AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

O

50955
BNWL-2164
UC-48

HEDR FILE COPY

RADIOACTIVE FALLOUT FROM CHINESE NUCLEAR WEAPONS TEST
SEPTEMBER 26, 1976 (a)

C. W. Thomas
J. K. Soldat
W. B. Silker
R. W. Perkins

Battelle, Pacific Northwest Laboratories
Richland, Washington

MASTER

yp
DISTRIBUTION RESTRICTED TO U.S. ONLY

(a) This paper is based on work performed under United States Energy Research and Development Administration Contract EY-76-C-06-1830.

RECEIVED
MAR 08 1994
OSTI

RADIOACTIVE FALLOUT FROM CHINESE NUCLEAR WEAPONS TEST

SEPTEMBER 26, 1976

ABSTRACT

Radioactive fallout from this Chinese nuclear test resulted in measurable deposition of short-lived debris over much of the United States. The fallout levels varied by more than 1000-fold and showed significant temporary or spatial fractionation with higher levels of deposition being associated with rain. The particle size with which the airborne debris was associated decreased continuously with time following detonation and a substantial fraction of the ^{131}I was associated with inorganic and organic gases. The potential radiation dose to an infant consuming milk produced at the location of the highest concentration of ^{131}I measured on grass was estimated to be 1 rem. This dose is about 50 times the annual dose received in the vicinity of a power reactor operating under the existing U. S. Nuclear Regulatory Commission design guides. The potential upper limit thyroid dose for the population of 17 eastern seaboard states from this single test was estimated to be about 2.4×10^6 man-thyroid-rem under the assumption that all dairy cows remained on fresh pasture throughout the month following the initial deposition of fallout debris. This dose is about 200 times the estimated dose from currently operating nuclear power reactors and about 50 times the annual U. S. population thyroid dose that would be received from 500 GWe of nuclear power reactors in the year 2000.

On September 26, 1976, the Chinese Peoples Republic tested a low-yield nuclear device reported to be 20-200 kilotons.⁽¹⁾ Fallout from this test was first observed in the United States at our Battelle, Pacific Northwest Laboratories in Richland, Washington. Evidence was derived from analysis of an air filter sample collected between October 1 at 1:30 P.M. and October 2 at 9:30 A.M. Our laboratory, under long-term ERDA sponsorship, has conducted rather extensive analyses of the physical and chemical properties of the initial fallout, together with measurements of its areal deposition over the United States. Trajectory analysis⁽²⁾ of the leading edge of the radioactive debris from this nuclear test indicated that it moved across the northern United States and southern Canada and that the most southern part of the debris cloud turned southward, entering a low pressure area which carried it to the Gulf states and subsequently along the eastern seaboard. This movement of the debris cloud, together with heavy precipitation along the eastern seaboard, resulted in significant deposition, particularly in eastern Pennsylvania, Connecticut, Massachusetts, and New Jersey.

In a continuing program, our laboratory has been studying the chemical and physical properties of some 30 long-lived natural and artificial radionuclides in the atmosphere, and when nuclear weapons testing is conducted, measurements of the properties of the short-lived radionuclides, together with limited analyses of areal distribution, are conducted. Analysis of the debris from this past test was particularly straightforward since the last significant above-ground nuclear test occurred on June 17, 1974, and therefore essentially all the previous short-lived fallout debris had decayed. On January 23, 1976, the Chinese carried out a small nuclear test that produced radioactive levels about 100-fold lower than the levels observed from this test. The tropospheric radioactivity levels prior to the latest test were actually lower than they have been since before the 1961-62 large-scale testing began.

In this communication, we are describing the areal distribution of ^{131}I and other short-lived radionuclides, the aerosol size fractions with which these radionuclides are associated, and the chemical forms of ^{131}I . We have placed special emphasis on the measurement of ^{131}I because it is the main contributor to the radiation exposure of the population by way of the air-grass-cow-milk-man pathway.⁽³⁾ In addition, we have compared the potential population exposure due to ^{131}I from this test with that which might be expected from the nuclear power industry.

Areal Distribution

To aid in determining the areal distribution of short-lived debris, we collected grass samples from pasture areas or from rest stops off major freeways along the west coast, between Texas and the Canadian border in the central United States, and along the eastern states. The sampling locations and the observed ^{131}I concentrations listed in units of disintegrations per minute per kilogram of grass (wet weight) are presented in Figure 1.

FIGURE 1.

CHINESE NUCLEAR TEST OF 9-26-76
DPM OF ^{131}I /kg OF GRASS (CORRECTED TO SAMPLING DATE)

It is evident that the fallout distribution varied substantially across the United States, with actual concentrations covering a range of about 1000. The highest concentrations were observed in the eastern states, particularly Pennsylvania, Massachusetts, Connecticut, and New Jersey, and were associated with regions of high precipitation. A cursory examination of other areas of high fallout suggests that these were also associated with high precipitation. The relatively high concentrations observed near the tip of Florida suggest that the initial debris cloud may have gone even farther south than Florida.

Atmospheric Concentrations on the West Coast

The atmospheric concentrations of ^{131}I on a daily basis through the month of October are listed in Table I. It is evident that while a peak concentration was seen on the first day on which fallout was observed (October 1-2, 1976), other peak concentrations were seen on October 5 through 6, October 9 through 10, and again on October 13 and 14. It thus appears that there were several separate air masses carrying debris from the detonation across our Richland, Washington monitoring station. We suspect that the precipitation scavenging of these later air masses may have resulted in additional areas of relatively high radioactive fallout similar to those observed along the east coast. During the period October 18 through October 25 even higher concentrations of airborne ^{131}I and other fallout debris were observed in the air at Richland, Washington, and we believe that this was associated with the second circumnavigation of the earth by the debris cloud.⁽⁴⁾ We have also shown in Table I the concentrations of ^{131}I corrected to the time of detonation. These values simply serve to indicate the relative amounts of radioactivity which the airborne masses initially contained. They also serve to indicate the relative amounts of the longer-lived radionuclides which have not decayed significantly over the time period of this comparison.

TABLE I

PARTICULATE IODINE-131 CONCENTRATIONS IN AIR AT RICHLAND, WASHINGTON

(dpm/10³m³)

<u>Date of sample (a)</u> <u>(October)</u>	<u>¹³¹I At</u> <u>Sampling Time</u>	<u>¹³¹I At</u> <u>Detonation Time*</u>
1	<6.8	<10
2	75	120
3	17	29
4	37	70
5	63	130
6	66	150
7	29	71
8	19	52
9	48	140
10	141	450
11	19	65
12	46	174
13	68	280
14	93	420
15	(b)	(b)
16	22	120
17	(b)	(b)
18	111	710
19	111	770
20	193	1460
21	163	1340
22	128	1150
23	119	1170
24	116	1240
25	66	770
26	6.7	85

*Decay corrected to time of detonation for comparison only.

(a) End of sampling period. Sampling periods were 18 to 30 hours.

(b) Pump stopped.

Comparison with Debris from Past Nuclear Tests

In Table II we have normalized the concentrations of the short-lived radionuclides observed in the past five major Chinese nuclear tests to those of ^{95}Zr . These comparisons show similarities and differences in the ratios of radionuclides from detonations of different types and yields. It is evident that the ratios of the fission products from most of these tests are quite similar. The debris from the Chinese test of March 18, 1972, is an exception. This ground-level test resulted in the production of large particulate material which showed a very high degree of fractionation of the various fission products. The debris from the present test is most similar to that of the Chinese nuclear test of January 7, 1972, which was also a low yield device. The radioisotopes ^{237}U and ^{239}Np result from neutron reaction with ^{238}U in the device and their concentrations and ratios depend on the type of device.

It is important to recognize that the low yield devices which have been tested in the Chinese mainland normally contribute a much larger initial exposure to the United States than the higher yield devices. This is due to the fact that the higher yield devices produce sufficient energy to inject most of the debris into the stratosphere from which it descends rather slowly and over a period of years across the entire northern hemisphere and even into the southern hemisphere. On the other hand, the low yield devices place much of the debris within the troposphere from which deposition is very rapid and precipitation scavenging by rain clouds can result in high levels of fresh fallout in certain areas.

Physical and Chemical Forms of Fallout Debris

Following the detonation of a nuclear device, the various radionuclides will condense on the surfaces of airborne particulate material which is available while highly volatile and gaseous radionuclides remain in the gas phase. These volatile radionuclides will subsequently condense on available aerosol

TABLE II
RATIOS OF ACTIVATION AND FISSION PRODUCTS TO ^{95}Zr
IN THE FIRST DEBRIS FROM RECENT CHINESE NUCLEAR TESTS
(Normalized Concentrations)

<u>Date</u>	$\frac{^{147}\text{Nd}}{^{95}\text{Zr}}$	$\frac{^{99}\text{Mo}}{^{95}\text{Zr}}$	$\frac{^{141}\text{Ce}}{^{95}\text{Zr}}$	$\frac{^{237}\text{U}}{^{95}\text{Zr}}$	$\frac{^{239}\text{Np}}{^{95}\text{Zr}}$	$\frac{^{131}\text{I}}{^{95}\text{Zr}}$	$\frac{^{140}\text{Ba}}{^{95}\text{Zr}}$	$\frac{^{132}\text{Te}}{^{95}\text{Zr}}$	<u>Yield, Kilotons</u>
1-7-72	1.4	8.9	1.2	0.1	8.6	2.2	2.6	5.6	<20
3-18-72	2.3	8.6	.50	96	172	.70	.20	1.2	20-200
6-28-73	1.4	21	1.8	33	230	6.3	5.0	16	1000-3000
6-17-74*	2.3	19	2.7	20	88	2.8	2.0	2.9	1000
9-26-76	2.2	21	1.2	0.25	38	2.4	2.7	7.6	20-200

*Since significant ^{95}Zr remained in the atmosphere from the 3-18-72 test we have simply normalized these data to the average of the three ^{147}Nd values (from 1-7-72, 6-28-73 and 9-26-76) in this table to permit a comparison.

particles, and as noble gas radionuclides decay to solid radioelements, these daughter products will also become attached to particles. Because of this complex relationship, one would expect that some fractionation of radionuclides relative to the ratios in which they are initially formed would occur. The potential for fractionation can be estimated from the particle size distribution with which the various radionuclides are associated.

In Table III-A we have presented the fractions of the various radionuclides which are associated with the four stages and the backup filter of a 20 CFM Andersen cascade impactor. In order to obtain this much detail on concentrations versus particle size, it was necessary to sample over the 10-day period as indicated in the caption and to take 1000 minute gamma ray spectral measurements with our high-sensitivity gamma ray spectrometers.^(5,6) In addition to those radionuclides which are associated with the debris cloud, we also measured ^7Be which is produced naturally in the atmosphere, mainly in the stratosphere, by cosmic ray spallation of atmospheric oxygen and nitrogen.

An appreciation for the relatively large particle size distribution of the debris is possible by comparing the fraction of each radionuclide which was collected on the backup filter of the Andersen impactor with that of ^7Be . Where nuclear testing debris has remained for weeks in the stratosphere or where radionuclides are formed in the stratosphere, they are always associated with comparatively small particles, even when they descend through the atmosphere to the earth's surface.⁽⁷⁾ It is significant that while greater than 80% of the ^7Be is associated with particles of less than $1.1\ \mu\text{m}$, the fresh fallout debris is mainly associated with particles of greater than $1.1\ \mu\text{m}$. This is not quite so evident, however, in the cases of ^{103}Ru , ^{140}Ba , ^{131}I , ^{132}Te , and ^{141}Ce . The ^{140}Ba and ^{141}Ce each have noble gas parents while the ^{131}I , ^{103}Ru and ^{132}Te are volatile elements. These characteristics help to explain the relatively high fraction of these radionuclides that exists on less than $1.1\ \mu\text{m}$ particles.

TABLE III-A and III-B
RADIONUCLIDE DISTRIBUTION vs PARTICLE SIZE*

(Percent in each size fraction)

A. First Circumnavigation of the Earth (10-8-76 through 10-18-76)

Particle Size	¹⁴⁴ Ce	⁹⁹ Mo	¹⁴¹ Ce	²³⁷ U	¹³² Te	²³⁹ Np	¹³¹ I	⁷ Be	¹⁰³ Ru	¹⁴⁷ Nd	¹⁴⁰ Ba	⁹⁵ Zr
>7	26	25	21	10	20	11	18	1	8	32	13	32
7-3.3	18	14	13	17	8	11	14	2	8	12	13	16
3.3-2	12	14	13	31	11	17	12	3	7	12	11	10
2-1.1	19	21	19	16	24	37	18	14	16	22	21	19
<1.1	25	26	34	26	37	24	38	80	61	22	42	23

B. Second Circumnavigation of the Earth (10-20-76 through 10-27-76)

Particle Size	¹⁴⁴ Ce	⁹⁹ Mo	¹⁴¹ Ce	²³⁷ U	¹³² Te	²³⁹ Np	¹³¹ I	⁷ Be	¹⁰³ Ru	¹⁴⁷ Nd	¹⁴⁰ Ba	⁹⁵ Zr
>7	14	8	11	7	10	--	11	1	5	19	8	18
7-3.3	32	22	28	14	19	--	20	2	11	40	21	41
3.3-2	13	10	14	10	17	--	12	3	11	13	14	15
2-1.1	14	12	17	15	18	--	13	13	17	11	19	14
<1.1	27	48	30	53	36	--	44	81	56	17	38	12

*Sample collected on a 20 CFM Andersen cascade impactor at Richland, Washington.

Analysis of the debris collected during the second circumnavigation of the earth, October 18 through 25, showed that nearly all of the radionuclides were largely associated with particles of less than $1.1 \mu\text{m}$. The more refractive radioelements ^{147}Nd and ^{95}Zr were still associated with relatively large particles (Table III-B). Thus there had been some substantial deposition of the larger particles during the first circumnavigation of the earth.

In Table IV we have shown the particle size distribution with which ^{131}I was associated during four time intervals. It is evident that the airborne particulate ^{131}I was associated with progressively smaller particles as a function of time following the detonation. Because of the difference in particle size distribution with which each of the radionuclides was associated (see Table III), one might expect significant differences in the ratios of the short-lived radionuclides collected on air filters during the first circumnavigation versus that of the second circumnavigation of the globe. The ratios of these radionuclides are shown in Table V. These concentration ratios, which have been normalized to the volatile radioelement ^{103}Ru , are higher for those radionuclides which were associated with the larger particle sizes during the first circumnavigation. The ratios of about 1.6 to 1.9 for ^{147}Nd , ^{99}Mo , ^{237}U , ^{95}Zr and ^{132}Te indicate that relative to ^{103}Ru approximately 30 to 50% of these radioisotopes were deposited during circumnavigation of the earth.

It was interesting to note that the ratios of the radionuclides in fallout debris which had been carried down by rain were significantly different in different parts of the country. In Table VI we have compared the ratios of the radionuclides to ^{95}Zr on grass samples collected at Tacoma, Washington, and Philadelphia, Pennsylvania. These ratios do show a factor of about 5 variation and suggest that the precipitation scavenging may have occurred in portions of the debris cloud with significantly different radionuclides ratios.

TABLE IV

131 I. Distribution on Atmospheric Aerosols As A Function of Particle Size*
(Percent in each size range)

<u>Particle Size</u>	<u>October 3-5</u>	<u>October 5-7</u>	<u>October 8-18</u>	<u>October 20-27</u>
>7.0	20	24	17	11
7.0-3.3	22	13	13	20
3.3-2.0	20	20	13	12
2.0-1.1	12	7	18	13
<1.1	22	36	39	44

*Samples collected on a 20 CFM Andersen cascade impactor at Richland, Washington.

TABLE V

Ratios of Airborne Radionuclides on the First
vs The Second Circumnavigation of the Earth*

(Ratios Normalized to ^{103}Ru)

^{95}Zr	^{147}Nd	^{144}Ce	^{99}Mo	^{141}Ce	^{237}U	^{132}Te	^{131}I	^{103}Ru	^{140}Ba
1.6	1.7	1.4	1.6	1.2	1.6	1.9	0.95	1	1.3

*Decay corrected to time of detonation.

TABLE VI

Radionuclide Concentrations on Grass and Normalized Ratios

	dpm/kg*		Ratio** PA/WA
	<u>10/4/76</u> <u>Tacoma, WA</u>	<u>10/6/76</u> <u>Philadelphia, PA</u>	
¹⁴⁴ Ce	180	3,700	0.50
⁹⁹ Mo	7500	460,000	1.5
¹⁴¹ Ce	500	39,000	1.9
²³⁷ U	460	14,000	.74
¹³² Te	2680	220,000	2.0
²³⁹ Np	5700	580,000	2.5
¹³¹ I	790	68,000	2.1
¹⁰³ Ru	96	9,700	2.5
¹⁴⁷ Nd	890	58,000	1.6
¹⁴⁰ Ba	1030	76,000	1.8
⁹⁵ Zr	286	11,530	1

*Corrected to detonation

**Normalized to 1 for ⁹⁵Zr

Radioiodine is often the largest single contributor to the radiation exposure received by people from fresh debris; and the dose received is dependent upon the relative amounts associated with different physical and chemical forms. The physical-chemical forms of ^{131}I as observed at the Richland, Washington monitoring site are compared in Table VII. The method used for separating physical and chemical forms involved passing air stream through an IPC filter followed by 2 charcoal filters and finally through a 10 cm long charcoal bed at a high flow rate. Using the particulate ^{7}Be as an indication of filter efficiency, we observed that between 91 and 92% of the particulate material was collected on the IPC filter. The charcoal filters served to remove I_2 , HI , and other reactive forms of iodine, while the charcoal bed removes methyl iodide and other organic iodides.⁽⁹⁾ These data show that a substantial fraction of the radioiodine was in the gaseous stage and this was divided roughly equally between reactive and organic forms.

Potential Radiation Dose to the Public

The radiation exposure which the public may have received from ^{131}I deposited from this test as a result of its movement through the air-grass-cow-milk-man food chain depends on several things, including the physical and chemical form of the iodine, whether or not cows are actually on pasture, and the time delay between production of milk and its utilization. Because of these uncertainties, it is difficult to make a highly accurate estimate of the radiation doses which the population may have received based upon grass samples taken over a relatively short period of time. However, an analysis can be made using practices which are currently employed for estimating potential radiation doses due to radioiodine in the environs of nuclear power reactors.^(10,11,12,13) This comparison has the direct benefit of placing in perspective the potential exposure from the ^{131}I from fallout versus the potential exposure from nuclear reactors.

TABLE VII

Physical-Chemical Forms of Airborne ^{131}I at Richland,
Washington from the Chinese Nuclear Test of 9-26-76
(Concentrations Normalized to Particulate Forms)

<u>Sampling Period</u>	<u>Particulate^a ^{131}I</u>	<u>Reactive^b ^{131}I</u>	<u>Organic^c ^{131}I</u>
October 3 to 5	1	0.60	--
October 8 - 18	1	0.16	0.19
October 21 - 23	1	0.21	0.08

^aParticle filter: IPC filter (operated at 1000 linear ft. per minute)

^bCharcoal filter

^c10 cm long charcoal bed

The Nuclear Regulatory Guide 1.109 contains factors for the transfer of ^{131}I from pasture grass to milk, milk consumption versus age for the population, and data on the time interval between milk production and consumption.⁽¹¹⁾ A supplement to Regulatory Guide 1.109 which is currently being prepared contains dose factors as a function of age in units of mrem per pCi of ^{131}I intake.⁽¹³⁾

The Federal Radiation Council Report No. 5⁽¹⁰⁾ indicates that the total integrated uptake of ^{131}I following an acute exposure of pasture grass will be equal to 7 times the first day's milk intake. Calculating the radiation exposure which the thyroid of a maximally exposed individual would receive requires the following information:

1. The average dairy cow consumes 50 kg of fresh forage per day and transfers 6×10^{-3} of each day's ^{131}I intake to each liter of milk produced.⁽¹¹⁾
2. An infant with a 2-gram thyroid consumes up to 1 liter of milk per day and the intake of ^{131}I following an acute contamination of forage is equal to 7 times the first day's intake.
3. The thyroid dose conversion factor for such an infant is 1.39×10^{-2} mrem per pCi of ^{131}I ingested.⁽¹³⁾

The product of grass consumption by a cow, 50 kg per day, the transfer coefficient from grass to milk, 6×10^{-3} , the 7-day equivalent exposure period following acute vegetation contamination, and the thyroid dose conversion factor of 1.39×10^{-2} gives a value of 2.92×10^{-2} . This factor relates grass concentrations in pCi per kg to thyroid dose in mrem for the case of an infant consuming 1 liter of milk per day.

Using this conversion factor, we have calculated the dose which an infant could receive based on the ^{131}I concentrations observed in grass as shown in Figure 1. These exposure estimates are presented in Figure 2. In making these calculations, we have assumed that iodine contamination of the vegetation occurred on October 4, 1975, and have simply made the decay corrections from the time the

vegetation was collected back to this date using the physical half-life of ^{131}I . Using this procedure, the highest potential infant thyroid dose which we estimated was 990 mrem, based on a sample collected at Lowell, Mass.

One can use a similar method of calculation to estimate the potential total thyroid dose (man-thyroid-rem) received by the population on the eastern seaboard. Table VIII summarizes the data which one may use in estimating this population dose by employing calculations similar to those discussed above. By using the fraction of the population in each age group, milk consumption rates, and dose factors shown in Table VIII, and correcting for 4 days decay between the cow and consumption one obtains the factor of 2.0×10^{-6} man-thyroid-rem per pCi/kg of grass.

The potential population dose in a given region of the country, can be obtained by simply multiplying this factor by the ^{131}I concentration observed on grass and by the exposed population in the region. In carrying out this calculation, the simplifying assumption was made that the average exposure to each state's population was equal to the average of the measurements made within the state.

Table IX summarizes our estimates of the man-thyroid-rem received in 14 states for which we have measurements, together with 3 states within the general region for which we have no measurements. This region represents a population of about 78 million. The potential upper limit population dose for this group as indicated in Table IX is 1.6×10^6 man-thyroid-rem via milk consumption. If one assumes that ingestion of leafy vegetation and inhalation increased this exposure by 50%, the total potential thyroid dose would become 2.4×10^6 man-thyroid-rem from the three pathways combined. Dividing this number by the population of the region gives an average per capita dose of about 20 mrem from the milk or 30 mrem from all three pathways. It is obvious from the data in Figure 2 that if radiation doses were calculated for the midwest and west, they would be very substantially lower than those of the eastern seaboard.

TABLE VIII

Factors Used in Calculating Population Thyroid Exposure
from ^{131}I

<u>Age Bracket</u>	<u>Fraction of Population^(14,15)</u>	<u>Milk Consumption Liter/yr</u>	<u>Dose Factor mrem/pCi⁽¹³⁾</u>
0-2	0.05	170	1.39×10^{-2}
> 2-10	0.15	170	5.72×10^{-3}
> 10-18	0.2	200	2.39×10^{-3}
> 18	0.6	110	1.95×10^{-3}

-9b-
TABLE IX

Potential Population Exposures for 17 Eastern States
from ¹³¹I Deposited by Chinese Nuclear Test
of September 26, 1976 (Man-Thyroid-Rem)

State	Population (Millions)	Average Grass Conc. pCi/kg	Man-Thyroid-Rem (in thousands of rem)	
			Milk	Total
Main	0.994	1160	2.31	3.46
New Hampshire	0.738	2500	3.69	5.53
Vermont*	0.445	2000	1.8	2.7
Massachusetts	5.69	34000	386	580
Connecticut	3.03	18000	109	164
New York	18.24	5010	183	274
New Jersey	7.17	18500	265	398
Pennsylvania	11.8	15100	356	534
Maryland	3.92	7000	54.9	82.4
Delaware	0.548	5700	6.25	9.37
Rhode Island*	0.950	20000	38	57
Virginia	4.65	9130	84.9	127
North Carolina	5.08	3150	32.0	48.0
South Carolina	2.59	2500	13.0	19.4
Georgia	4.59	1540	14.1	21.2
Florida	6.79	1400	19.0	28.5
West Virginia*	<u>1.70</u>	<u>1000</u>	<u>3.4</u>	<u>5.1</u>
Total for 17 States	77.9	--	1570	2360
per Capita Dose	--	--	0.021	0.032

*Estimate based on data from surrounding states.

Addition of the exposure of individuals in these regions of the country would not significantly increase the total population dose estimate.

Comparison of exposure from this nuclear test with that from power reactors

The existing Design Objectives for the operation of light water reactors are contained in Regulatory Guide 1.109⁽¹¹⁾. These guidelines limit the radiation dose to the thyroid from radioiodines and particulates released with gaseous effluents to 15 mrem/yr. However, the external exposure limits of 5 mrem/yr to the total body from gaseous effluents and 10 mrem/yr to any organ from all liquid effluent pathways, allow for additional thyroid exposure. Even though the sum of these three guides is 30 mrem/yr, it is unlikely that the total thyroid exposure would exceed ~ 20 mrem/yr per reactor operating under this guide.

Thus, the subject nuclear test which produced a projected maximum thyroid dose of 1 rem was 50 times the annual dose which could potentially be received at the site boundary of a nuclear power reactor operating under current Design Objectives.

The total U. S. population dose from operating nuclear reactors in the U.S. can be estimated from the data and assumptions given in an environmental statement for light water power reactors, WASH-1258⁽¹²⁾. In this document it was assumed that operating at a guideline of 10 mrem/yr to the thyroid (5 mrem/yr from gaseous effluents and 5 mrem/yr from liquid effluents) that the per capita dose rate to the U.S. population would be 0.1 mrem/yr from LWRs generating a total of 500 billion watts (500 GWe) of electricity in the year 2000. Assuming the newer guideline might permit as much as 20 mrem/yr to the individual thyroid, then the per capita dose rate would be 0.2 mrem per person per year. The population dose rate then is simply the product of the per capita dose rate and the population in the year 2000 of about 250×10^6 people, or 5×10^4 man-thyroid-rem per year.

It is apparent that the potential upper limit population dose from this nuclear test of 2.4×10^6 man-thyroid-rem is about 50 times that which could result each year from 500 GWe of power reactor operation in the year 2000 under the current Design Objectives.

Estimates of the total population thyroid doses received from the currently operating nuclear power reactors are difficult to make. Most of the current generation of power reactors were built prior to the adoption of the new Appendix I guidelines although several have been backfitted with improved rad-waste systems in recent years. In addition the power levels of most of the currently operating reactors are well below the value of 1.2 GWe assumed in WASH-1258⁽¹²⁾.

Assuming that the maximum thyroid dose at the-fence line for existing reactor averages two to three times higher than proposed in the new Appendix I guidelines and that there are about 50 operating reactors in the U. S., then the U.S. population thyroid dose rate would be about 10^4 man-thyroid-rem per year. Thus the population dose from the subject nuclear test is about 200 times that currently received by the population from one year's operation of nuclear power reactors in the U.S.

Perspective as to the potential thyroid dose from the test can be compared with the Protective Action Guides (PAG) defined by the old Federal Radiation Council (FRC) for acute contamination events. In report number 5⁽¹⁰⁾ the FRC had defined a projected dose of 30 rem to the thyroid of a maximum individual member of the population as the dose below which no protective action should be taken, since the harmful effects of the remedy could be worse than the effect of the dose received in the absence of any such action.

Summary

It has been observed that the recent low-yield nuclear detonation in mainland China resulted in a significant deposition of short-lived radioactivity over much of the U. S. Variations in meteorological conditions resulted in more than a 1000-fold difference in levels deposited on vegetation with the higher concentrations being associated with precipitation. The particle size distribution with which the radionuclides were associated at our Richland, Washington monitoring site changed substantially with time following the detonation to progressively

smaller average sizes. Relative to ^{103}Ru , the deposition loss of the more refractory short-lived radionuclides which did not have noble gas precursors include ^{95}Zr , ^{147}Nd , ^{99}Mo , ^{132}Te , and ^{237}U was larger up to twofold following circumnavigation of the earth. The ^{131}I ranged from about 30 to 50% in the gaseous form and this gaseous fraction was distributed in roughly comparable amounts between inorganic and organic fractions.

The potential radiation doses to the population of the eastern U. S. seaboard states were estimated using reasonably conservative assumptions. The potential maximum thyroid dose to an infant consuming 1 liter per day of milk was estimated to be about 1 rem. The upper limit integrated population thyroid dose from inhalation and consumption of leafy vegetables and milk was estimated to be 2.4×10^6 man-thyroid-rem received by a population of 78×10^6 people. The population thyroid doses received in the midwestern and western United States were much less than those on the eastern seaboard.

The potential maximum individual thyroid dose of 1 rem is well below the older Protective Action Guide of 30 rem defined for the maximum thyroid dose from acute contamination events and no drastic measures to reduce this dose appear to have been warranted.

By comparison, the potential thyroid dose rate to ^{131}I received from nuclear power reactors operating in the year 2000, assuming they comply with existing Appendix I guidelines⁽¹¹⁾ would not be over 20 mrem/yr from all pathways of exposure. A corresponding integrated population dose would not be likely to exceed 5×10^4 man-thyroid-rem/yr. At this rate, it would take nearly 50 years of such reactor operations to yield the population thyroid dose of 2.4×10^6 man-thyroid-rem that the eastern U. S. population may have received from this single Chinese nuclear test.

The estimated population thyroid dose from currently operating nuclear reactors is approximately 10^4 man-thyroid-rem. Thus, the recent Chinese nuclear test produced a potential population thyroid dose of about 200 times that

currently received each year from operating nuclear power reactors.

It must be emphasized that the actual dose which was received either from the subject test or from nuclear power reactor operation depends on whether cows are actually on pasture and their milk is actually being consumed; also on whether leafy vegetables are being produced and consumed. We believe, however, that the comparison made between the potential thyroid doses from nuclear power reactors and from this recent Chinese nuclear test are reasonable since they both employ the similar assumptions about the ^{131}I pathways.

REFERENCES

1. Associated Press news release, September 27, 1976.
2. Air Resources Laboratory, Air Trajectory Bulletin--September 29, 1976, N.O.A.A., Silver Springs, Maryland.
3. J. K. Soldat, "Modelling of Environmental Pathways and Radiation Doses from Nuclear Facilities," BNWL-SA-3939, Battelle, Pacific Northwest Laboratories, Richland, Washington (1971)
4. C. W. Thomas, Radiological Chemistry, Hanford Radiological Sciences Research and Development Annual Report for 1964, BNWL-36-111, Battelle-Pacific Northwest Laboratories, Richland, Washington, pp 3.62-3.65 (1965).
5. J. A. Cooper, R. W. Perkins, "A Versatile Ge(Li)-NaI(Tl) Coincidence-Anticoincidence Gamma Ray Spectrometer for Environmental and Biological Problems," BNWL-SA-3972, Battelle, Pacific Northwest Laboratories, Richland, Washington (1971).
6. N. A. Wogman, R. L. Brodzinski, "The Development and Application of a Beta-Gamma-Gamma Multidimensional Spectrometer," Nucl. Instrum. Methods 109, pp 277-283 (1973).
7. R. W. Perkins, J. D. Ludwick, C. W. Thomas, M. R. Petersen, and J. A. Cooper, "Pacific Northwest Laboratory Annual Report for 1973 USAEC Div. Biol. Med., Part 3, Atmospheric Sciences," BNWL-1850, Battelle-Pacific Northwest Laboratories, Richland, Washington, pp 4-17 (1974).
8. S. C. Stern, H. W. Zeller, A. I. Schekman, "The Aerosol Efficiency and Pressure Drop of a Fibrous Filter at Reduced Pressures," J. Colloid Sci. 15, pp 546-562 (1960).
9. J. D. Ludwick, "Investigation of the Nature of ^{131}I in the Atmosphere," Hanford Radiological Sciences Research and Development Annual Report for 1963, HW-81746 (AEC), p 3.58 (1964).
10. Federal Radiation Council, "Background Material for the Development of Radiation Protection Standards," Staff Report No. 5 (July 1964)
11. USNRC Office of Standards Development Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I." (March 1976).
12. U. S. Atomic Energy Commission, Directorate of Regulatory Standards, "Final Environmental Statement Concerning Proposed Rule Making Action: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents-Volume 1, The Statement," WASH-1258 (July 1973).

13. G. R. Hoenes, J. K. Soldat, "Age-Specific Radiation Dose Commitment Factors for a One Year Chronic Intake." To be published by Nuclear Regulatory Commission.
14. U. S. Bureau of the Census, 'Statistical Abstract of the United States: 1973 (94th Edition), Washington, D. C., 1973.
15. Report of the Advisory Committee on the Biological Effects of Ionizing Radiation. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Division of Medical Sciences, National Academy of Science-National Research Council (November 1972).

DATE

FILMED

6 / 23 / 94

END