UCRL-73310
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HEALTH PHYSICS ASPECTS OF LRL TRITIUM RELEASE

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July 16, 1971

This paper was prepared for presentation at the Tritium Symposium conducted by the Southwestern Radiological Health Laboratory and the University of Nevada at Las Vegas, Nevada, August 30 to September 2, 1971.

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Abstract

On August 6, 1970, 289,000 Ci of tritium gas was accidentally released through an exhaust stack at the Lawrence Radiation Laboratory in Livermore, California. Soon after the release, emergency-response personnel surveyed the site with portable tritium air monitors and an extensive environmental sampling program was initiated. The results from this sampling program indicate that no significant exposure to on- or off-site individuals resulted from the release. All environmental samples of water, milk and urine contained normal background levels of tritium. Although detectable levels of activity were found in some vegetation and atmospheric water vapor samples, the highest measured concentrations as well as the calculated maximum credible ground level air concentrations during cloud passage were well below the off-site maximum permissible concentrations for continuous exposure. Since tritium was not present in urine samples above detectable levels, the maximum undetectable dose which could have been received from exposure to the cloud would have been about 0.025 mrem. Based on vegetation sampling results, the maximum dose to a child exposed via the forage-cow-milk pathway would be about 70 mrem.

Introduction

On Thursday morning, August 6, 1970, 289,000 Ci of tritium gas was accidentally released through the 120 ft-high stack of the Gaseous Chemistry Building at the Lawrence Radiation Laboratory in Livermore, California. Shortly after the radiation alarm was sounded, emergency response personnel were called out to operate tritium air monitors and to collect environmental samples in order to assess the immediate effects of the release.

During the following four days an extensive environmental sampling program was undertaken by the Hazards Control Department of the Laboratory with the assistance of personnel from the California State Health Department. Numerous air, water, vegetation, milk and urine samples were collected and analyzed for tritium. The survey covered an area extending northeast from the Livermore Valley to Lodi, California, and southeast in the San Joaquin Valley from Lodi to Visalia, California. This sampling pattern was based on the meteorological conditions which prevailed during and shortly after the release.

*Work performed under the auspices of the U.S. Atomic Energy Commission.

The emergency response activities immediately following the release are described in this report and the results obtained from the environmental sampling program are compared with pre-accident measurements and off-site maximum permissible concentrations (MPC's) as defined in AEC Manual Chapter 0524.

The Sequence of Events

The release of the tritium was detected and the amount recorded by a flow-through ionization chamber which sent a high-level radiation alarm to the Laboratory Fire Station at 0614 on Thursday, August 6, 1970. A spill team was activated at 0615 and the Off-Site Emergency Survey Team was called in at 0708 to operate tritium air monitors and to collect environmental samples on-site and along several roads north and east of the Laboratory. Predictions based on early meteorological data indicated that the activity would be carried northeast of the Laboratory by light southwesterly winds.

At 0802 a urine sampling program was initiated for all personnel involved in the initial emergency response. Urine samples were also obtained from other LRL employees who were on-site during the release. An extensive air, water, vegetation and on-site urine sampling program was continued throughout the day.

In the initial off-site survey environmental samples were collected along the roads between Livermore and Tracy, and southeast of Tracy through the San Joaquin Valley as far as Firebaugh. Since the release involved the dispersal of radioactivity to the off-site environment, a representative of the California State Health Department was notified at 1530, Thursday, August 6. This representative then assisted in the collection of milk samples, which were returned to the Laboratory for analysis on Friday, August 7.

Results of the first day's environmental sampling program were summarized at 0800 the following morning (August 7). Vegetation samples containing low levels of tritium activity had been collected at a few locations northeast of the Laboratory. Based on these results, the environmental sampling program was increased in this area. Additional samples were collected around Tracy and farther north at Lodi.

On Friday afternoon (August 7), an off-site urine sampling program was initiated after consultation with the representative of the California State Department of Public Health. Based on meteorological predictions and initial vegetation sampling results, the area immediately north and northeast of the Laboratory was exposed to the highest tritium concentration during cloud passage. Urine samples were, therefore, obtained from several individuals who were in this area at the time of the release.

The off-site environmental sampling program was continued for several weeks, with primary emphasis on those areas where tritium was detected in vegetation samples.

Meteorological Predictions

The atmospheric conditions at LRL at the time of release were characterized by south to southwest winds at 2 to 4 mph. The morning radiosonde data from the Oakland Airport indicated a surface-based inversion with a top at about 2800 ft. This

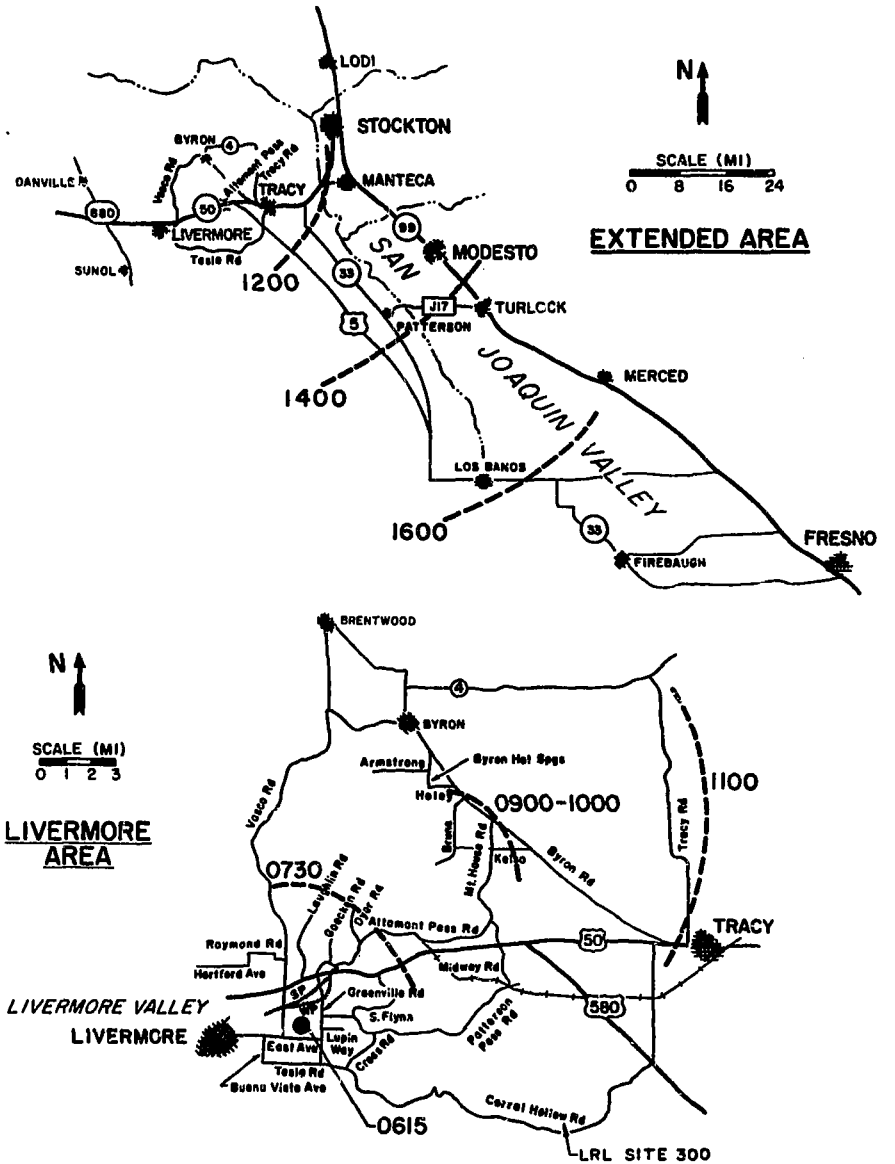

Fig. 1. Cloud path and estimated arrival times based on meteorological predictions.

inversion probably prevailed over the Livermore Valley. The tritium gas was released into the atmosphere at an effective height of about 150 ft. The surface winds would have carried the cloud northward (see Fig. 1) where it would have been forced into various canyons in the area about 1 hr after release (i.e., at 0730). At this time, the cloud may have been forced upward into the predominantly westerly flow which existed at the higher altitudes according to wind data from the Laboratory's Site 300. In any case, the cloud was forced over the foothills in the Altamont Pass Road area and into the San Joaquin Valley. Best estimates of arrival time at Byron Road would be 0900 to 1000. At this time surface winds at Tracy changed from light southeast to strong westerly, which indicated the possible breakup of the inversion. The cloud would probably have moved slightly northward during its eastward passage, passing north of Tracy at approximately 1100.

Stockton and Manteca surface winds were northerly to northwesterly at 6 to 12 mph between 1100 and 1300. As the cloud moved closer to Stockton, it would have been forced southward and it probably passed between Tracy and Manteca at about 1200, continuing on a southerly track down the San Joaquin Valley. Using the surface winds from Modesto, Merced and Crows Landing, the cloud could be estimated to have crossed Patterson Road (J-17) at about 1400 and reached the Los Banos area at about 1600.

Environmental Measurements

AIR MONITORING

T-446 and T-290 tritium air monitors* were used to survey the LRL parking lots and areas along roads north and east of the Laboratory between 0730 and 0830 on the morning of the release. The only positive off-site values (approximately 5 $\mu Ci/m^3$) were recorded with a T-446 monitor a few hundred yards east of the Laboratory boundary. Minimum detectable concentration for this instrument is about 5 $\mu Ci/m^3$.

*The T-446 and T-290 tritium air monitors are manufactured by the Sandia Corporation and Curtiss-Wright Corporation respectively. Reference to a company or product name does not imply approval or recommendation of the product by the U. S. Atomic Energy Commission to the exclusion of others that may be suitable.

AIRBORNE WATER VAPOR SAMPLES

The method of collecting and analyzing airborne water vapor was as follows. The samples are collected by inserting an aluminum pipe into a dewar filled with liquid nitrogen. When the exposed portion of the pipe becomes cold, atmospheric water vapor condenses on it. After the liquid nitrogen evaporates, the aluminum pipe returns to ambient temperature, causing the ice on the pipe to melt. The melt water (approximately 5 ml) collects in the dewar. A 1-ml aliquot of the sample is then added to the proper liquid scintillant and analyzed for tritium activity in a liquid scintillation counter. The minimum detectable tritium concentration by this method is about 40 pCi/m^3. Knowing

the relative humidity, the amount of water vapor per unit volume of air at any particular temperature can be calculated. With this information, and the tritium activity per ml of water, the activity of tritiated water vapor per unit volume of air can be determined.

The results of this survey, listed completely in Table 1 and summarized in Table 2, are based on a relative humidity of 50%. The locations where these samples were taken are shown in Fig. 2.

VEGETATION SAMPLES

The vegetation samples selected were mostly varieties which remain green during the dry season so that a reasonable amount of sample water could be obtained for analysis. In general, each sample consisted of a single variety of vegetation and weighed about 250 grams, but this value varied considerably.

Water was extracted from the vegetation by a freeze-drying technique. A small portion of the original sample was placed in a vacuum flask and frozen by immersing the flask in liquid nitrogen. This fixed the water to the vegetation during the evacuation process. A 50 micron vacuum was pulled on the sample and the evolved water was collected in a liquid-nitrogen-cooled receiver while the sample flask returned to room temperature. The water vapor transfer was allowed to proceed until a minimum of 1 ml of water was collected in the receiver. Tritium activity in the collected water was measured with a liquid scintillation counter. The minimum detectable tritium concentration of the counting system is approximately 0.05×10^5 pCi/liter.

Table 1. Airborne water vapor sample tritium activities in pCi/m^3. Activities lower than 40 pCi/m^3 are not listed.

Sample No.	Series[a] AS-1	AS-2	AS-3	AS-4
1	230	77	1,400	260
2	98	—	470	96
3	140	200	310	250
4	200	1,200	180	330
5	Lost	850		2,600
6	230	1,400		630
7	160	880		—
8	120	570		90
9		420		—
10		58		59
11		96		59
12		350		100
13		610		78
14				—
15				170
16				12,000
17				—
18				110
19				55
20				9,800

[a]Times and locations of samples were as follows:

- AS-1: Along State Highway 33 from Interstate 5 to Firebaugh, 1200 to 1700, August 6.
- AS-2: On-site at LRL, 0830 to 0930, August 6.
- AS-3: On Greenville Road east of LRL, 0800 to 0900, August 6.
- AS-4: On-site at LRL, 1350 to 1600, August 6.

Table 3 lists the locations where vegetation samples were collected. The landmarks used for identification may be found in Fig. 3. Table 4 lists the tritium activity of these vegetation samples and Table 5 gives a summary of the vegetation sampling results.

Table 2. Summary of airborne water vapor sampling results.

Activity (pCi/m^3)	All samples		Off-site samples		On-site samples	
	No. of samples	Percent of total	No. of samples	Percent of total	No. of samples	Percent of total
<100	15	34	1	9	14	42
100—500	18	41	9	82	9	27
500—1,000	5	11	—	—	5	15
1,000—5,000	4	9	1	9	3	9
5,000—12,000[a]	2	5	—	—	2	7
Totals	44		11		33	

[a]Highest value recorded.

WATER SAMPLES

Water samples were collected from storage ponds and tanks in 1-liter plastic bottles at the locations shown in Fig. 4. One ml of each sample was analyzed with a liquid scintillation counter. Table 6 lists the tritium activity of these water samples.

MILK SAMPLES

Milk samples were collected at a number of locations in the Livermore and San Joaquin Valleys. These samples were treated by a freeze-drying process similar to that used for treating the vegetation samples. Figure 5 shows the locations where these samples were collected, and Table 7 gives the dates when they were collected and the measured tritium activities.

URINE SAMPLES

Based on release parameters including meteorological conditions and analysis of environmental samples, it was established that the potential exposure risk to individuals both on-site and off-site was very low. However, urine samples were collected to confirm these predictions. These urine samples were prepared for analysis by distilling off the water and counting 1 ml of the distillate in a liquid scintillation counter.

LRL Personnel

Thirty-nine urine samples were obtained from 31 LRL employees who were on-site during or shortly after the release. No activity above the minimum detectable level of 0.05×10^5 pCi/liter was found.

Off-Site Individuals

Urine samples were obtained from 19 individuals who were in the area to the north and northeast of the Laboratory as outlined in Fig. 6 on the morning of the release. No activity above the minimum detectable level of 0.05×10^5 pCi/liter was found.

Cows

Urine samples were taken from two cows quartered in the LRL Bio-Medical Department Facility on August 6, 1970.

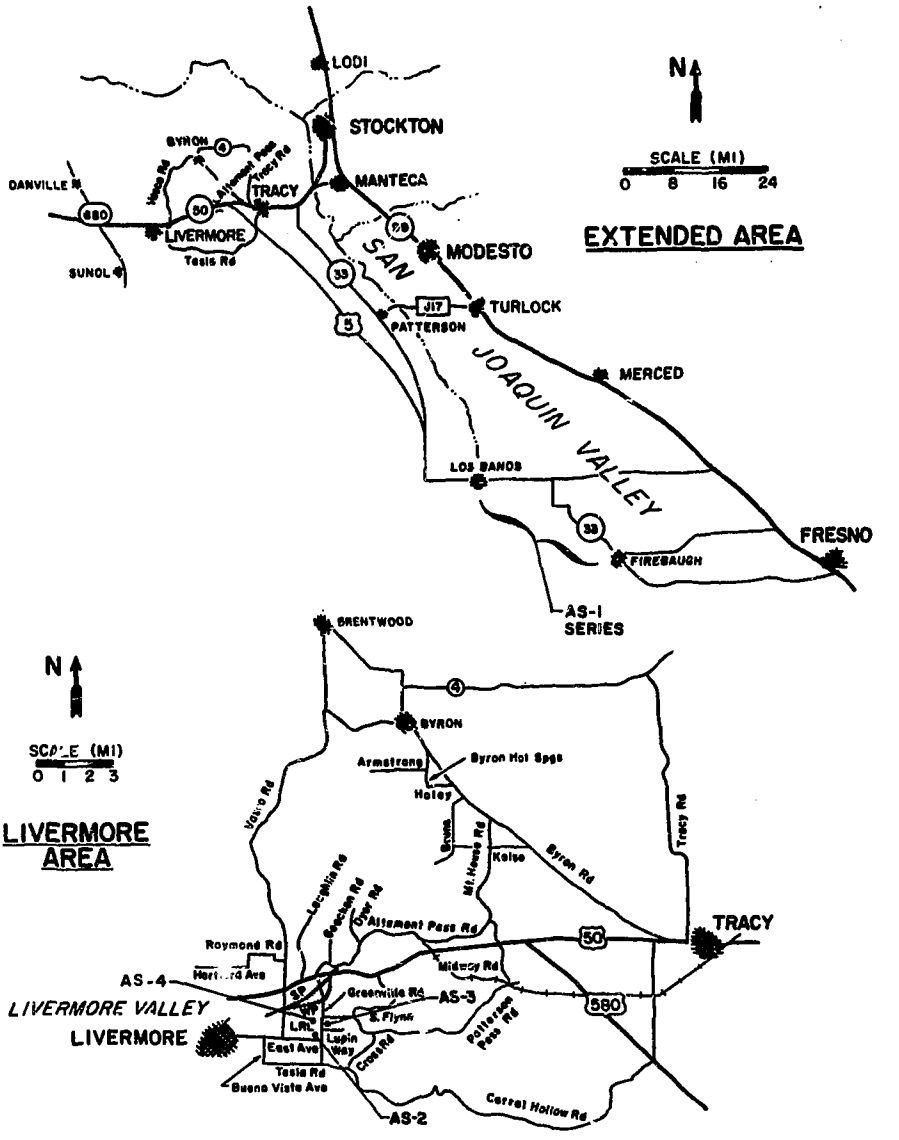

Fig. 2. Airborne water vapor sample locations.

Table 3. Locations where vegetation samples were collected.

Sample series	Location
VS-1	Interstate 680 from Danville to Sunol.
VS-2	Altamont Pass Road at Goecken Road.
VS-3	From Byron along Hwy 4 and Tracy Road to Tracy.
VS-4	From Tracy South on Hwy 33 to Patterson, East on J-17 to Turlock, North on Hwy 99 to Manteca, and West on Hwy 120 to Tracy.
VS-5	Vicinity of Lodi.
VS-6	South of Fresno on Hwy 99.
VS-7	Goecken Road.
VS-8	West from Greenville Road along Western Pacific and Southern Pacific R. R. Tracks.
VS-9	From Hwy 580 on Vasco Road and Camino Diablo Road to Byron then South on Byron Road and Mountainhouse Road to Altamont Pass Road.
VS-10	From Mountainhouse along Mountainhouse Road, Kelso Road, Bruns Road, Holey Road, Armstrong Road, and Byron Hot Springs Road to Byron.
VS-11	North of Hwy 580 on Laughlin Road, West along Hwy 580 to Vasco Road, North on Vasco Road to Raymond Road, and West on Raymond Road and Hartford Avenue.
VS-12	West on Tesla Road from Las Positas Avenue to Buena Vista Road, North on Buena Vista Road to East Avenue, and intersection of Vasco Road and Western Pacific R. R. Track.
VS-13	North on Greenville Road from Patterson Pass Road to Hwy 580, West on 580 to Laughlin Road, North on Laughlin Road.
VS-14	East on Altamont Pass Road from Hwy 580 to Mountainhouse, North on Vasco Road from East Avenue to Hwy 580, East along Hwy 580 to Laughlin Road.
VS-15	North on Dyer Road from Altamont Pass Road.
VS-16	East on Patterson Pass Road from South Flynn Road to Midway.
VS-17	East on Altamont Pass Road from Hwy 580 to Midway Road, South on Midway Road to Midway.
VS-18	Along Flynn Road from Patterson Pass Road to Hwy 580.
VS-19	South on Interstate 5 from Hwy 50 to Hwy 33, East on Hwy 33 through Los Banos to Firebaugh.
VS-20	East on Corral Hollow Road from Cross Road to Hwy 580, West on Hwy 580 to Greenville Road.
VS-21	East on Tesla Road and Corral Hollow from Greenville Road to LRL-Site 300.
VS-22	East perimeter of LRL-Livermore Site.
VS-23	North on Greenville Road from East Avenue to Hwy 580, East on Patterson Pass Road from Flynn Road to Cross Road, South on Cross Road to Tesla Road.
VS-24	East on Lupin Way from Greenville Road.
VS-25	LRL-Livermore Site.

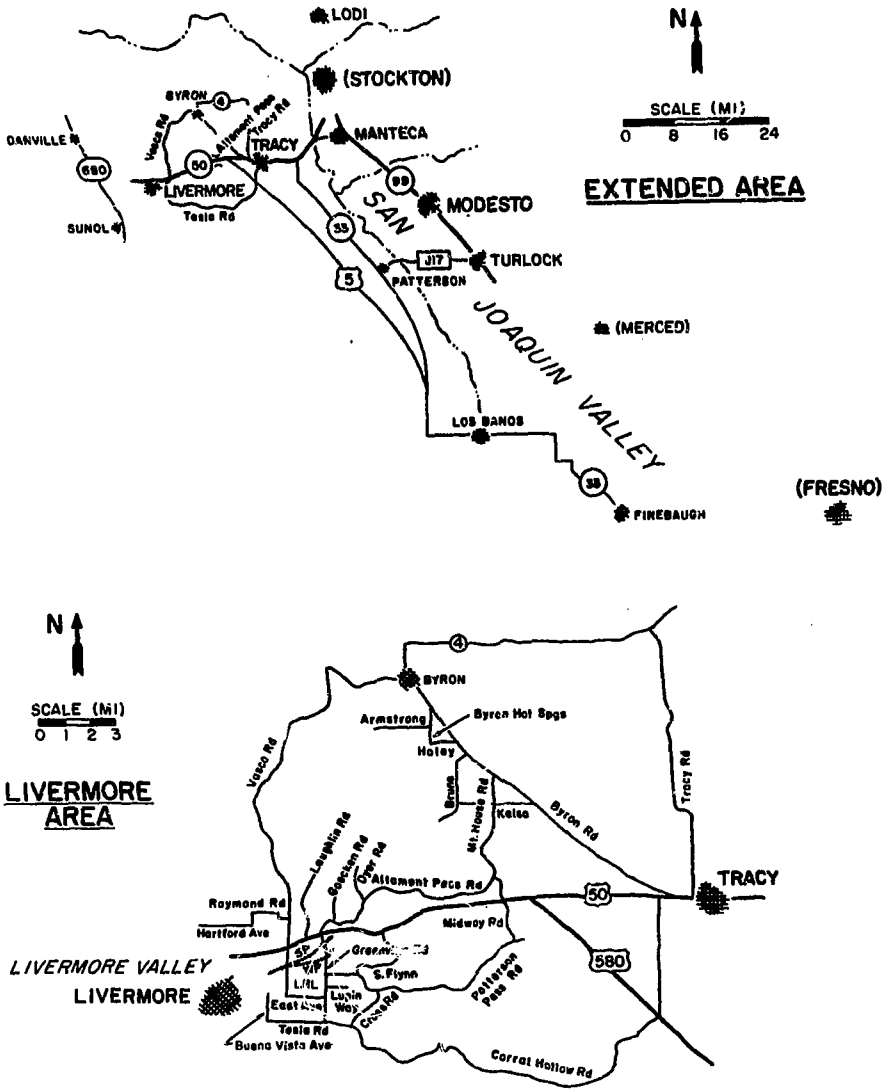

Fig. 3. Vegetation sample locations. Numerous samples were taken along the routes shown (other roads not shown); see Table 3 for a more detailed listing of sample series by number and location.

Table 4. Vegetation sample tritium activities in pCi/liter × 10^5. Activities lower than the minimum detectable level of 0.05×10^5 are not listed.

Sample No.	Sample Series																							
	VS-1	VS-2	VS-3	VS-4	VS-5	VS-6	VS-7	VS-8	VS-9	VS-10	VS-11	VS-12	VS-13	VS-13 (rerun)	VS-14	VS-14 (rerun)	VS-15	VS-16	VS-17	VS-18	VS-19	VS-20	VS-21	VS-22	VS-23	VS-24	VS-25
1	—	0.09	0.09	—	0.11	—	0.12	0.11	0.08	0.15	3.3	—	—		0.85		0.30	0.09	0.18	—	0.09	—	0.07	0.11	—	0.14	0.64
2	—	0.39	0.09	0.07	—	—	0.07	0.23	0.10	0.17	2.0	0.11	0.11		0.34		0.39	0.07	1.55	—	0.14	—	—	0.23	0.30	—	0.64
3	—	0.27	—	0.09	0.25	—	0.10	0.14	0.15	0.19	6.8	—	—		1.50		0.23	0.09	0.36	0.07	0.09	—	—	0.27	0.14	0.14	0.77
4	—	0.93	0.07	0.07	—	—	—	0.48	—	0.15	0.60	—	—		0.50		0.27	0.09	0.20	0.07	—	—	0.09	0.23	0.18	0.07	4.90
5	—	0.14	—	—	—	—	—	0.36	—	0.10	0.14	—	0.11		0.85		0.07	—	1.10	—	0.09	—	—	0.27	0.23		12.0
6	—		0.07	—	0.09		—	0.25	—	0.24	0.85	—	0.14		0.18		0.07	0.09	0.14	—	—	—	—	0.36	0.14		3.10
7	—		—	0.07				2.10	—	0.28	0.18	—	0.30		0.18		—	—	0.11	0.07	—	0.07	—	0.14	0.16		11.0
8	—		—	—				0.34	—	0.20	0.25	—	0.09		0.18		—	—	—	—	0.14	0.14	—	0.14	0.20		1.70
9	—		—	—				0.20	—	0.15	0.08		0.68	0.90	0.14		—	0.07	—	—	—	0.11	—	0.14	0.18		0.36
10	—		0.07	—				0.80	—	—	0.08		6.8	8.0	0.14		0.11	—	—	—	0.07	—	—	0.23	—		0.45
11	—		—	—				0.91	—	—	0.08		0.18		0.18	0.20	0.07	—	—	—	0.14	0.14	0.07	0.27	—		
12	—		—	—				0.91	—	—	—		0.09		8.30	3.9	0.07	0.07	—	0.14	—	—		0.36	0.11		
13	—		0.07	—				3.20	—	—	0.12		3.00		0.09			—	0.07	0.07		0.14		0.55	—		
14	—		0.09	—				0.07	—	0.13	0.07		0.23		0.09			—	—	0.09		—		0.45			
15	—		—	—				0.19	—	—	0.14		0.55		—			—	—	—		0.14		0.07			
16	—		0.07	—				—	0.06	—	0.12		0.07		—			—	0.09			0.09		2.10			
17	—		0.09	—				0.20	—	—	0.07		—		—			—	—			0.09		2.00			
18	—		0.07	—				—	0.25	—	0.12				—			—	0.23			0.23					
19	0.1		0.07	—					0.15	0.07	0.07				—			—									
20			0.14	—						0.05					—			0.07									
21			0.16	—						—					—												
22			0.14	—						0.06					0.07												
23			0.11	—						—					—												
24			0.16	—											—												
25			0.25	—											—												
26			0.21	0.06											—	0.10											
27			0.34	0.15											11.0	8.6											
28			0.18	0.11																							
29				—																							
30 through 42				—																							
43				0.06																							
44				—																							

Table 5. Summary of vegetation sampling results.

Activity (pCi/liter × 10^5)	All samples		Off-site samples		On-site samples	
	No. of samples	Percent of total	No. of samples	Percent of total	No. of samples	Percent of total
<0.1	250	63	249	68	1	4
0.1-0.5	110	28	95	26	15	56
0.5-1.0	15	4	11	3	4	15
1.0-5.0	12	3	8	2	4	15
5.0-12.0[a]	7	2	4	1	3	10
Totals	394		367		27	

[a]Highest value recorded.

Table 6. Water sample tritium activities in pCi/liter × 10^5. Activities lower than the minimum detectable level of 0.05 pCi/liter are not listed.

Sample No.	Activity	Sample No.	Activity
WS-1	—	WS-16	—
WS-2	—	WS-17	—
WS-3	—	WS-18	—
WS-4	—	WS-19	—
WS-5	—	WS-20	0.09
WS-6	0.08	WS-21	0.07
WS-7	—	WS-22	0.09
WS-8	—	WS-23	—
WS-9	—	WS-24	0.11
WS-10	—	WS-25	—
WS-11	—	WS-26	0.14
WS-12	—	WS-27	—
WS-13	—	WS-28	—
WS-14	—	WS-29	—
WS-15	—		

This facility is located 0.8 miles north of the exhaust stack of the Gaseous Chemistry Building. The activities measured were 0.28 × 10^5 and 0.45 × 10^5 pCi/liter, respectively.

Table 7. Milk sample tritium activities in pCi/liter × 10^5. Activities lower than the minimum detectable level of 0.05 × 10^5 pCi/liter are not listed.

Sample series	Date (August)	
MS-1	6	—
	7	—
	7	—
	8	—
MS-2	7	—
	8	—
MS-3	7	0.07
MS-4	8	—
MS-5	8	0.06
MS-6	8	—
MS-7	7	—
MS-8	7	—
MS-9	7	—
MS-10	7	—
MS-11	10	—
MS-12	10	—
MS-13	10	0.08

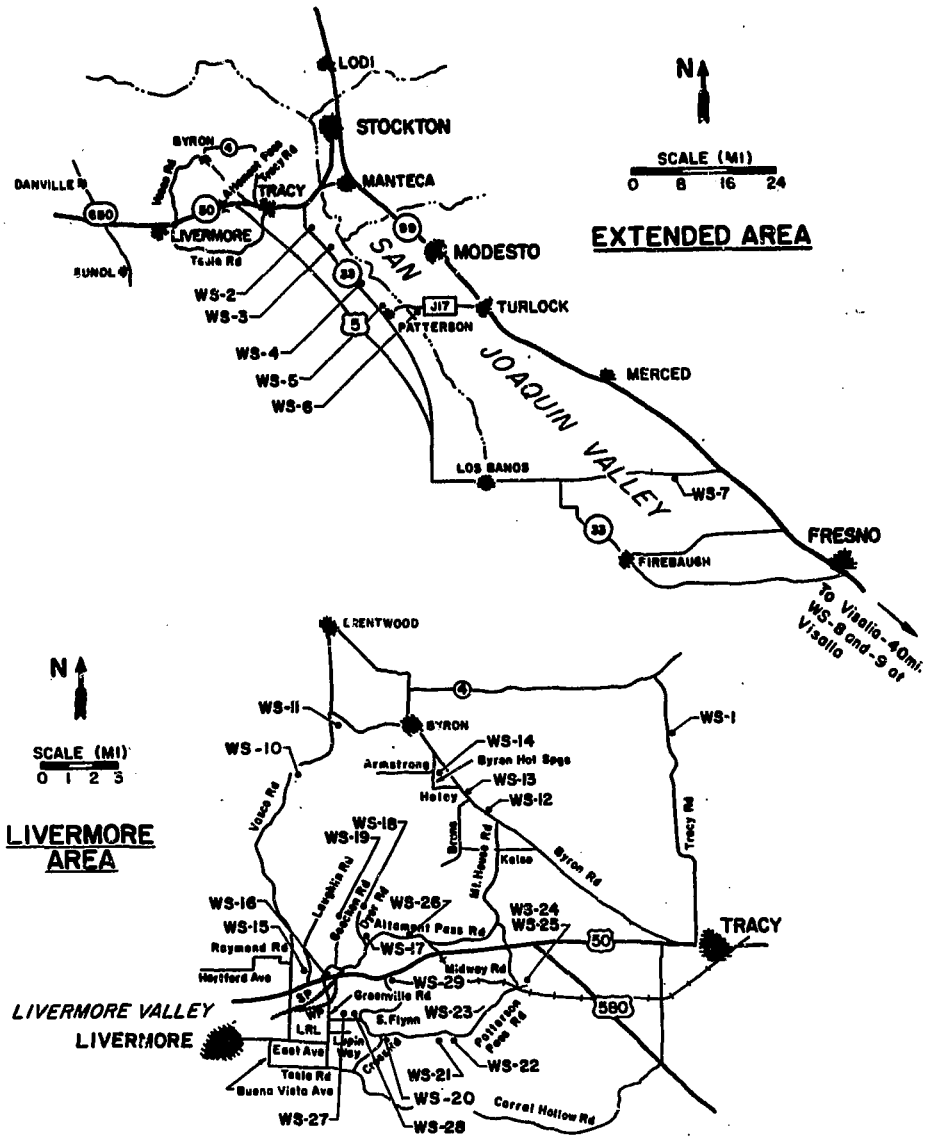

Fig. 4. Water sample locations.

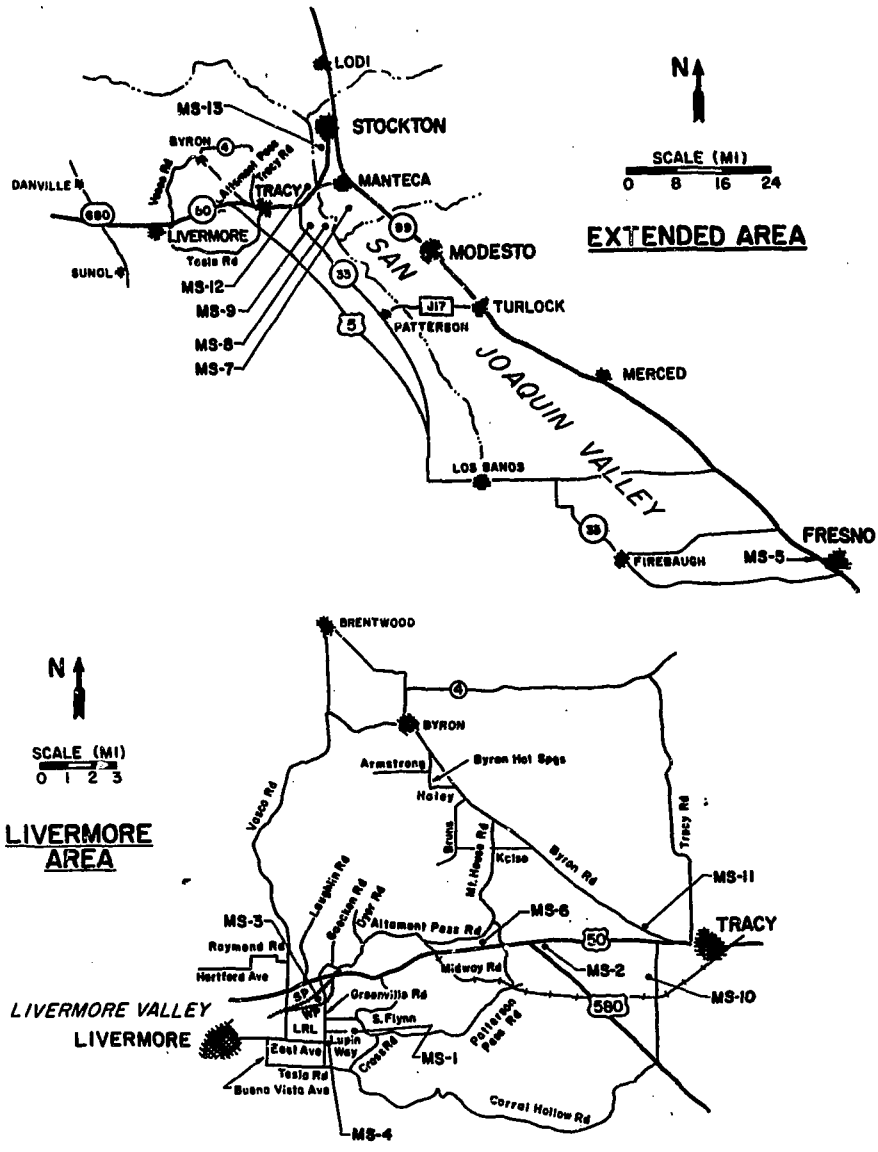

Fig. 5. Milk sample locations.

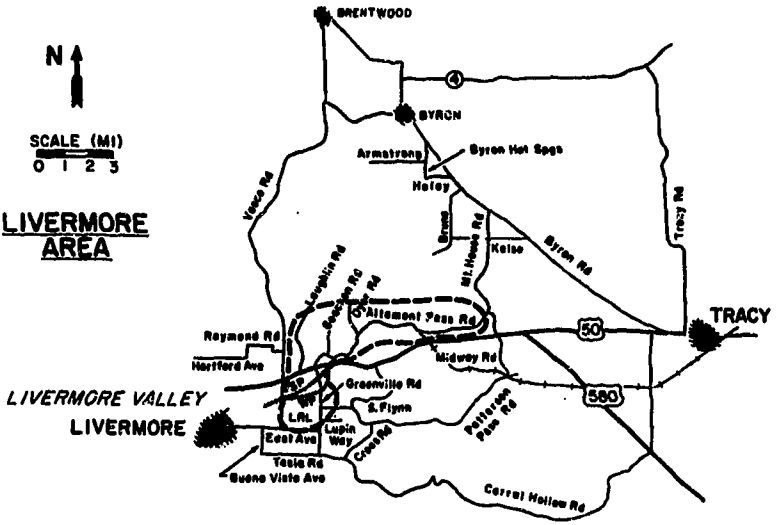

Fig. 6. Area in which urine samples were obtained—enclosed by dashed line.

Accidental Release Levels as Related to Maximum Permissible Concentrations

Table 8 provides a comparison between the levels of off-site tritium activity measured after the release with previous measurements (which established background

Table 8. Comparison of tritium activities for samples taken before and after accidental tritium release. Values are in pCi/liter unless otherwise noted.

Sample	Max accident levels	Pre-accident levels	Off-site MPC's	Detection limit
Water	1.4×10^4	$< 5 \times 10^3$	3×10^6 [b]	5×10^3
Water vapor in air	1.4×10^3 pCi/m^3 of air[a]	$< 4 \times 10^1$ pCi/m^3 of air[a]	2×10^5 pCi/m^3 of air[a]	4×10^1 pCi/m^3 of air[a]
Milk	8.0×10^3	$< 5 \times 10^3$	3×10^6 [b]	5×10^3
Vegetation (water)	1.0×10^6	1.0×10^4 (av) 2.5×10^5 (max)	3×10^6 [b]	5×10^3
Urine	$< 5 \times 10^3$	$< 5 \times 10^3$	3×10^6 [b]	5×10^3

[a] The minimum sensitivity would depend on the relative humidity, which was 50% at the time of the release.

[b] Assuming that tritium was equilibrated in the environment. This would only be true for a chronic release situation. The values are useful as reference points, however.

levels), off-site maximum permissible concentrations (MPC's), and the minimum measurable activities for the listed samples.

All environmental samples of water, milk and urine contained normal background levels of tritium. Tritium was detected in the vegetation and water vapor in the air; however, even the highest concentrations were below off-site MPC's for continuous exposure. The maximum values obtained from on-site samples were 1.2×10^4 pCi/m^3 for water vapor and 1.2×10^6 pCi/liter for vegetation. The on-site MPC's are 1×10^8 pCi/liter for vegetation, assuming equilibration in the environment, and 5×10^6 pCi/m^3 for water vapor.

Hazards Analysis

There are two potential areas of concern regarding exposure to individuals off-site as a result of the release. They are (1) the dose an individual could have received had he been located downwind at the point of maximum ground concentration during the entire passage of the cloud and (2) the dose an individual could have received through the forage/cow/milk exposure pathway from the tritium deposited on vegetation. Each of these cases is discussed briefly in the following paragraphs.

EXPOSURE TO THE CLOUD

Given the meteorological conditions which existed at the time of the release (very stable with light winds) and the stack height (120 ft) the estimated point of maximum ground level concentration is about 0.6 to 0.75 miles downwind. This distance coincides approximately with the nearest off-site location in the downwind direction. If it is assumed that an individual was standing on the centerline of the cloud's track at the nearest downwind off-site location and that 1% of the tritium was present in the more hazardous oxide form (HTO or T_2O), the estimated dose to this individual would be about 3 mrem. As a point of reference, if we assume that all of the tritium was converted to the oxide form (which would only be likely in the event of a fire or explosion at the point of release), the maximum projected exposure at the site boundary would be 300 mrem. This compares with a maximum permissible annual dose to a non-occupationally exposed individual of 500 mrem. Since all urine samples collected off-site indicated that there was no tritium *present* above detectable levels (5×10^3 pCi/liter), the maximum undetectable dose which could have been received from exposure to the cloud would have been about 0.025 mrem.

FORAGE/COW/MILK EXPOSURE ROUTE

The second potential concern is the dose that could be received by an individual drinking milk produced by cows which have grazed on contaminated vegetation. As noted earlier, positive indications of tritium were found in off-site vegetation with the maximum being 1.0×10^6 pCi/liter in one sample. However, there was no indication of tritium in water or milk above normal levels.

If we make the conservative assumption that a large area of pastureland was uniformly contaminated to the maximum level observed, the dose to a child drinking the milk from cows grazing on this vegetation can be estimated by techniques used to predict internal dose from radionuclides released to the biosphere.*

If we assume that there were about 4 liters of water per square meter of vegetation, then the fallout concentration at the point of maximum deposition would be

$$(4 \text{ liters/m}^2) \times (1.0 \times 10^6 \text{ pCi/liter}) = 4.0 \ \mu\text{Ci/m}^2.$$

This level of fallout concentration would result in a dose to a child exposed via this pathway of 70 mrem. This value should be considered a conservative maximum because it assumes large-area contamination at the highest level found at one location in the survey, which is actually unlikely because a) no other locations reaching this level of contamination were found and b) it is unlikely that any such locations were missed because of the extensiveness of the survey. This conservatism is further supported by the fact that no tritium activity above background levels was found in any of the milk or urine samples collected.

Conclusions

The results from this environmental and bioassay sampling program indicate that no significant exposure to on- or off-site individuals resulted from the release. All samples of water, milk, and urine contained normal background levels of tritium. Although detectable levels of activity were found in some vegetation and atmospheric water vapor samples, the highest measured concentrations as well as the calculated maximum credible ground-level air concentrations during cloud passage were well below the off-site maximum permissible concentrations for continuous exposure. If all of the tritium was assumed to be converted to the oxide form, the calculated maximum exposure at the site boundary as a result of exposure to the cloud would be 300 mrem. Since tritium was not present in urine samples above detectable levels, the maximum undetectable dose which could have been received would have been about 0.025 mrem. Based on vegetation sampling results, the maximum credible dose to a child exposed via the forage-cow-milk pathway would be about 70 mrem.

*Y. C. Ng, C. A. Burton, S. E. Thompson, R. K. Tandy, H. K. Kretner and M. W. Pratt, Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices, IV Handbook for Estimating the Maximum Internal Dose from Radio Nuclides Released to the Biosphere, Lawrence Radiation Laboratory, Livermore, Rept. UCRL-50163, Part IV (1968).

Acknowledgments

The authors would like to acknowledge the assistance of the many members of the Hazards Control Department who participated in the initial emergency response and the extensive sample collection, preparation, and counting programs.

In addition, special thanks should be given to the following individuals: Todd Crawford and Joe Knox from the Plowshare Division who supplied early meteorological information which was used to predict the path of the cloud during the first several hours after release, Amasa Cornish of the State Department of Public Health who assisted in the collection of milk and urine samples, the Bio-Medical Division which assisted in the collection of on-site vegetation samples, and R. G. Barton of the Technical Information Department for his advice and assistance in preparing this data for publication.