An Investigation of the April 1986 Chernobyl Radioactivity Releases as Detected in Muncie, Indiana

William W. Wong
Cheryl A. Bye
and
David R. Ober
Department of Physics and Astronomy
Ball State University
Muncie, Indiana 47306

Introduction

On Apil 26, 1986, a severe accident at the Soviet Union's Chernobyl Unit 4 Nuclear Power Station caused an intense fire that lasted several days, melted large quantities of reactor fuel, and released into the environment a large fraction of the reactor's inventory of volatile radioactive fission products. Observers in Poland and Scandinavia were the first to trace the radioactive fallout to a source in the Soviet Union. The fallout cloud was expected to reach the United States within several weeks, so it was decided to carry out a study of the local fallout at Muncie, Indiana, following the Chernobyl accident.

Two objectives were established for this study: (1) to identify the fission products from the fallout and (2) to determine the concentrations of the fission products above the local background. Furthermore, it was hoped that comparisons could be made with concentration levels in Muncie with those in other parts of the United States and the world.

Experimental Details

A. Air Sampling Procedure

A high volume air sampler (General Metal Works model 2000 H) was used to collect the fallout debris on an asbestos-like filter paper. The fine mesh filter paper, approximately 8 × 10 in, was sufficient to capture particulate matter with sizes greater than or approximately equal to 0.3 micron. The air sampler was placed in a small enclosure at the Ball State University weather station on the Ball State campus and allowed to operate for 24 hours. During this time a volume of approximately 2000-2200 cubic meters was drawn through the filter.

After removal from the air sampler, the filters were folded and gamma-ray spectra were recorded for a 20-hour period with the high-resolution germanium detector in a standard face-to-face geometry. The detector and filter were enclosed by four inches of lead shielding to minimize the room background radiation.

The sample-acquisition and -counting procedures were repeated for approximately two months (May and June), with samples being obtained about three times a week.

A second set of five filters was obtained from the Indiana State Board of Health. These filters had been obtained from a Muncie sampling station (on top of Muncie Central High School) operated by the state. The filters were taken at six-day intervals from May 2 through May 26. Each filter had about 1800 cubic meters of air drawn through it and its radioactivity contents were determined in the same manner as the Ball State Weather Station filters.

B. Spectrometer System

FIlter activities were determined by observing gamma rays associated with the fission decay products. The gamma-ray spectrometer system included the following: a high voltage power supply, 12.5% efficient germanium detector, preamplifier, linear amplifier, and a Nuclear Data (model ND 62) 4096-channel multichannel analyzer.

The germanium detector was chosen for its superior energy resolution (2.5-keV full-width maximum at 1332 keV for Co-60). Its high resolution (compared to NaI detectors) and large peak-to-Compton ratios enabled one to identify the presence of weak gamma-ray yields and confirm their associated energies with a much smaller number of total photopeak counts than would be required with a NaI detector.

The gamma-ray energies and intensities of the photopeaks were recorded for each sample. The radioisotopes present in the samples were then identified by their known gamma-ray energies and half-lives. Comparisons were made with compilations of standard spectra as found in the Nuclear Data Tables.

C. Room Background

The natural background radiation in the room was also detected while counting the sample filters. Even though lead shielding surrounded the germanium detector, the background plus sample spectra were dominated by the room background radiation.

Present in the room background spectrum are gamma rays from the decay of K-40 present in the soil and concrete surrounding the laboratory. Most of the room background came from Tl-208, Pb-214, and Bi-214, the daughter products associated with the isotopes of radon (Rn-222) and thoron (Rn-220).

D. Germanium Detector Photopeak Efficiency

To make absolute activity determinations it was necessary to determine the germanium detector's photopeak efficiency. Calibrated standards, including Na-22, Cs-137, and Radium, from the National Bureau of Standards were used for this purpose. A photopeak efficiency curve as a function of gamma-ray energy was then obtained for the detector. Interpolations of efficiencies from this graph were used to assign the absolute activities quoted in this investigation.

Experimental Details

A. Air Filter Spectra

Shown in Figure 1 is the gamma-ray spectrum associated with an air filter sample drawn for 24 hours on May 13, 1986 at the Ball State Weather Station. The gamma-ray spectrum is for a 20-hour count period.

Photopeaks were identified for the following isotopes attributed to the Chernobyl releases: Ru-103, I-131, Cs-134, and Cs-137. Photopeak energies associated with these isotopes are 497 keV, 364 keV, 796 keV, and 662 keV, respectively. Photopeaks that have not been labeled are associated with the nautral room background; the 1460.7-keV and 2614.5-keV photopeaks of K-40 and Tl-208, respectively, are identified to assist in relative intensity and energy observations.

B. Radiation Associated with Chernobyl

Presented in Figure 2 and Table 1 are the graphical and tabulated results of detected radiation related to the Chernobyl releases. Each day's results were obtained by analyzing the gamma-ray spectrum associated with the 24-hour filter drawn on that day. In Figure 2 it should be noted that the log of activity is plotted along the y-axis as a function of time.

From the graph it can be seen that most of the radioactive fallout arrived at Ball State University on May 13, 1986, two weeks after the accident. It was for this reason that the second set of filters was obtained from the State Board of Health; these filters bracketed this period of high activity and their results are presented in Table 2.

Clearly the I-131 is characteristic of the Chernobyl accident, but it is also evident that the other isotopes detected in this investigation (Ru-103, Cs-134, and Cs-137) reached maximum activity level (20 times above normal background) at the same time as did

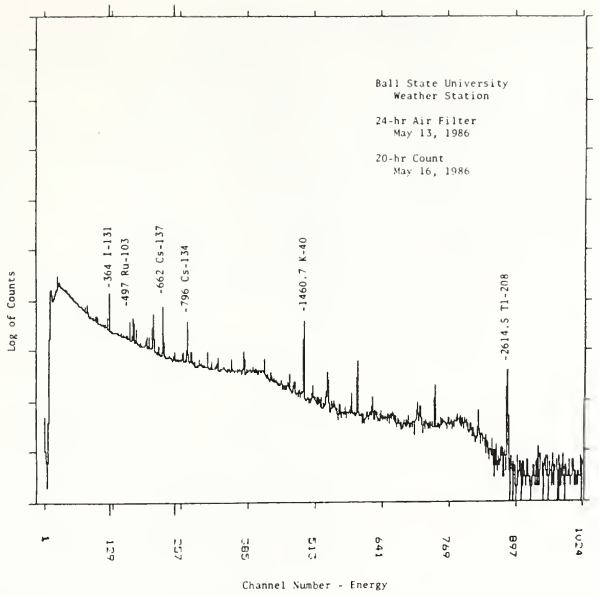

FIGURE 1. A gamma-ray spectrum acquired from a 20-hr count of the filtered particulat air sample taken at the Ball State Weather Station; identified activities are labeled by th parent nuclide and energies are expressed in keV. The isotopes associated with the Che nobyl releases are Ru-103, I-131, Cs-134, and Cs-137.

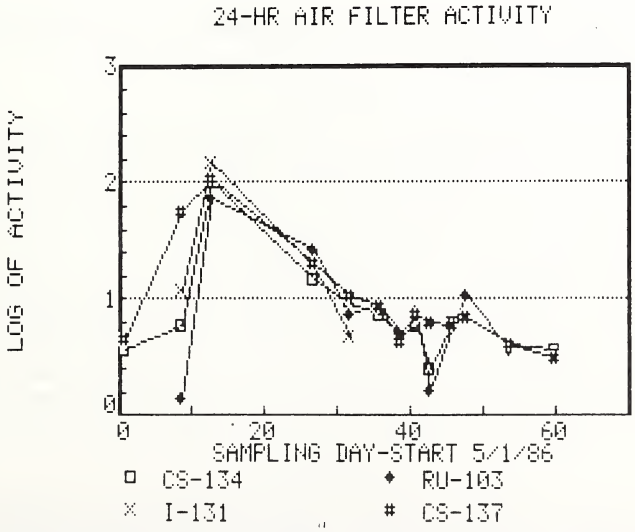

FIGURE 2. Daily activities of the Chernobyl related fallout in Muncie (Ball State Weat Station) from May 1 to June 29, 1986. Presented in Table 1 is the numerical data sho in this figure.

TABLE 1. Ball State University 24-hr Air Filter

Filter	Date	Measured Activities (pico Curies)/2200 m³ Ru-103	I-131	Cs-134	Cs-137
May	1	—	—	3.1 ± 1.3	4.6 ± 1.0
	9	1.4 ± 1.3	12 ± 1.7	5.0 ± 1.5	56 ± 1.3
	13	76 ± 2	148 ± 2	89 ± 2	111 ± 2
	27	27 ± 1.4	20 ± 1.4	13 ± 1.2	21 ± 1.1
June	1	7.5 ± 1.1	4.9 ± 1.4	7.8 ± 1.4	11 ± 1.2
	5	9.3 ± 1.1	—	6.4 ± 1.3	8.8 ± 1.1
	8	5.1 ± 1.0	—	4.2 ± 1.3	4.3 ± 1.1
	10	7.7 ± 1.2	—	5.1 ± 1.4	7.5 ± 1.1
	12	1.7 ± 1.2	—	2.2 ± 1.4	6.2 ± 1.3
	15	5.9 ± 1.4	—	5.6 ± 1.5	5.9 ± 1.3
	17	11 ± 1.1	—	5.9 ± 1.1	7.0 ± 1.1
	23	2.8 ± 1.0	—	3.6 ± 1.1	4.2 ± 0.7
	29	—	—	3.3 ± 1.2	3.1 ± 0.9

TABLE 2. Muncie Central (State Board of Health) 24-hr Air Filter

Filter	Date	Measured Activities (pico Curies)/1872 m³ Ru-103	I-131*	Cs-134	Cs-137
May	2	8.0 ± 2.8	—	0.4 ± 0.4	0.6 ± 0.4
	8	2.5 ± 1.5	—	1.6 ± 0.6	1.4 ± 0.4
	14	200 ± 5	—	41 ± 1	72 ± 1
	20	8.3 ± 2.0	—	6.5 ± 0.6	11.0 ± 0.6
	26	14.5 ± 2.4	—	6.4 ± 0.6	10.4 ± 0.6

* The air filters were counted for activity 89-108 days after the samples were drawn; therefore, the 8-day I-131 activity was not detected at that time.

the I-131 activity. It should be noted that these three additional isotopes are characteristic of a reactor discharge.

Discussion

The current investigation demonstrated that valuable air-quality information can be obtained from gamma-ray measurements on radioactive samples collected on high volume air filters. It also was found that one wave of radioactivity from Chernobyl passed over Ball State University on May 13; data taken several months later from filters taken at a second sampling site in Muncie showed similar results.

Information obtained from the Indiana State Board of Health for radioactivity levels associated with the Chernobyl accident and detected in other states, showed that the Chernobyl radioactivity levels were greater for the western states of the United States (of order 1 pCi/cubic meter and less) than observed in this study for Muncie. The radioactivity levels deposited on the eastern states of the United States seemed to be less than that found in this investigation. The isotopes detected in this study (I-131, Ru-103, Cs-134, and Cs-137) were basically the same as those observed in other parts of the United States.

Acknowledgments

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