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Internally Deposited Fallout from the Chernobyl Reactor Accident

DISCLAIMER

R. A. Schlenker, B. G. Oltman, and H. F. Lucas
Division of Biological and Medical Research
Argonne National Laboratory
Argonne, Illinois

ABSTRACT

Measurements of fallout radioactivity were made in the thyroid region, abdomen, whole body, or urine of 96 persons who were in eastern Europe at the time of the Chernobyl reactor accident or who went there shortly afterward. The most frequently encountered radionuclides were ^{131}I, $^{134,137}Cs$, and $^{103}Ru/^{103}Rh$. The median ^{131}I activity in the thyroids of 42 subjects in whom radioiodine was detected and who were in Europe when the accident began was projected as 42 nCi the day the accident began. The median total body activity of ^{134}Cs in 40 subjects in which it was detected was 1.7 nCi upon arrival in the U.S. For 51 subjects with detectable ^{137}Cs burdens, the total body activity was 4.6 nCi. The risk of fatal thyroid cancer is less than 3×10^{-6} for nearly all subjects in this series. The risk of fatal cancer from $^{134,137}Cs$ for subjects with cesium exposures similar to the ones observed by us, but who remained in Europe, is estimated as 1.4×10^{-6} to 4.2×10^{-5} with 95% of the risk attributable to ^{137}Cs.

INTRODUCTION

Shortly after the Chernobyl reactor accident, April 26, 1986, we began a program to evaluate the internal deposition of radioactivity in people arriving in the Chicago area from eastern Europe. The purposes of the program, as authorized by the U.S. Department of Energy, were to determine if the accident would have major health consequences for people outside the immediate vicinity of the reactor and to provide information for concerned persons about their radiological status. Radiological evaluation services were offered to anyone who requested them and consisted of whole- and partial-body counts to determine the internal deposition of gamma-ray-emitting radionuclides. A urinalysis was done to determine the radionuclide excretion rate. At the subject's request, articles of clothing and luggage were also measured. To determine activity patterns while abroad and other information that might relate to the level of exposure, subjects were interviewed. This information was subsequently used in estimating health risks for the subject population. An initial report of the results of this work is presented here.

MATERIALS AND METHODS

Body Counting. Subjects were measured for gamma-ray-emitting radionuclides in a subterranean low-background body counting facility (5).

Most subjects received three measurements: one of gamma-ray emission from the thyroid region, a second of emission from the abdominal region, and a third of emission from the whole body. Sodium iodide detectors were used for each of the measurements, and the gamma-ray spectra were examined for evidence of fallout radioactivity. The spectra were quantitatively analyzed by integrating the area under total absorption peaks after correcting for interference from other radionuclides and then applying calibration factors to determine the amount of radioactivity detected. The sodium iodide crystals for counts of the thyroid and abdomen were 11.5-in.-diameter x 4-in.-thick cylinders with a limited solid angle for acceptance of gamma rays. The sodium iodide crystal for counting of the whole body was a 6-in.-diameter x 8-in.-long cylinder used with the subject in a tilted-chair counting geometry. The crystal was able to accept gamma rays coming from all directions.

Urinalysis. For most subjects, urine was collected just prior to measurement or overnight the night preceding measurement. The urine volumes varied from a few tens of ml to more than 1 liter; the urine was measured without chemical processing in polyethylene containers whose maximum capacity was 400 ml. A calibrated high-resolution germanium gamma-ray detector was used. A second measurement was made for tritium content by placing an aliquot of urine in a liquid scintillator.

Interview. The subjects were interviewed to determine their locations and movements within Europe from April 26, 1986, or their date of arrival if after April 26, until they departed for the U.S. They were asked to describe their diets and the sources of the food consumed. The subjects were asked about their consumption of fluids, the number of hours spent outdoors, and the frequency of open windows in their dwellings. The subjects were also asked if they had received iodide treatment for radioiodine exposure because it was known that a large fraction of the population in Poland had received such medication at government clinics between April 29 and May 1.

Population. The subjects included U.S. citizens and citizens of foreign countries. Some of the subjects were tourists, some were residents of foreign countries. Table I shows the European locations of the subjects who were examined through mid-September 1986. A few additional subjects measured after that are not included in this report. The column heading "Primary" designates subjects spending most of their time in the country shown to the left; "Only" designates subjects spending all of their time in the one country. Table II presents an age and sex breakdown of the population. Most subjects under 16 did not accommodate well to body counting; consequently, the results presented here do not include their measurements.

TABLE I. GEOGRAPHIC DISTRIBUTION

Country	Primary	Only	Total
Poland	10	60	70
Russia	8	2	10
Lithuania	8	--	8
Estonia	1	--	1
Yugoslavia	1	3	4
Iceland	--	1	1
Unknown	--	--	2
Totals	28	66	96

TABLE II. AGE AND SEX

Total:	96
Under 16:	13
Over 16:	83
Male:	47
Female:	49

RESULTS

Radionuclides Detected. The radionuclides detected by whole-body counting or counting of the thyroid region are shown in Table III. No additional radionuclides were detected in the abdominal region. During May and the first part of June 1986, nearly all subjects showed ^{131}I, $^{134,137}Cs$, and $^{103}Ru/^{103}Rh$. The other radionuclides listed in the table were found infrequently. After about the first of July, ^{131}I ceased to be detectable in all but a very few subjects. Late in 1986, $^{134,137}Cs$ became the only radionuclides that could be detected. The rest of this paper will be devoted to a discussion of ^{131}I and the two cesium isotopes because these are the ones of greatest concern for health impacts.

TABLE III. GAMMA EMITTERS DETECTED BY WHOLE-BODY OR THYROID COUNTING

Nuclide	$T_{1/2}$
$^{95}Zr/^{95}Nb$	65 d/35 d
$^{103}Ru/^{103}Rh$	39.5 d/stable
$^{106}Ru/^{106}Rh$	1 y/30 s
^{131}I	8.0 d
^{134}Cs	2.05 y
^{137}Cs	30.0 y
$^{140}Ba/^{140}La$	12.8 d/40.2 h

^{131}I. ^{131}Iodine was detectable in the thyroid region of 42 of the subjects who were in Europe April 26, 1986. Although subjects who went to Europe after April 26 sometimes acquired small amounts of ^{131}I, the levels were substantially greater in persons who were there at the time the accident occurred; our attention will be limited to these subjects. The median activity at the time of measurement for these 42 subjects was 1.4 nCi, and the activity was assumed to be located entirely in the thyroid. When the measured values were extrapolated back to April 26, assuming a single exponential retention function for thyroid-deposited iodine and an 8-day effective half-life, the median activity was 42 nCi. The frequency distribution of activity had a lognormal appearance. The extrapolated activities lay between approximately 2 and 1200 nCi.

This back extrapolation implies that the ^{131}I was received as a flash exposure April 26. Actual exposures began after April 26 for some subjects due to delayed transport of radioactivity to their locales, and exposures were extended over many days due to the prolonged period of releases from the reactor and to intake by the ingestion pathway.

The thyroid dose commitments for nearly all subjects in the study were less than 1 rad apiece. If one adopts the current International

Commission on Radiological Protection (ICRP) values for the thyroid weighting factor and the whole-body cancer risk (1), a risk factor of 3×10^{-6} per rad to the thyroid is implied for individuals, indicating a very low fatal thyroid cancer risk for this exposure level. Table IV shows the extrapolated ^{131}I burdens by country and by locale within Poland. The numbers of subjects included in the results for each country or each locale are shown in parentheses. The data by country include a few subjects who arrived in Europe after April 26; the data by locale within Poland are limited to subjects who remained in one locale during their stay. In addition to the range of activities, the median value of activity is shown for the locales in Poland.

TABLE IV. GEOGRAPHICAL DISTRIBUTION OF INITIAL ^{131}I BURDENS IN THE THYROID

By country		
Poland (35)	2-1200 nCi	
Russia (6)	2-130	
Lithuania (4)	7-60	
Yugoslavia (2)	9-50	
By locale within Poland		
Northeast (13)	9-1200 nCi	110 nCi
Northwest (1)	---	40
Southeast (8)	20-60	30
Southwest (5)	10-80	60

The subjects from Poland were scattered throughout the country and include some who traveled extensively within the country. Those from Russia were mostly tourists who visited Moscow, Leningrad, Kiev, and the Black Sea area. The Lithuanian subjects were almost exclusively in Vilnius, the capital city, and the two subjects from Yugoslavia traveled substantial distances within the country. The high end of the exposure range for Poland is due to subjects from the northeastern part, a section reported to have been heavily contaminated during the first few days after the accident. It is noteworthy that when these subjects are removed and a comparison among Russia, Lithuania, southeast and southwest Poland is made, exposures in the different areas were of similar magnitude.

^{134},^{137}Cs. The median activity of ^{134}Cs in 40 subjects for whom the isotope was detectable was 1.7 nCi at the time of arrival in the U.S. For ^{137}Cs, the median activity in 51 subjects for whom the isotope was detectable was 4.6 nCi at the time of arrival in the U.S. Frequency distributions of the data have a lognormal appearance. In order to estimate body content at the time of arrival, body content on the day of measurement was extrapolated backward in time, assuming a 100-day half-life for cesium retention and a single exponential retention function. The doses implied by these cesium levels are very small. Based on ICRP methodology (2), a 50-year dose commitment to the whole body for the median level of ^{134}Cs would be 0.15 mrad and for ^{137}Cs, it would be 0.04 mrad.

Persons remaining abroad would continue to accumulate cesium in their bodies through the consumption of foodstuffs and would gradually accumulate higher levels of cesium than we observed in our subjects. When the data on ^{137}Cs for our subjects were plotted as a function of the amount of

time spent abroad following April 26, the cesium activity was found to increase at the rate of 1.3% per day. Among 19 persons who traveled to eastern Europe after April 26 and remained there from 8-91 days, the average rate of accumulation of ^{137}Cs lay in the range of 0.01 to 0.37 nCi per day. When this rate of accumulation and a corresponding rate for ^{134}Cs were included in dose calculations for the 19 subjects and radiation risk estimates based on the ICRP total body risk factor, 10^{-4} fatal cancers per rad (1), were made, it was found that the 50-year risk of fatal cancer lay between 1.4×10^{-6} and 4.2×10^{-5} per person with 95% of the risk attributable to ^{137}Cs.

DISCUSSION

The primary public health concern stemming from the Chernobyl reactor accident is the risk of cancer induction among people resident outside of the vicinity of the reactor. Our data provide information applicable to dose assessment and risk estimation for these people. The dose values and the risk values given in this paper for subjects in our study are preliminary in the sense that very simple models were used to arrive at the final values and that more detailed data-reduction procedures may change body burden values somewhat. The geographical areas covered by the subject population are among those known to have been most highly contaminated by fallout beyond the boundary of the 30-km-radius Exclusion Zone centered on the reactor from which Soviet authorities ultimately evacuated approximately 135,000 residents. Therefore, the risk estimates are probably representative of risks to be encountered by persons in geographical regions of relatively high exposure within or bordering the Soviet Union. Because our risk estimates are based on direct measurements of internal radioactivity, their credibility is highly significant; they are 10 times lower than some estimates published in the lay press following the accident. In an August 1986 report to the International Atomic Energy Agency (4), Soviet authorities compared ^{137}Cs body burden measurements that they had made with estimates from environmental transport models. The Soviets reported that transport models predicted 10 times more internally deposited ^{137}Cs than the average found in 1000 subjects from the Exclusion Zone measured within 90 days of the accident. An unpublished review of environmental distribution models (3) indicates a large degree of overprediction for iodine deposition following the Chernobyl accident, also. Thus, it appears that the soundest basis for risk estimation from internal radioactivity is data such as ours obtained by direct measurement of internal deposition.

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