamichieli

'The Characterization of Radionuclides in Global Surface Air and Deposition
Following the Chernobyl Accident'

This report

Leifer, R., I. K. Helfer, K. M. Miller and S. Silvestri

'Concentrations of Gaseous ^{131}I in New York City Air Following the Chernobyl Accident'

This report

Milford J. B. and C. I. Davidson

'The Sizes of Particulate Trace Elements in the Atmosphere - A Review'

J. Air Pollut. Control Assoc., 35, 12 (1985)

Twomey, S.

'Comparison of Constrained Linear Inversion and an Iterative Algorithm Applied to the Indirect Estimation of Particle Size Distribution'

J. Computational Phys. 18, 188 (1975)

TABLE 1

CONCENTRATIONS OF PARTICULATE ^{131}I , ^{134}Cs and ^{137}Cs
IN NEW YORK AIR (MAY 9-12, 1986)

Stage	^{131}I			^{134}Cs			^{137}Cs		
	Concen. Error ^a			Concen. Error ^a			Concen. Error ^a		
	(mBq/m ³)	(fCi/m ³)	(%)	(mBq/m ³)	(fCi/m ³)	(%)	(mBq/m ³)	(fCi/m ³)	(%)
1	.22	6.0	9	.006	.16	48	.01	.35	50
2	.39	10.5	7	.02	.44	17	.03	.80	32
3	.49	13.2	6	.07	1.8	30	.12	3.2	16
4	.50	13.5	8	.17	4.5	21	.35	9.5	11
5	1.26	34.1	6	.65	17.6	9	1.13	30.6	7
BU-F ^b	11.0	298	6	3.1	83.6	16	4.81	130	11
Total	13.9	375	-	4.0	108	-	6.4	174	-

^a Two sigma counting error

^b Back-up filter

TABLE 2

AMAD AND GMD VALUES FOR ^{131}I , ^{134}Cs , ^{137}Cs NUCLIDES

Reference	Limits (μm)	Type	Nuclide diam. (μm)		
			^{131}I	^{134}Cs	^{137}Cs
This work	0.05-40	GMD	.24	.25	.26
" "	" "	AMAD	.17	.23	.25
" "	0.20-40	GMD	.38	.36	.38
" "	" "	AMAD	.26	.29	.30
Bondietti and Brantly	(N.A.)	AMAD	.37	.40	.40

N.A. = not available

Figure 1. Size distribution curves of ^{131}I from Chernobyl fallout in New York City.

Figure 2. Size distribution curves of ^{134}Cs from Chernobyl fallout in New York City.

Figure 3. Size distribution curves of ^{137}Cs from Chernobyl fallout in New York City.

CONCENTRATIONS OF GASEOUS ^{131}I IN NEW YORK CITY AIR FOLLOWING THE CHERNOBYL ACCIDENT

Robert Leifer, Irene Helfer, Kevin Miller and Susan Silvestri

INTRODUCTION

On April 26, 1986 an accident at the Chernobyl nuclear power plant released large quantities of radioactive aerosols and gases into the atmosphere. The radioactive material was transported around the globe by atmospheric winds and was expected to reach the New York City area some time in early May. The Environmental Measurements Laboratory (EML) has a historical and continuing interest in measurements of radioactivity released into the atmosphere and, therefore, set up a sampling program to characterize the composition of radionuclides in the plume from Chernobyl as they passed over New York City. These data will ultimately be used in conjunction with other measurements to assess the exposure of the population to radioactivity from Chernobyl. This paper will present gaseous ^{131}I data for air samples collected on the roof of EML during the period May 7 through June 12, 1986.

CHEMICAL FORMS OF GASEOUS ^{131}I

The major forms of gaseous ^{131}I released into the atmosphere during a nuclear power plant accident may be methyl iodide ($\text{CH}_3^{131}\text{I}$), elemental iodine ($^{131}\text{I}_2$) (Collins et al., 1966), and hypoiodous acid (HO^{131}I) (Keller et al., 1970). It has been reported that gaseous ^{131}I was the major radioactive material released into the atmosphere by the Chernobyl plant accident (Jensen and Lindhe, 1986). Measurements made in southern Bavaria showed that the gaseous iodine was split between the methyl and elemental compounds (Winkelmann et al., 1986).

SAMPLING PROCEDURE

The sampling equipment used for collection of gaseous ^{131}I was located on the roof of EML (12 story building) in a well ventilated wood enclosure. Figure 1a is a photograph of the sampling equipment. An M14 gas mask canister, containing a double stacked high efficiency particulate aerosol (HEPA) absolute filter was used as a pre-filter to remove aerosol radioiodine from the airstream. The gas cartridge was filled with 5% coated triethylenediamine (TEDA) North American Charcoal G-618. A flow rate of 113 L/min was maintained throughout the sampling period, with a Radeco vacuum pump model H809V. Sampling times varied from ~ 24 hours to 4 days. Activated charcoal was changed after each sampling period.

ANALYSIS OF GASEOUS ^{131}I

Because of the large number of samples collected and analyzed at EML during the May-June period, the charcoal cartridges were limited to a counting period of 20 min, leading to a larger than desired counting error in some cases. Counting occurred within an hour after removal from the pump on a 22%

efficient shielded coaxial Ge(Li) gamma ray spectroscopy system. Although the geometry of this sample configuration is unlike that of our normal tuna can or reentrant beaker, the cylindrical shape of the cartridge allowed us to apply a generalized efficiency computation routine (Ren and Miller, 1983) for the ^{131}I full absorption peak at 365 keV. Since the distribution of the iodine on the charcoal within the cartridge was not expected to be perfectly uniform, our calibration cannot be expected to be exact. However, the effects of nonuniformity were lessened to some degree by inverting the cartridge midway through its counting period. From our knowledge of the variation in efficiency for a point source as a function of distance from the detector window center, we estimate that the overall systematic error for this calibration was $\pm 20\%$.

RESULTS

The charcoal cartridges were submitted for gamma counting as blind samples in the original container. In addition, three blanks were included during the month long sampling period. None of the blanks showed detectible ^{131}I . The results of 35 days of sampling from May 7, 1986 to June 12, 1986 are shown in Table 1. Included in this table are the start and stop times, the total gaseous ^{131}I collected on the coated charcoal traps and the counting error (1σ) associated with the analyses. For nuclides with no discernable peak, a lower limit of detection (reported as less than values) was determined from $4.7\sqrt{N}$, where N is the number of counts in the continuum in a 3 keV band at a peak energy (Volchok and de Planque, 1983). The data are corrected to the middle of the sampling period and are reported in fCi/m^3 and mBq/m^3 . These data are also shown in Figure 2, with the concentration plotted at the midpoint of the sampling period. The lower limit of detection values are plotted as $0 \pm 1\sigma$.

The low counting error shown at the first peak of Figure 2 (May 10-12) is due to a longer counting time. The time integrated gaseous ^{131}I over the period May 8 through June 12 is $4.6\text{ pCi}\cdot\text{day}/\text{m}^3$ ($170\text{ mBq}\cdot\text{day}/\text{m}^3$). Almost 70% of the gaseous ^{131}I activity occurred during the first week following detection of the plume from Chernobyl. The gaseous ^{131}I in air was 70% of the total ^{131}I measured over the entire period (Larsen et al., 1986).

DISCUSSION OF RESULTS

It is well known that collection efficiencies of carbon traps for gaseous ^{131}I can vary depending on the absorption chemistry at the charcoal surface, the residence time of the gas stream in the sampling bed and the concentration and specie of the gases in the air (Collins et al., 1966). Uncoated activated charcoal is a poor collector of methyl iodide, but is excellent for elemental iodine (Collins et al., 1966). When the charcoal is coated with 5% TEDA, high collection efficiencies for methyl iodide are obtained (Collins et al., 1966). Since a sizeable fraction of the radioactive iodine in the atmosphere was in the form of an aerosol (Larsen et al., 1986) it was imperative that a high efficiency prefilter be used to remove the aerosol from the gas stream before the gas reached the absorption bed. EML's sampling equipment contained HEPA filters that are extremely efficient for removing aerosols and are typically used in the nuclear industry in sampling trains (Keller et al., 1980). In the sampling schedule set up at EML, we did not change the filter every day and there was a concern that some of the iodine could desorb from the aerosol and contribute to the gaseous iodine activity on the charcoal traps. To verify whether this was occurring in our sampling train, a second filter and trap was installed as shown in Figure 1b. This setup was used for only one-24 hour

sampling period. No detectible ^{131}I was found on the second carbon trap. More controlled experiments need to be performed to provide full assurance that the desorption of iodine from aerosol would not contribute to gaseous iodine activity on the charcoal bed. Based on our data it appears that this was not a problem during the period in which we sampled the gaseous iodine from Chernobyl.

Although no efficiency tests were conducted at EML for collection of gaseous iodine in the sampling equipment, the difference in front to back activity (40% more when counted from the front), discussed in the counting procedure, indicates a non-uniform penetration profile in the charcoal beds. Residence times in the EML charcoal bed were comparable to those found by other researchers where high collection efficiencies were reported (Langhorst and Morris, 1985).

There appears to be three distinct periods associated with the data shown in Figure 2. The first major peak occurred in the second week of May and reflects the first wave of radioactivity to impact New York City from the Chernobyl accident. The gaseous ^{131}I was detectible for many days, although the concentrations decreased with time, partly due to radioactive decay. The time history of the emissions from the Chernobyl power plant is not well defined and it is difficult to know whether the subsequent increases are due to changes in emission or to circumnavigation of the plume around the globe. Precipitation in the New York area would also play a significant role in determining the local ambient gaseous ^{131}I concentrations.

When the data from all investigators are analyzed a more coherent picture of the time history of the radionuclides in the New York City from the Chernobyl accident will emerge.

SUMMARY

Gas samples were collected on the roof of EML from May 7 through June 12, 1986. Gamma spectroscopy indicated that many of our activated charcoal air filters showed activity due to ^{131}I , which was related to emissions following the Chernobyl accident. Of the total gaseous ^{131}I activity measured during the May to June sampling period, almost 70% occurred during the first week of sampling. The total gaseous activity measured during May 7 through June 12 was 4.6 pCi.day/m³ (170 mBq.day/m³). The gaseous ^{131}I in air was 70% of the total ^{131}I measured over the entire period (Larsen et al., 1986). Based on the limited amount of samples collected and tests conducted at EML we feel that the data presented in this paper, on the average, is accurate to within an error of $\pm 30\%$.

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REFERENCES

- Collins, D. A., L. R. Taylor and R. Taylor
'The Development of Impregnated Charcoal for Trapping Methyl Iodide at High Humidity'
Proceedings of the Ninth AEC Air Cleaning Conference, Vol. 1, September (1966)
- Jensen M. and J. C. Lindh
'Activities of the Swedish Authorities Following the Fallout from the Soviet Chernobyl Reactor Accident'
National Institute of Radiation Protection, Stockholm, Sweden
Report No. 1986-05-12, Preliminary Edition (1986)
- Keller, J. H., F. A. Duce, D. T. Pence and W. J. Maeck
'Hypoiodous Acid: An Airborne Inorganic Iodine Species in Stream-Air Mixtures'
Proceedings of the Eleventh AEC Air Cleaning Conference, Vol. 2 (1970)
- Keller J. H., D. W. Akers, S. W. Duce, B. G. Motes, T. E. Cox and J. W. Tkachyk
'Measurements of ^{133}Xe , ^{14}C and Tritium in air and ^{131}I in Vegetation and Milk around the Quad Cities Nuclear Power Station, Exxon Nuclear Idaho Co., Inc.'
Technical Report NUREG/CR--1195, TI86 000134 place (1980)
- Langhorst S. M. and J. S. Morris
'Investigation of Charcoal Filters Used in Monitoring Airborn Radioactive I'
Health Physics, 48, pp. 344-347 (1985)
- Larsen, R. J., C. G. Sanderson, W. T. Rivera and M. Zamichieli
'The Characterization of Radionuclides in Global Surface Air and Deposition Following the Chenobyl Accident'
This Report
- Ren, T. and K. M. Miller,
'Application of a Semi-Empirical Ge(Li) Detector Calibration Technique for Large Volume Samples'
USDOE Report EML-409 (1983)
- Volchok, H. L. and de Planque, G. (Editors)
'EML Procedures Manual'
USDOE Report HASL-300, pp. D-08-04 to D-08-06, 26th Edition (1983)
- Winkelmann I., et al.
'Ergebnisse von Radioaktivittsmessungen nach dem Reaktorunfall in Tschernobly'
Institute for Radiation Hygiene of West German Federal Health Office,
ABE-250/ISH-99 (1986)

Table 1

CONCENTRATION OF GASEOUS ^{131}I IN NEW YORK CITY^a

Sample		Concentration		Error ^b
Start Date	Stop Date	(mBq/m ³)	(fCi/m ³)	(%)
May 7	May 8	<1.9	<70	c
8	9	1.6	40	20
9	10	18.5	500	20
10	12	23.3	630	4
12	13	20.4	550	25
13	14	9.8	265	15
14	15	8.7	235	15
15	16	8.0	215	9
16	18	5.6	150	14
18	19	5.4	145	20
19	20	3.3	90	26
20	21	1.9	50	41
21	22	1.9	50	39
22	23	<1.9	<70	c
23	27	2.7	75	14
27	28	2.7	75	28
28	29	3.0	80	29
29	30	3.3	90	29
30	June 2	2.6	70	18
June 2	3	1.5	40	52
3	4	1.1	30	52
4	5	1.1	30	50
5	6	1.1	30	63
6	10	0.4	10	50
10	11	1.5	40	52
11	12	<1.9	<70	c

^a Samples collected on the roof of EML during the period May 7 through June 12, 1986.

^b 1 σ counting error.

^c For nuclides with no discernable peak, a lower limit of detection was determined from $4.7N$, where N is the number of counts in the continuum in a 3 keV band at a peak energy (Volchok and de Planque, 1983).

a

b

Figure 1 a: Photograph of the sampling equipment used on EML's roof for the Chernobyl accident. The prefilter and the charcoal trap are shown disassembled.

b: Block diagram of the added filter and trap to evaluate the desorption of gaseous ^{131}I from the aerosol filter.

Figure 2. Concentration of gaseous ^{131}I in New York City during the sampling period May 7 through June 12, 1986. Error bars are 1σ . Arrow at April 26 marks the beginning emissions of radionuclides from the Chernobyl accident.

CONCENTRATIONS OF ^{131}I , ^{134}Cs , AND ^{137}Cs IN MILK
IN THE NEW YORK METROPOLITAN AREA
FOLLOWING THE CHERNOBYL REACTOR ACCIDENT

Catherine S. Klusek, Colin G. Sanderson and William Rivera

INTRODUCTION

The Environmental Measurements Laboratory (EML) routinely monitors radioactive fallout in milk and other diet items collected from local markets in the New York area (Klusek, 1984). During the week following the Chernobyl accident, daily samples of fresh farm milk and pasteurized dairy milk were examined by gamma-ray spectrometry for ^{131}I , ^{137}Cs and ^{134}Cs .

The main pathways by which the public is exposed to internal irradiation after an airborne release of radioactivity are ingestion of contaminated milk, drinking water and other foods, and also by inhalation of radioactive materials contained in the plume. Contaminated milk and fresh leafy vegetables from areas receiving Chernobyl fallout would be the major sources of exposure, via ingestion, immediately following the event. Milk is an important food chain link, not only for ^{131}I but also for a number of other radionuclides, because grazing cattle consume activity deposited on grass over large areas. Chernobyl fallout on grass in the New York area is described in another paper in this report (Dreicer et al., 1986). Radionuclides of iodine are readily transferred to people via milk from cows grazing on contaminated pastures. Once ingested, iodine is concentrated in the thyroid gland.

In this report we will present the results of these milk measurements. The measurements described will be supplemented by radiochemical analysis for ^{89}Sr and ^{90}Sr .

MATERIALS AND METHODS

Samples

Fresh farm milk was obtained from a dairy located in northern New Jersey, about 40 miles west of EML, during the period May 5 through June 6. The dairy has about 40 cows that were put to pasture on May 5 and remained on pasture for the entire sampling period. Supplemental feed (grain and ground corn) was also given to the cows and constituted ~ 25% of their diet. The milk samples were collected from the holding tanks after the morning milking. The milk in the tanks at the time of collection represents a mixture of the morning milking and milk from the previous evening that was not shipped to the processor.

Pasteurized dairy milk was obtained from local supermarkets in New York City. For consistency, only milk labeled with consecutive container dates (expiration date) from the same processor were purchased. These samples represent a blend of farm milk from different origins and varying times of collection. The processor obtained the milk mainly from dairies in central New York. Not all of the dairies in the milkshed area would have had their cows on pasture. However, feed lot cows would have been fed green chop. Those dairies with cows on pasture would have put the cows on pasture between mid-May and the first week of June. All cows on pasture would have received

some supplemental feed (grains, corn and possibly hay and silage). It was estimated that 5 to 7 days elapsed between the collection of the milk at the local farm and the expiration date on the container (Personal Communication, New York State Department of Agriculture and Marketing, Milk Control Division, Albany, NY).

Analysis

The samples were analyzed by gamma-ray spectrometry using high resolution germanium detectors in two different configurations: Ge(Li) and HPGe coaxials. The relative efficiencies (^{60}Co 25 cm) are 18% and 22%, respectively. The milk samples were counted in 600 cm² Marinelli (reentrant) beakers for 1000 min. For nuclides with no discernable peak, the lower limit of detection (LLD) was determined following prescribed calculations (Volchok and de Planque, 1983). Setting α , the risk of concluding falsely that activity is present, at 0.05, the LLD is equivalent to 3.3σ . The LLD of the HPGe coaxial detector was estimated to be about 8 pCi/L. Due to the detector design and resolution, the Ge(Li) coaxial detector had an LLD nearly twice as high.

Due to the number of samples, time constraints and limited availability of counters, quality control samples were minimal. The gamma ray spectrometric systems are, however, calibrated with standards traceable to the National Bureau of Standards. The accuracy of the analyses is estimated to be within $\pm 5\%$. The uncertainty in the analysis was generally 10 to 15% (coefficient of variation) for concentrations >10 pCi/L and up to 30% for samples with lower activity.

RESULTS

The results of the analyses of the fresh farm milk are shown in Table 1 in units of pCi/L and Bq/L $\pm 1 \sigma$ Poisson counting error. The less than values are the LLD previously discussed. The measurements in the fresh farm milk have been corrected for radioactive decay since the day of milking. The ^{131}I and ^{137}Cs concentrations are shown graphically in Figures 1 and 2, respectively. In the figures, the nondetectable values are shown as $0 \pm 1 \sigma$.

The pasteurized dairy milk concentrations are presented in Table 2 and Figures 3 and 4. The pasteurized dairy milk measurements have been decay-corrected to the processing date. This date was determined from the expiration date by allowing for a 96 hour shelf life following pasteurization. Pasteurized milk samples for May 28 through June 4 were not analyzed for several weeks after purchase because a suitable spectrometer was not available. The ^{131}I at the time of counting was no longer detectable and the reported values reflect a decay correction of 2 to 3 half-lives.

DISCUSSION

When considering exposure from contaminated milk, a distinction must be made between the fresh farm milk and the pasteurized dairy milk. Dairy milk, which is a blend of various sources of farm milk, need not show the same concentrations as those found in milk from a single farm. Pasteurized dairy milk purchased in New York City is a mixture of milk produced on different days from a larger geographical region which probably received differing amounts of fallout. In addition, the source farms have different feeding regimes. The cows may feed partly, or not at all, on contaminated grass and the milk produced may be diluted with uncontaminated milk at the dairy. There is usually a 2 to 3 day time loss for the milk to be processed by commercial

dairies and for delivery to the consumer, so that the short-lived nuclides in the fresh fallout have decayed to a certain degree. Previous studies have shown however, that analyzing single random samples of pasteurized milk in New York City provides a satisfactory estimate for the milk supply as a whole (Eisenbud et al., 1963).

^{131}I Concentrations

Milk collected at the farm was found to have a measurable quantity of ^{131}I by May 12. The concentrations of ^{131}I in the fresh farm milk were at their highest levels during the second week of May, reaching a maximum on the 13th and again on the 17th. Thereafter, the concentration steadily decreased. Maximum values of ~ 40 pCi/L (1.45 Bq/L) were observed. Collection of the fresh milk was discontinued after 5 weeks on June 6 at which time the levels had decreased to 25% of their peak values. Decreasing levels of deposition, together with decreasing levels of ^{131}I in the grass due to radioactive decay and weathering processes account for the reduction in the milk ^{131}I concentration. It appears that after June 2 the concentration of ^{131}I increased slightly to about 8 pCi/L (0.30 ± 0.07 Bq/L). However, because of the delay in analyzing the samples collected on May 31 and June 2 it is not possible to conclude this with certainty. It is possible that the concentration remained at about 8 ± 2 pCi/L (0.3 Bq/L) for the period May 28 to June 6. Future examination of the deposition and grass concentrations in the Chester area may help explain whether this apparent rise in the ^{131}I concentration was real.

Detectable levels of ^{131}I were first observed in pasteurized milk processed on May 15. Considering the lag between milking and processing, this is a reasonable lapse in time between the first observations of activity in the fresh milk and the pasteurized milk. The pasteurized milk reached its highest observed levels during the third week of May, 31 ± 3 pCi/L (1.1 ± 0.1 Bq/L) and decreased steadily through May 27. When counting of pasteurized milk was resumed on June 5, the ^{131}I concentration had fallen below the detectable level.

Because pasteurized milk is a blend of milk produced on different days, attempting to determine the exact date of milking corresponding to a particular processing date is impossible. However, correcting for the decay of an additional two days prior to the process day will give a rough estimate (± 1 day) of the ^{131}I concentration at milking. The concentration at milking would then be about a factor of 1.2 times the pasteurized concentrations as reported. These data are plotted along with the fresh farm milk for comparison in Figure 5. There is reasonable agreement between the two data sets with the highest concentrations of ^{131}I observed between May 11 to 19.

Early reports from Europe of ^{131}I in milk showed levels at least an order of magnitude higher than our values for the United States: a peak concentration of 41 Bq/L on May 8 in local dairy milk from Chilton, U. K. and levels of ~ 400 Bq/L in an area of the U. K. with high rainfall (Hill et al., 1986 and Fry et al., 1986); ~ 30 Bq/L peak concentration from nongrazing cows during the first and second week of May in Finland (Finnish Centre for Radiation and Nuclear Safety, 1986); 10 Bq/L from nongrazing cows in Studsvik, Sweden (Devell et al.; 1986) and ~ 20 Bq/L in dairy milk from 11 regions in Sweden during the first week of May (Jensen and Lindhe, 1986).

Integrated Activity of ^{131}I

The integrated activities in units of pCi.day/L and Bq.day/L are shown in Table 3. The integrated activity of ^{131}I in the fresh farm milk is estimated to be 360 pCi.day/L (14 Bq.day/L). This agrees reasonably well with calculated estimates of the integrated activity (Peterson and Smith, 1970) based on the peak concentration on May 13, where the integrated ^{131}I activity in milk, I_m , is related to the maximum concentration, c_m by the relation,

$$I_m = \int_0^{\infty} c_m e^{-\lambda t} dt.$$

Assuming a 5.1 day effective half-time and including a 10 to 15% contribution from activity prior to reaching the peak value, $I_m = 8 c_m$. Using the maximum concentration of 39 pCi ^{131}I /L, the integrated activity, I_m , is about 310 pCi.day/L.

By comparison, the integrated activity following the September 1976 Chinese nuclear test was 1300 pCi.day/L in fresh farm milk and an order of magnitude lower in pasteurized milk (HASL, 1976).

Estimated ^{131}I Dose to the Thyroid

Because of a smaller thyroid mass, infants receive a higher concentration and higher doses to their thyroids than adults for a given intake of ^{131}I . (Radiation dose is the energy absorbed per unit mass of irradiated tissue.) The transfer factor relating thyroid dose in infants to the integrated ^{131}I concentration in milk has been estimated at 0.0115 mrad per pCi.day/L (3 μGy per Bq.day/L) fresh milk (UNSCEAR, 1982). Using the observed integrated concentration of 360 pCi.day/L, the dose to the thyroid of infants would be about 4 mrad (40 μGy). This would be the highest individual dose in the consumption area and clearly overestimates the thyroid dose where fresh milk is a small fraction of the total milk consumed by infants. The dose to adults will be at least an order of magnitude lower (~ 0.2 mrad) because of the difference in thyroid size and daily milk consumption.

^{134}Cs Concentrations

The observed ^{134}Cs concentration in fresh farm milk in the New York area reached a level of 10 pCi/L (0.36 Bq/L). This level occurred when ^{131}I reached its peak concentration on May 17. At this time, the ^{131}I concentration was 3 to 4 times higher than the ^{134}Cs concentration, but the levels became more nearly identical by May 26. The ratios of ^{131}I to ^{134}Cs and other isotopic ratios are shown for the entire sampling period on Table 4. In pasteurized milk the concentration of ^{134}Cs was rarely above the level of detection. This compares with values reported for Chilton, U. K. of 4 Bq/L and of ~ 200 Bq/L in high rainfall areas of the U. K. (Fry et al., 1986).

^{137}Cs Concentrations

In the New York fresh farm milk, concentrations of ^{137}Cs reached their highest value on May 19, 18 pCi/L (0.66 Bq/L). The concentration then declined, but returned to about the same value on May 30, followed by a gradual decline over the remainder of the sampling period. The long-lived ^{137}Cs was present in concentrations between 17 and 35% of the ^{131}I concentra-

tion during the 2nd week of May when levels were at their highest. The ratios of $^{131}\text{I}/^{137}\text{Cs}$ are shown on Table 4 for the entire sampling period. After May 19 the $^{131}\text{I}/^{137}\text{Cs}$ was <1 (within the uncertainty of the calculations).

In pasteurized milk, measurable ^{137}Cs was not observed until May 23, 10 days later than in the fresh farm milk. In general, ^{137}Cs concentrations in the pasteurized milk never reached the levels observed in the fresh milk, however, the same general patterns were observed. The highest concentration measured was 11 pCi/L (0.4 Bq/L), but the concentration of ^{137}Cs remained at 8 ± 2 pCi/L for most of the sampling period. Because of the large number of samples with concentrations below the limits of detection, very little data are available to compute the nuclide ratios in the pasteurized milk (Table 5).

Prior to the Chernobyl accident, the levels of ^{137}Cs in pasteurized milk collected in Chicago, IL had been at or below 4 pCi/kg (the limit of detection) since 1976 (Karttunen, 1981). ^{137}Cs , with a long half-life of about 30 years, is readily transported through various food chains, and exposes man both externally from deposition on the ground and internally through ingestion of food. Following worldwide releases of radioactive fission products from nuclear weapons tests, ^{137}Cs was found in most common foods, such as milk, meat and grain products. Figure 6 shows the variation with time of the mean yearly concentrations in milk collected in Chicago for the period 1960 to 1981. Maximum concentrations of 150 pCi/kg were observed in April 1964, but dropped off rapidly following the moratorium on weapons testing.

For comparison, levels of ^{137}Cs in the U. K. have been reported at peak concentrations of ~ 2 Bq/L in farm milk (Fry et al., 1986), a factor of three higher than the values reported here. Elsewhere in the U. K., in an area receiving high rainfall, peak values of ~ 400 Bq ^{137}Cs /L have been reported (Fry et al., 1986). Concentrations of <3 Bq/L were reported in Finland for most samples analyzed during the first week of May (Finnish Centre for Radiation and Nuclear Safety, 1986).

Integrated ^{137}Cs Activity

The integrated ^{137}Cs activity in fresh farm milk was 250 pCi.day/L (9.4 Bq.day/L) (see Table 3). This is 0.7 of the integrated ^{131}I activity.

Action Levels

The purpose of an action level is to prevent acute effects of the radiation and to restrict the late effects to as few people as reasonably possible. Fairly soon after the accident (May 6) an assessment was made by the WHO, based on the reported radiation levels, that no acute radiation effects were to be expected outside of the USSR either from external exposure or from ingestion (Beninson and Lindell, 1986). All recommendations have been aimed at reducing the radiation exposure to the public.

Action levels, at which ingestion of contaminated milk should be curtailed, are given by national and international authorities in an attempt to reduce the dose to the thyroid. The response level used in the United States (FDA protective action guidance levels, PAGs) is 0.15 μCi (5600 Bq) ^{131}I /L peak milk activity, which is the level equivalent to a projected dose commitment of 15 rem (0.15 Sv) to the thyroid. At this level, responsible officials would isolate milk and determine whether condemnation or other disposition is appropriate. (Schleien, 1983).

It can be seen in Tables 1 and 2 that the ^{131}I contamination in milk in the metropolitan New York area was at least two orders of magnitude lower than these action levels.

SUMMARY

In the weeks following the Chernobyl accident fresh farm milk and pasteurized dairy milk were collected in the metropolitan New York area. Detectable levels of ^{131}I in fresh farm milk were first observed on May 12, ^{137}Cs on May 13 and ^{134}Cs on May 17. The highest concentrations measured in fresh farm milk were 40 pCi (1.47 Bq) $^{131}\text{I}/\text{L}$; 18 pCi (0.66 Bq) $^{137}\text{Cs}/\text{L}$; and 10 pCi (0.36 Bq) $^{134}\text{Cs}/\text{L}$. The integrated activities were 360 pCi $^{131}\text{I}.\text{day}/\text{L}$ and 250 pCi $^{137}\text{Cs}.\text{day}/\text{L}$ in fresh farm milk. The results of the measurements in pasteurized dairy milk purchased in New York City reflect processing time, mixture of milk from a larger geographical area and various feeding regimes. Concentrations of ^{131}I in pasteurized dairy milk were similar to fresh farm milk. ^{137}Cs and ^{134}Cs concentrations were, however, only slightly above the detection limits during the entire sampling period.

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REFERENCES

- Beninson, D. and B. Lindell
'Chernobyl Reactor Accident'
World Health Organization, Copenhagen, May (1986)
- Devell, L., H. Tovedal, V. Bergstrom, A. Appelgren, J. Chryssler,
and L. Andersson
'Initial Observations of Fallout from the Reactor Accident at Chernobyl'
Nature, 321, 192-93 (1986)
- Dreicer, M., I. K. Helfer and K. M. Miller
'Fallout Activity in Grass and Soil at Chester, NJ'
This report
- Eisenbud, M., B. Pasternack, G. Laurer and L. Block
'Variability of the ^{131}I concentration in the milk distribution system of a
large city'
Health Physics, 9, 1303-1305 (1963)
- Finnish Centre for Radiation and Nuclear Safety
'Radiation Situation in Finland from 5 to 16 May 1986'
Second Interim Report, STUK-B-VALO 45, Helsinki, May (1986)
- Fry, F. A., R. H. Clarke and M. C. O'Riordan
'Early Estimates of UK Radiation Doses from the Chernobyl Reactor'
Nature, 321, 193-195 (1986)
- 'HASL Measurements of Fallout Following the September 26, 1976 Chinese Nuclear
Test'
USERDA Report HASL-314, October (1976)
- Hill, C. R., I. Adam, W. Anderson, R. J. Ott, and F. D. Sowby
'Iodine-131 in Human Thyroids in Britain following Chernobyl'
Nature, 321, 655-656 (1986)
- Jensen, M. and J. Lindhe
'Activities of the Swedish Authorities Following the Fallout from the Soviet
Chernobyl Reactor Accident'
National Institute of Radiation Protection Report, Stockholm, May (1986)
- Karttunen, J. O.
' ^{137}Cs in Various Chicago Foods'
USDOE Report EML-390, May (1981)
- Klusek, C. S.
' ^{90}Sr in the U.S. Diet, 1982'
USDOE Report EML-429, July (1984)

Peterson, H. T. and J. M. Smith

'Guides for Predicting Thyroid Dose from Environmental Measurements following Radioiodine Releases'

in: Environmental Surveillance in the Vicinity of Nuclear Facilities, pp. 172-188, W. C. Reinig (Editor), Charles C. Thomas Publisher, Springfield, IL (1970)

Shleien, B.

'Preparedness and Response in Radiation Accidents'

Health and Human Health Services Publication FDA 83-8211, Rockville, MD, August (1983)

UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation

'Ionizing Radiation: Sources and Effects'

United Nations, New York, p. 141 (1982)

Volchok, H. L. and G. de Planque (Editors)

'EML Procedures Manual'

USDOE Report HASL-300 (26th Edition), pp. D-08-02 to D-08-05 (1983)

TABLE 1
CONCENTRATION IN FRESH FARM MILK^a

Date ^b	¹³¹ I		¹³⁷ Cs		¹³⁴ Cs	
	(pCi/L)	(Bq/L)	(pCi/L)	(Bq/L)	(pCi/L)	(Bq/L)
May 5	<7	<0.25	<8	<0.30	<5	<0.19
6	<7	<0.24	<7	<0.26	<5	<0.18
7	<7	<0.24	6+1	0.23+0.06	<8	<0.29
8	<8	<0.32	<8	<0.33	<7	<0.27
9	<10	<0.37	<8	<0.33	<8	<0.30
12	29+2	1.07+0.07	<12	<0.40	<8	<0.31
13	39+2	1.45+0.07	8+2	0.30+0.06	<7	<0.27
14	36+2	1.35+0.07	6+1	0.23+0.05	<8	<0.29
15	30+2	1.12+0.06	5+1	0.20+0.04	<5	<0.21
16	36+2	1.35+0.08	7+3	0.28+0.06	<8	<0.31
17	40+2	1.47+0.08	13+2	0.47+0.06	10 +1	0.36+0.04
19	24+2	0.88+0.07	18+2	0.66+0.06	8 +1	0.28+0.05
20	21+2	0.77+0.07	12+2	0.46+0.07	8 +1	0.29+0.05
23	17+4	0.6 +0.2	17+3	0.64+0.10	<15	<0.55
26	13+2	0.47+0.08	16+1	0.60+0.05	6 +1	0.20+0.03
27	10+2	0.38+0.06	16+2	0.59+0.06	7 +2	0.27+0.06
28	8+1	0.29+0.06	15+2	0.54+0.06	<10	<0.35
29	10+2	0.37+0.08	15+2	0.56+0.06	8 +1	0.28+0.04
30	6+2	0.23+0.08	19+2	0.70+0.07	7 +1	0.28+0.04
31	<53	<1.96	17+2	0.63+0.09	<16	<0.36
June 2	<21	<0.79	14+2	0.52+0.06	6 +1	0.23+0.05
3	8+2	0.28+0.06	15+2	0.57+0.06	<10	<0.21
4	9+2	0.32+0.08	14+1	0.52+0.04	6.5+0.8	0.24+0.03
5	7+1	0.26+0.04	11+1	0.40+0.03	5.0+0.8	0.18+0.03
6	9+2	0.35+0.08	15+2	0.56+0.07	5 +1	0.18+0.04

^a + 1 σ Poisson counting error; less than values are the LLD at $\alpha = 0.05$.

^b Date of collection, i.e., milking.

TABLE 2
CONCENTRATION IN PASTEURIZED DAIRY MILK^a

Date ^b	¹³¹ I		¹³⁷ Cs		¹³⁴ Cs	
	(pCi/L)	(Bq/L)	(pCi/L)	(Bq/L)	(pCi/L)	(Bq/L)
May 1	<7	<0.25	<9	<0.32	<7	<0.24
5	<7	<0.22	<7	<0.27	<6	<0.22
14	<12	<0.42	<11	<0.39	<7	<0.25
15	17±3	0.6 ±0.1	<8	<0.32	<6	<0.22
16	24±2	0.98±0.09	<7	<0.26	<5	<0.20
17	33±5	1.2 ±0.2	<12	<0.43	<8	<0.30
19	34±3	1.3 ±0.1	7 ±2	0.26±0.06	<8	<0.28
20	28±4	1.0 ±0.2	<17	<0.64	<12	<0.45
21	33±5	1.2 ±0.2	<12	<0.64	<10	<0.36
22	23±2	0.87±0.09	<10	<0.36	<7	<0.28
23	16±2	0.58±0.06	7 ±1	0.26±0.05	<7	<0.25
24	15±3	0.5 ±0.1	11 ±3	0.4 ±0.1	<10	<0.35
26	15±1	0.55±0.05	6.7±0.8	0.25±0.03	<4	<0.15
27	9±2	0.33±0.08	<9	<0.35	<8	<0.29
28	<82	<3.0	<16	<0.60	<10	<0.39
29	<73	<2.7	8 ±1	0.28±0.05	<8	<0.28
30	<43	<1.6	9 ±2	0.32±0.06	<8	<0.29
31	<56	<2.1	7 ±1	0.27±0.05	<9	<0.32
June 2	<53	<1.9	8 ±1	0.28±0.05	<6	<0.24
3	<25	<0.94	8.0±0.8	0.30±0.03	<4	<0.15
4	<36	<1.4	6 ±1	0.22±0.04	<7	<0.27
5	13±4	0.47±0.14	8 ±2	0.31±0.06	<7	<0.27
10	<18	<0.68	8 ±1	0.28±0.05	<8	<0.31
11	<11	<0.42	10 ±2	0.39±0.06	6 ±1	0.20±0.04
12	<13	<0.51	10 ±2	0.37±0.06	<8	<0.28
18	<18	<0.69	<10	<0.38	<6	<0.21
19	<8	<0.33	9 ±1	0.31±0.05	5 ±1	0.20±0.05
21	<7	<0.24	8.4±0.8	0.31±0.03	3.3±0.5	0.12±0.04
25	<11	<0.44	<10	<0.35	4 ±1	0.15±0.04
26	<13	<0.48	6 ±1	0.22±0.05	<8	<0.28

^a ± 1 σ Poisson counting error; less than values are the LLD at α = 0.05.

^b Processing date.

TABLE 3
INTEGRATED ACTIVITY (day/L)

Sample Type	Time Period	¹³¹ I		¹³⁷ Cs		¹³⁴ Cs	
		(pCi)	(Bq)	(pCi)	(Bq)	(pCi)	(Bq)
Fresh Farm	5/5-6/6	360	14	250	9	77	2.8
Pasteurized Dairy	5/1-6/26	320	12	137	5	18	0.7

TABLE 4
NUCLIDE RATIOS

Date	Fresh Farm Milk		
	$^{131}\text{I}/^{137}\text{Cs}$	$^{134}\text{Cs}/^{137}\text{Cs}$	$^{131}\text{I}/^{134}\text{Cs}$
May 13	5 $\pm$ 1 (20%)	-	-
14	6 $\pm$ 1 (22%)	-	-
15	6 $\pm$ 1 (21%)	-	-
16	5 $\pm$ 1 (22%)	-	-
17	3.1 $\pm$ 0.4 (14%)	0.8 $\pm$ 0.1 (17%)	4.1 $\pm$ 0.5 (13%)
19	1.3 $\pm$ 0.2 (12%)	0.42 $\pm$ 0.08 (20%)	3.1 $\pm$ 0.6 (19%)
20	1.7 $\pm$ 0.3 (18%)	0.6 $\pm$ 0.1 (23%)	2.7 $\pm$ 0.5 (19%)
23	1.0 $\pm$ 0.3 (29%)	-	-
26	0.8 $\pm$ 0.1 (19%)	0.33 $\pm$ 0.06 (17%)	2.3 $\pm$ 0.5 (19%)
27	0.6 $\pm$ 0.1 (19%)	0.5 $\pm$ 0.1 (24%)	1.4 $\pm$ 0.3 (25%)
28	0.5 $\pm$ 0.1 (23%)	-	-
29	0.7 $\pm$ 0.2 (24%)	0.50 $\pm$ 0.09 (18%)	1.3 $\pm$ 0.3 (25%)
30	0.3 $\pm$ 0.1 (36%)	0.40 $\pm$ 0.07 (17%)	0.8 $\pm$ 0.3 (35%)
June 2	-	0.4 $\pm$ 0.1 (25%)	-
3	0.5 $\pm$ 0.1 (24%)	-	-
4	0.6 $\pm$ 0.2 (26%)	0.46 $\pm$ 0.08 (15%)	1.3 $\pm$ 0.4 (27%)
5	0.6 $\pm$ 0.1 (17%)	0.45 $\pm$ 0.08 (18%)	1.4 $\pm$ 0.3 (21%)
6	0.6 $\pm$ 0.2 (26%)	0.32 $\pm$ 0.08 (25%)	2.0 $\pm$ 0.7 (33%)

TABLE 5
NUCLIDE RATIOS

Date	Pasteurized Dairy Milk	
	$^{131}\text{I} / ^{137}\text{Cs}$	$^{134}\text{Cs} / ^{137}\text{Cs}$
May 19	5 $\pm$ 1 (23%)	—
23	2.2 $\pm$ 0.5 (21%)	—
24	1.3 $\pm$ 0.4 (32%)	—
26	2.2 $\pm$ 0.3 (15%)	—
June 5	1.5 $\pm$ 0.5 (36%)	—
11	—	0.5 $\pm$ 0.1 (26%)
19	—	0.6 $\pm$ 0.2 (29%)
21	—	0.4 $\pm$ 0.1 (31%)

Figure 1. Concentration of ^{131}I in fresh farm milk.

Figure 2. Concentration of ^{137}Cs in fresh farm milk.

Figure 3. Concentration of ^{131}I in pasteurized dairy milk.

Figure 4. Concentration of ^{137}Cs in pasteurized dairy milk.

Figure 5. Concentration of ^{131}I in fresh farm milk vs. pasteurized dairy milk. Pasteurized milk concentration estimated for the day of collection.

Figure 6. Concentration of ^{137}Cs in Chicago milk, 1960 to 1981.

A STUDY OF THE COLLECTION EFFICIENCY OF GUMMED-FILM FOR FISSION PRODUCTS

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INTRODUCTION

The occurrence of Chernobyl fallout in the New York area during May, 1986, provided an opportunity to study the efficiency of gummed-film for collecting fallout particles deposited by precipitation and also to directly compare the collection efficiency for ^7Be with that for fission products. Gummed-film was used extensively for monitoring weapons fallout during the 1950's, however, its efficiency for collecting and retaining fallout, particularly under conditions of heavy rainfall, was never satisfactorily determined (Beck, 1984). Samples of gummed-film were, therefore, exposed daily during the period from early May to early June 1986 at two New York area sites. Both prior to and subsequent to this period, gummed film samples had been exposed at one of these sites as part of an ongoing study of the collection efficiency of gummed-film as a function of precipitation intensity for naturally occurring ^7Be . Data comparing the collection efficiency for Chernobyl fallout vs. ^7Be during rainfall at one of these two sites are presented here and are discussed in the context of these ongoing experiments with ^7Be .

BACKGROUND

The Environmental Measurements Laboratory (EML) is currently involved in several programs designed to reconstruct the radiation exposure of the United States population from fallout from weapons testing at the Nevada Test Site during the 1950's and early 1960's. (See recent EML's annual reports for a more detailed description.) As part of these efforts, we have been reassessing the large quantity of monitoring data collected by EML during the testing period. Most of these data were measurements of beta activity collected on gummed-film. A recent EML report describes the re-evaluation of these gummed-film data in some detail (Beck, 1984). One of the most difficult problems in reassessing these gummed-film data has been determining what the collection efficiency of the gummed-film was relative to naturally occurring deposition on soil, in particular, for wet deposition and as a function of precipitation intensity. It is generally believed that the efficiency must have been diminished under heavy rainfall conditions due to the soluble nuclides being lost as excess water flows off the surface of the film, while particulate interception and retention would have been reduced due to deterioration of the sticky surface. In order to attempt to shed some light on at least the relative collection efficiency as a function of rainfall intensity, we have been exposing film, essentially identical in its tackiness to that used in the 1950's, and in a manner similar to that used in the 1950's, to naturally occurring precipitation on the roof of the building housing EML. We then compare the naturally occurring cosmogenic ^7Be collected on the film with that collected in stainless steel pots identical to those used since the late 1950's by EML to measure fallout deposition. Although these experiments are

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giving us some useful data on the relative collection efficiency of gummed-film as a function of precipitation intensity, and other meteorological conditions, the absolute efficiencies inferred are subject to question with regard to whether or not ^7Be is a reasonable physical analogue for tropospheric weapons fallout. ^7Be is generally assumed to be in solution in rainwater and, thus, may not adequately simulate particulate fallout. Also, the retention efficiency of the gummed-film may depend on the chemical composition of the fallout, which may differ from that of ^7Be .

SAMPLING AND ANALYSIS

During the period from May 5 through early June, duplicate 640 cm² samples of gummed-film were exposed both on the roof of EML, as well as at the EML field monitoring station at Chester, New Jersey. Samples on the EML roof were exposed for ~ 24 h periods, while the Chester samples were generally exposed for 48-72 h. After exposure, samples were returned to EML where they were counted for periods of at least 1000 min on large Germanium diode gamma-ray spectrometers in order to determine individual fission product activities as well as ^7Be activity. Because of the generally small amounts of activity deposited and/or retained by the gummed-film, particularly for ^7Be , the two duplicate samples from each site were composited into a single sample for analysis. The precipitation analyses are described elsewhere in this report (Juzdan et al., 1986).

RESULTS

Unfortunately only 4 to 5 rain events occurred during this period where the precipitation and gummed-film samples each contained both sufficient fission product and ^7Be activity to make statistically significant comparisons. As shown in Table 1, which gives the results for the samples exposed on the EML roof, the measured efficiencies for ^{131}I , ^{137}Cs , and ^{103}Ru were all in reasonable agreement with that for ^7Be for 4 separate events, even though the absolute efficiency varied considerably from event to event. The uncertainties given, which are quite large, represent 1 σ counting errors only and do not include variance in collection efficiency itself. Past experience suggests sampling errors are of the order of $\pm 25\%$ for the 1280 cm² gummed-film samples and 10-15% for the 755 cm² pot samples. ^{134}Cs was also detected on some films, but not with a low enough counting error to allow reasonable comparisons with ^7Be .

Data obtained from the samples exposed at the Chester site during periods of precipitation have not been included in Table 1 since these samples, because they were generally exposed for several days, reflect a combination of both wet and dry fallout deposition, complicating their interpretation. Both the gummed-film and stainless-steel pots collected significant amounts of dry fission product deposition at various times. However, it is not clear whether the stainless steel pots collect dry fallout with 100% efficiency, and neither the film nor the pots collect sufficient ^7Be during dry periods to allow a comparison of collection efficiencies. For this reason, the data for the remaining samples from both sites, which were exposed mainly during dry periods, will also not be discussed in this report.

DISCUSSION

The deposition of both ^7Be and fission products was very small for all of these rain events, and since the individual sample uncertainties are very large and the efficiency of the film does appear to be significantly reduced for heavy rain, the few data obtained do not provide a definitive answer regarding the validity of ^7Be as a surrogate for weapons fallout. They do, however, strongly suggest ^7Be behaves in a similar manner to fallout from the Chernobyl reactor as far as its interception and retention on gummed-film is concerned. Thus, that the relative collection efficiencies for ^7Be can probably be used to estimate the variation in efficiency for weapons fallout, keeping in mind the possibility that weapons fallout may differ both physically and chemically from that produced by the Chernobyl accident. Because of the relatively low collection efficiency of gummed-film, averaging only about 20%, and the small and variable amount of ^7Be in rain, it will be necessary to accumulate data for a large number of precipitation events in order to adequately characterize the variation in efficiency as a function of rainfall intensity and type.

We expect to present the final results of these experiments, along with the complete data from the Chernobyl fallout, as part of a paper presenting the results of our re-analysis of the gummed-film and our revised fallout depositions from weapons testing at the Nevada Test Site during the 1950's, at a special symposium on fallout reconstruction to be held at the June 1987 annual meeting of the Health Physics Society.

REFERENCES

Beck, H. L.

'Estimates of Fallout from Nevada Weapons Testing in the Western United States Based on Gunned-Film Monitoring Data'

USDOE Report EML-433, October (1984)

Juzdan, Z. R., I. K. Heifer, K. M. Miller, W. Rivera, C. G. Sanderson and S. Silverstri

'Deposition of Radionuclides in the Northern Hemisphere Following the Chernobly Accident'

This report

TABLE 1

RATIO OF ACTIVITY COLLECTED ON GUMMED-FILM TO THAT COLLECTED
IN STAINLESS-STEEL POT (± 1 S.D. COUNTING ERROR)

Date (1986)	Precipitation (cm)	^7Be	^{131}I	^{137}Cs	^{106}Ru
5/8-9/86	<0.25	.34 $\pm$.12	.42 $\pm$.05	1.2 $\pm$.9	.56 $\pm$.36
5/14-15/86	.5	.07 $\pm$.04	.13 $\pm$.01	.35 $\pm$.05	.18 $\pm$.04
5/16-17/86	<.25	.43 $\pm$.06	.37 $\pm$.02	.59 $\pm$.08	.45 $\pm$.09
5/20-21/86	.8	.13 $\pm$.02	.10 $\pm$.04	.25 $\pm$.16	.50 $\pm$.35