EMSL-LV-539-2

EMSL-LV-539-2

GASEOUS RADIOIODINE TRANSPORT IN THE AIR-FORAGE-COW-MILK SYSTEM

Environmental Monitoring and Support Laboratory
U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

April 1976

This research was performed as a part of the Bioenvironmental Research Program under Memorandum of Understanding No. AT(26-1)-539
for the
U.S. Energy Research and Development Administration

AVAILABLE FROM THE NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

PRICE: PAPER COPY $4.50 MICROFICHE $2.25

 EMSL-LV-539-2

GASEOUS RADIOIODINE TRANSPORT IN THE AIR-FORAGE-COW-MILK SYSTEM

S. C. Black, R. L. Douglas*, and D. S. Barth

Environmental Monitoring and Support Laboratory
U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

*Las Vegas Facility
Office of Radiation Programs
U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

April 1976

This research was performed as a part of the Bioenvironmental Research Program under Memorandum of Understanding No. AT(26-1)-539
for the
U.S. Energy Research and Development Administration

Effective June 29, 1975, the National Environmental Research Center-Las Vegas (NERC-LV) was designated the Environmental Monitoring & Support Laboratory-Las Vegas (EMSL-LV). This laboratory is one of three Environmental Monitoring & Support Laboratories of the Office of Monitoring & Technical Support in the U.S. Environmental Protection Agency's Office of Research & Development.

Abstract

To study the transport of I_2 in the air-forage-cow milk system, a gaseous form of ^{131}I was released over a field of growing alfalfa which also contained some baled hay and dairy cows in pens. Some of the alfalfa was converted to hay and fed to cows, and some was used as green chop for other cows and goats.

The results of this experiment suggest that the deposition velocity of gaseous iodine is much less than that for iodine bound to particulates; that cows ingesting hay secrete a higher percentage of ^{131}I in milk than cows ingesting green chop; that gaseous forms do not penetrate hay bales to any great extent; that the gaseous form is transferred to milk in a manner similar to particulate forms; that ingestion of contaminated forage results in 80 times as much ^{131}I transfer to milk as does "inhalation" exposure to the same cloud; and that goats transfer ^{131}I from forage to milk more efficiently than do dairy cows.

Acknowledgement

The radioiodine studies conducted by this Division for the Bio-environmental Research Program all required a team effort involving a majority of the Division personnel whose efforts are deeply appreciated. Particular acknowledgement is made for the technical and theoretical contributions of Richard E. Stanley, Benjamin J. Mason, Donald D. Smith and David N. McNelis.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

In a series of experiments to study the air-forage-cow-milk system for the transport of radioiodine, this Laboratory has used various types of synthetic aerosols tagged with ^{131}I, contaminated effluent from Plowshare cratering tests, accidental ventings from underground nuclear tests, and other tests where appropriate. Since this was a strongly field-oriented program, the synthetic aerosols were generated over a field of growing forage at the Experimental Dairy Farm on the Nevada Test Site to simulate the planned or accidental release of fission products to the environment. This farm has been described previously.[(1)]

In all cases, the contaminated forage was fed to lactating cows in measured amounts, and, in some cases, cows were placed in the path of the experimental aerosol plume to receive an air exposure. Three previous experiments have involved different sizes of solid aerosols[(2-4)] while a fourth involved a liquid spray to simulate a rainout situation.[(5)]

The experiment reported herein involved the release of a gaseous form of radioiodine (presumably $^{131}I_2$) and was given the acronym MICE (Molecular Iodine Contamination Experiment). The objectives of this experiment, conducted in September of 1967, were to:

1. Determine the deposition velocity and forage retention of molecular iodine in gaseous form.

2. Determine the percent of radioiodine transferred to milk when dairy cows ingest hay or fresh forage contaminated with this gaseous material.

3. Determine the relative importance of air uptake versus ingestion as reflected by the amount appearing in milk.

4. Compare the milk transfer parameters with those obtained in the previous experiments.

5. Compare the milk transfer parameters for lactating goats with those for dairy cows.

PROCEDURES

An area measuring 65 by 70 meters was established in the growing alfalfa field at the Experimental Dairy Farm to be used for this study. This area was further subdivided into plots to provide: (1) a vegetation half-life study area, (2) an area to include cow pens for the air uptake study, (3) an area to provide green chop for feeding 6 cows for 8 days, and (4) an area with baled hay and forage for hay feeding. The study area and the instrumentation necessary to determine deposition and air concentration data are shown in Figure 1. The precise plot layout and instrumentation descriptions were included in an earlier publication.[6]

The lactating cows in the dairy herd were stratified by milk production and then randomly assigned to three experimental groups as follows: (I) six cows to receive an inhalation exposure and to be fed contaminated hay, (II) six cows to receive an inhalation exposure and to be fed contaminated green chop, and (III) six cows to receive an inhalation exposure only. Data on these cows are shown in Table 1.

Approximately two hours prior to aerosol generation, all cows were placed in pens in the study area. Group I cows were placed in a pen containing a water tub and feed bunk with 15 kg of loose hay for each cow. Groups II and III were placed in a common pen with water tubs but no feed. Also, 10 bales of hay were placed south of the pens to be contaminated by the aerosol cloud.

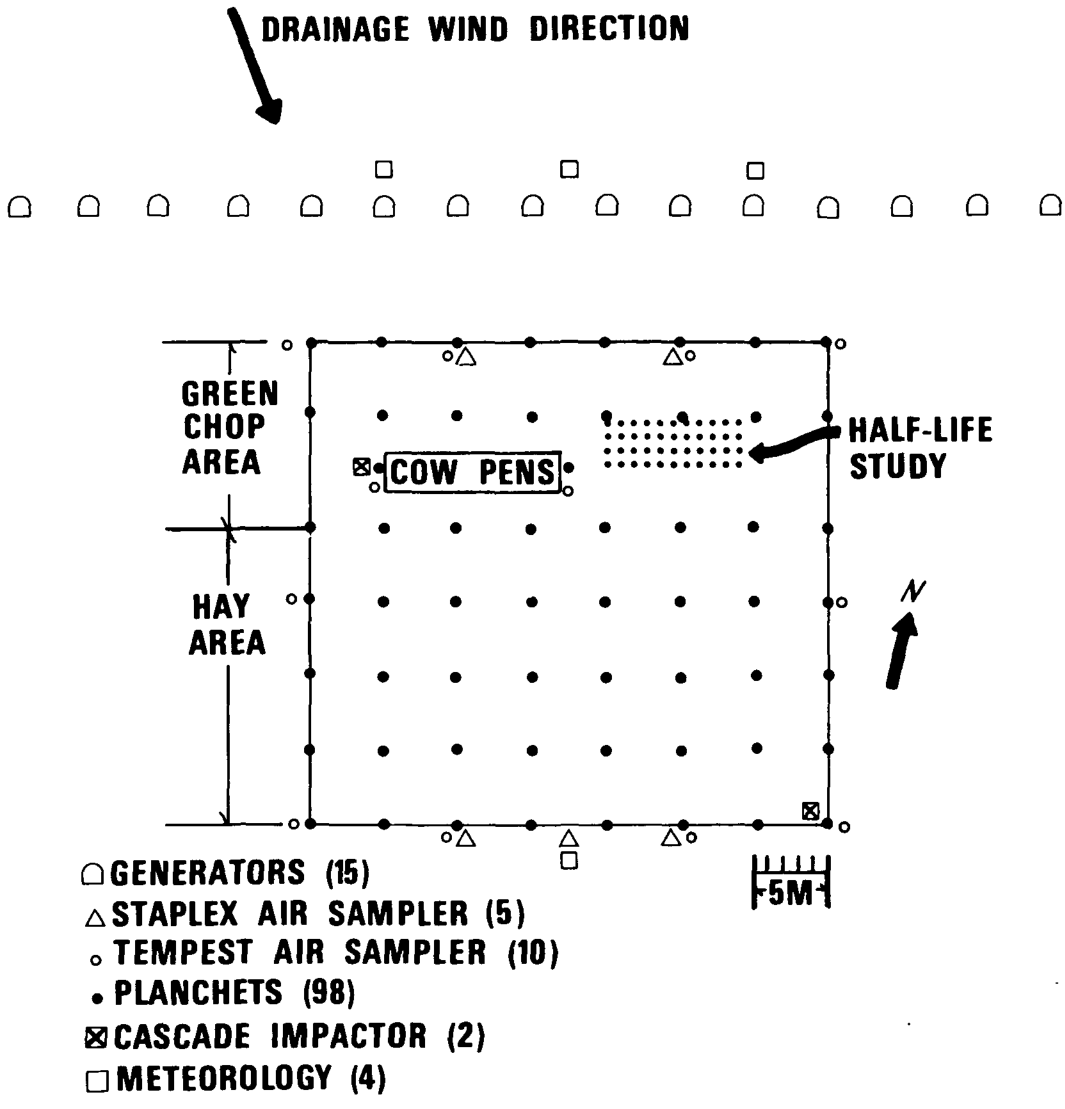

FIG.1 EXPERIMENTAL PLOT AND INSTRUMENTATION

Generation of the $^{131}I_2$ aerosol began at 2345 hours on September 21 and continued for about 30 minutes. A previous publication [6] contains details of the generation procedure. After aerosol generation was stopped, measurements of gamma radiation were made in the plot with survey instruments and all of the samples collected by instrumentation in the study area were prepared for analysis by gamma-ray spectrometry. The cows were left in the pens for about seven hours after exposure. The twelve cows from Groups II and III were then led from the field pens, washed down with a high-pressure water spray, and placed in the feed lot. After the Group I cows had eaten the loose hay in the exposure pen, they were also washed down and placed in the feed lot. Each cow in Groups I and II was placed in an individual stall after milking so that ingestion of contaminated feed could be controlled.

The feeding and milking procedures were similar to those used in the previous studies[2-5] with the exception of the Group I cows. These cows, in addition to the air exposure, ate contaminated hay present in their mangers during and after the aerosol release. They were then fed hay for three days from the bales of hay which were in the experimental plot during the aerosol release. Finally, they were fed hay made from the contaminated alfalfa which had been mowed on the day of release and allowed to dry *in situ* and then baled in the late afternoon of the third day. The amounts of contaminated and uncontaminated forage offered to each cow are shown in Table 1. Each cow also consumed 3-4 kg of high protein grain at each

Table 1. Experimental Cow Groups

Group	Cow No.	Milk Output liters/day	Days in Lactation	Feeding Schedule* Hay	Green Chop	Remarks
	2	19.4	212			
	27	23.8	59			Fed 7.5 kg hay after each milking.
I	35	15.4	176	15 kg**		
	43	22.0	34			
	86	21.1	22			
	87	13.6	289			
	Average	19.2	132			
	16	27.2	150			
	21	30.8	43			Fed green chop after morning milking, hay after evening milking.
II	28	10.1	221			
	36	12.8	159	7.5 kg	20 kg**	
	45	14.1	175			
	46	21.6	43			
	Average	19.4	132			
	13	27.2	57			
	29	23.3	155			Fed green chop after morning milking, hay after evening milking.
III	39	13.2	165	7.5 kg	20 kg	
	44	25.9	37			
	47	18.5	129			
	84	23.3	22			
	Average	21.9	94			

*Each cow received 3-4 kg of grain at each milking.
**Denotes forage contaminated with ^{131}I.

milking. Any residue of forage remaining in the individual mangers was removed and weighed after each feeding to quantitate the amount ingested.

To compare feed to milk transfer in another species, four lactating goats were placed in individual pens and each was offered 2 kg of contaminated green chop daily for 8 days. The balance of the goat's diet consisted of uncontaminated hay and grain.

The effective half-life of radioiodine on alfalfa was studied in the plots indicated in Figure 1. Each plot was divided into 48 blocks. Using a randomized block design, two blocks were sampled in each plot at specified times up to 19 days after release. Each sample consisted of all plants within an area of $0.15\,m^2$, cut off two inches above ground.

Analytical Procedures: All samples were placed in plastic bags when collected and then placed in a second bag after a sample identification number had been assigned. For forage and milk samples, or any sample which was weighed, the weighing and bagging was done as soon as possible after collection.

The gamma spectrometry system used was capable of detecting 20 pCi of ^{131}I per sample and had an accuracy of ± 10% or 20 pCi, whichever was greater.

RESULTS

The midpoint of the gaseous aerosol release was 0000 hours September 22, 1967, so all times are figured from that point. Of a total of 92.1 mCi ^{131}I in the aerosol generation flasks, 69.1 mCi was released, or 75%.

Eighty-five percent of the radioiodine collected by air samplers was on the charcoal cartridges. The deposition velocity as determined from paired air sampler-planchet data was 0.51 cm/s.(6) Both suggest that the majority of the aerosol was either gaseous or, if attached to atmospheric particulates, very small particles. The total deposit on the experimental plot as estimated from planchet data was about 3 mCi with an average deposit of 0.66 $\mu Ci/m^2$. The average integrated air concentration was 129 $\mu Ci\text{-}s/m^3$.

Analysis of grain, water, and uncontaminated forage fed to the cows indicated that these materials contributed no measurable ^{131}I to the diet.

Data on the contaminated forage ingested by the three groups of cows and the resultant concentration of ^{131}I in their milk are presented in Figures 2 and 3. The relationships among the groups resulting from the different exposure modes are readily apparent in Figure 2. For example, the concentration of radioiodine in the first milk from Group II is almost identical to that from Group III. This concentration resulted from air uptake* exposure only while the concentration in the first milk from Group I was higher because of the combined air exposure and ingestion of contaminated

*See p. 14

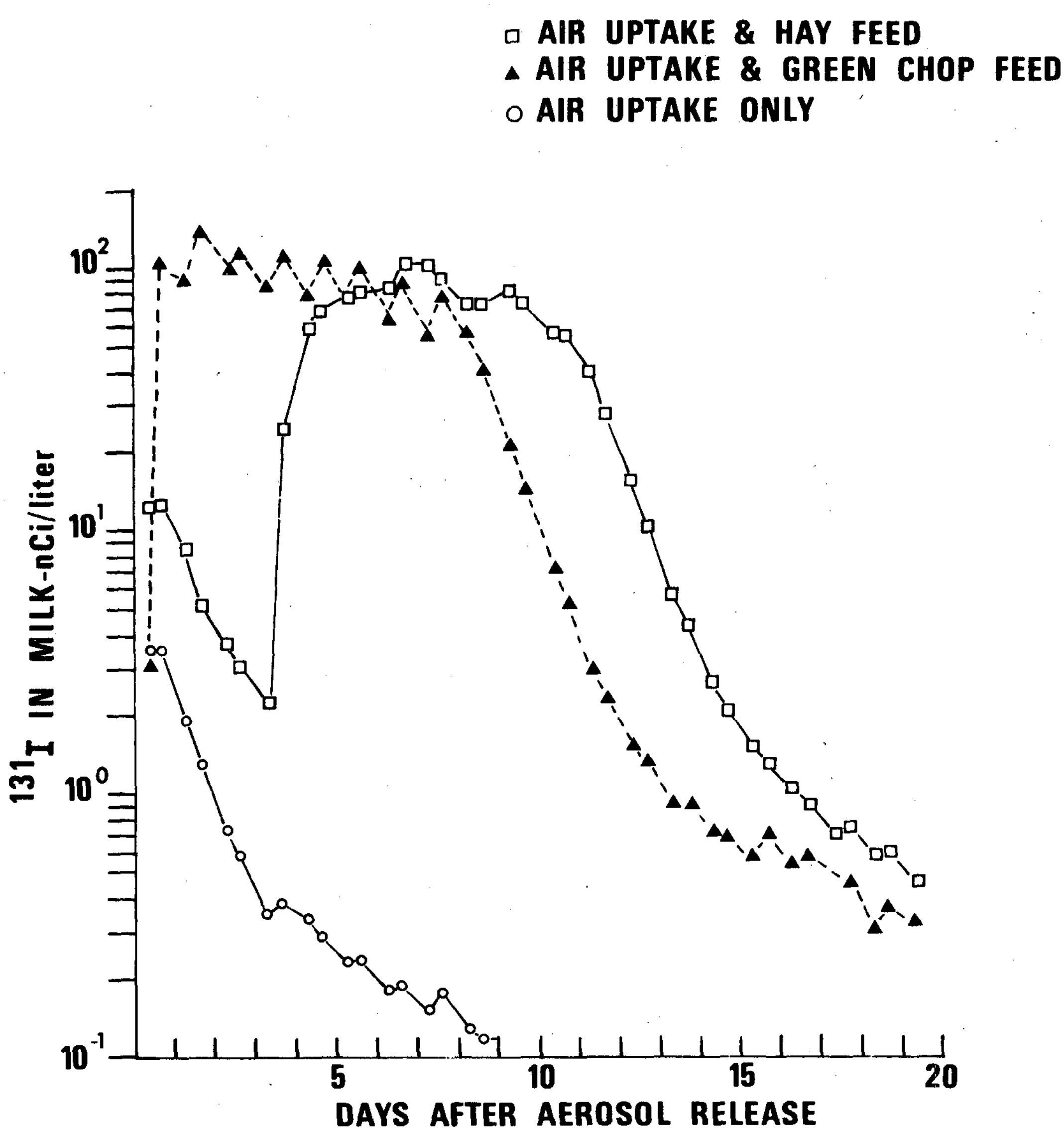

FIG. 2 ^{131}I CONCENTRATION IN MILK FROM THE THREE GROUPS OF COWS.

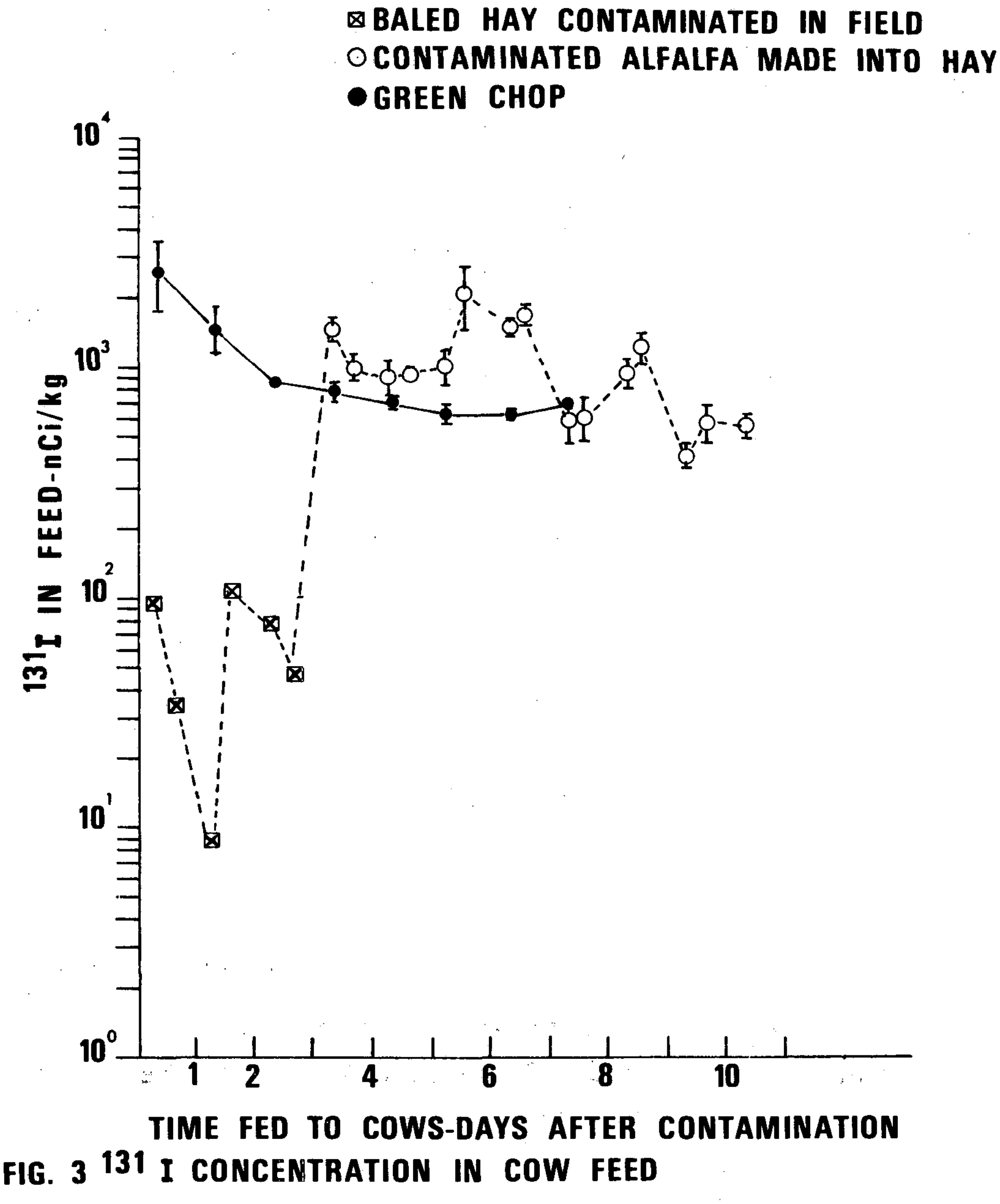

FIG. 3 ^{131}I CONCENTRATION IN COW FEED loose hay. Note also that baled hay exposed to the aerosol cloud (⊠ ⊠ in Fig. 3) retained less of the contaminant than either fresh green chop (● ●) or hay made from the contaminated pasture (○ ○). The individual data for each cow are tabulated in Appendix A and the various parameters derived from the data are shown in Table 2 in the Discussion section of this report.

The group average data for ^{131}I concentration in ingested forage and in secreted milk for the four goats are shown in Figure 4. Individual data for the goat study are tabulated in Appendix B.

The effective half-life of the gaseous ^{131}I deposited on alfalfa, as determined from hand-cut pasture samples, was 2.2 days for the first two days and then lengthened to 7.4 days.[9] Because the green chop was necessarily cut from a different section of the pasture each day, the green chop samples give variable results. However, the concentration of ^{131}I in green chop shown in Figure 2 illustrates an initial short effective half-life and a subsequent longer one.

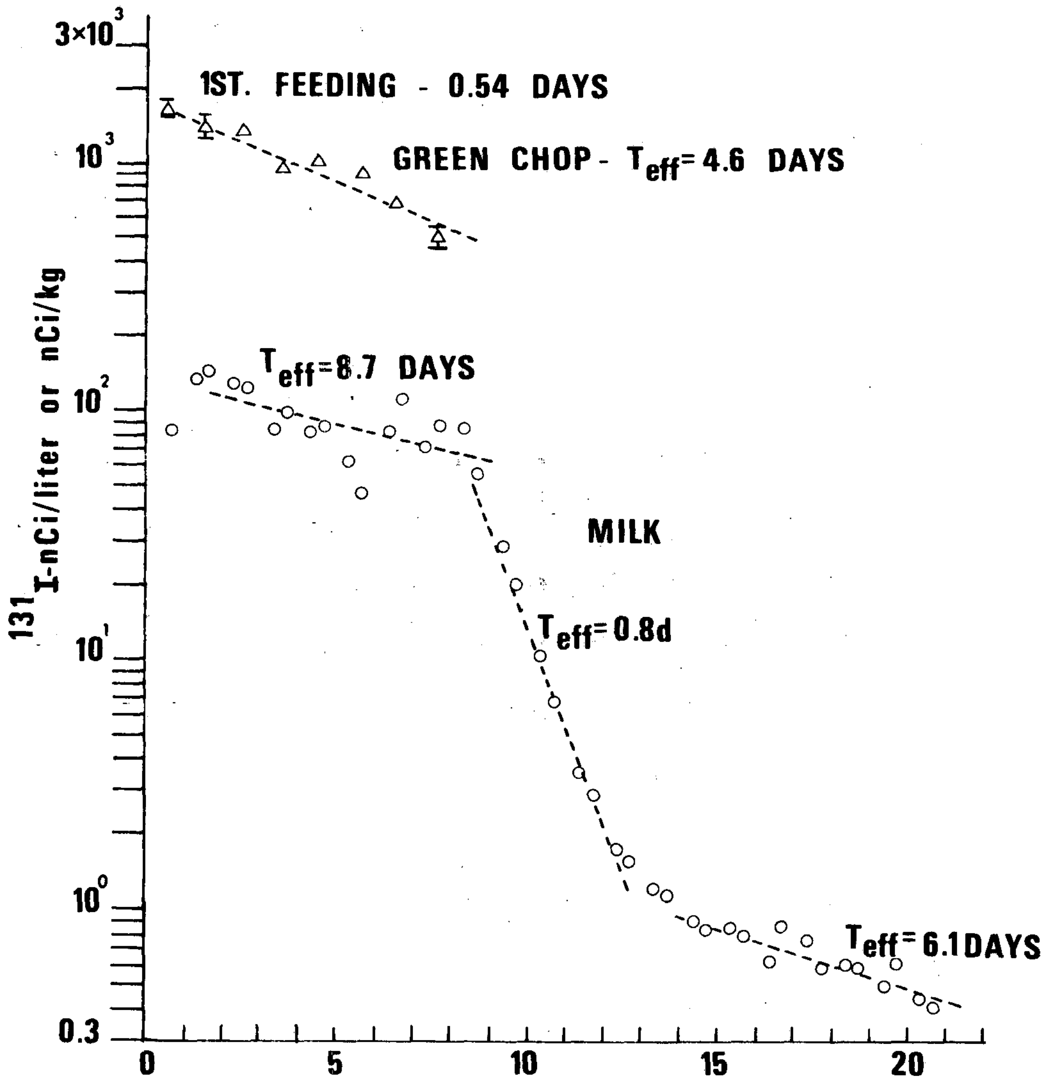

FIG.4 ^{131}I CONCENTRATION IN FORAGE AND MILK - GOAT STUDY.

DISCUSSION

The data from Group I cows (air uptake exposure plus ingestion of contaminated hay) illustrate some of the problems in the determination of exposure when baled hay is the contaminated forage. From the average concentration of ^{131}I in hay (Figure 3), it is apparent that even a predominantly gaseous aerosol does not penetrate very far into the hay. Also, even bales relatively close to each other become contaminated to markedly different levels as shown in the figure and in the first six concentrations shown in Appendix A-4. On the other hand, pasture contamination appears relatively uniform. When the forage was mowed, allowed to dry, and then baled; the concentration in the resultant hay did not vary quite so markedly. In addition to the variable deposit on the baled hay, the radioiodine may have been lost rapidly from this rather inert material as the decline in milk concentration of Group I cows approached that of the cows exposed only to air uptake during the three days they were fed the contaminated baled hay.

In contrast to the above, the rather firm binding or incorporation of gaseous radioiodine to growing alfalfa is reflected by the correspondence of the milk concentration data for Groups I and II, after the Group I cows were fed the hay made from the contaminated alfalfa. The similarity of the hay and green chop concentrations starting about Day 3 is evident in Figure 3. The slightly higher average concentration in the latter hay compared to green chop may be a consequence of moisture loss when the alfalfa was converted to hay.

Some of the milk transfer parameters derived from this study, two studies conducted following accidental venting from underground nuclear tests,[7-8] and from four other aerosol studies at the Dairy Farm are shown in Table 2. These data suggest that ^{131}I on sudan grass appears less biologically available than ^{131}I on alfalfa; that the peak concentration in milk from cows fed contaminated green chop is about 50 times that in cows exposed by air uptake to the same aerosol plume; and that goats appear to transfer radioiodine from forage to milk to a greater extent than do cows ingesting the same forage.

The reason for the use of the term "air uptake" rather than "inhalation exposure" can be ascertained from the data in Appendix A-3. At an average milk output of 22 liters/day, the total ^{131}I output in 20 days after air uptake was 160 nCi. Using the integrated air concentration of 129 $\mu Ci\text{-}s/m^3$, and assuming 100 liters/min for the minute-volume of a cow, the inhalation exposure can be calculated to be 215 nCi so about 75% of this was measured in milk. This high a percentage transfer to milk appears improbable so some concurrent ingestion is postulated; thus "air uptake" rather than "inhalation."

The percent of ingested radioiodine which was secreted in milk is shown in Table 3 for the cows and goats. These data are based on about 8 days of ingestion and on milk content for a total of 20 days. Because of limitations on the amount of ^{131}I that could be used, sufficient green chop was available for only a single feeding per cow per day. Feeding twice daily (usual practice)

Table 2. Results from Seven Field Studies with ^{131}I

Study Name	Type of Contaminant	Type of Green Chop	Particle Size*	Type of Exposure	Milk Concentration Peak (nCi/liter)	Time to Peak (days)	T_{eff} During Feeding (days)	Peak nCi/liter / Peak nCi/kg	% in Milk
Pike (7)	Fission Products	Alfalfa	-	Green Chop	0.38	4.0	3.8	0.08	-
				Hay	0.07	3.0	5.9	0.054	-
Pin Stripe (8)	" "	Alfalfa	-	Green Chop	4.6	2.0	5.6	0.086	10.4
				Green Chop	1.1	3.0	4.0	0.078	4.9
Hayseed (2)	Particulate Aerosol	Sudan Grass	23μm	Green Chop	22	2.0	3.0	0.008	2.1
				Hay	11	1.0	2.7	0.027	6.3
				Air Uptake	0.6	1st Milk	-	-	-
Alfalfa (3)	" "	Alfalfa-Oats	2μm	Green Chop	109	1.5	2.5	0.029	12.5
				Hay	39	1.0	8.0	0.069	15.2
				Air Uptake	2.0	1st Milk	-	-	-
SIP (4)	" "	Alfalfa	0.13μm	Green Chop	69.5	1.6	5.2	0.061	7.6
				Hay	4.3	0.6	-	0.040	17.9
				Air	1.2	1st Milk	-	-	-
Rainout (5)	Solution of I	Alfalfa	-	Green Chop	860	1.0	7.9	0.041	6.1
				Hay	130	1.0	2.5	0.013	4.5
MICE(cows)	Gas	Alfalfa	-	Green Chop	140	2.0	6.9	0.053	8.7
				Hay	110	3.2	4.6	0.051	11.4
				Air Uptake	3.6	1st Milk	-	-	-
MICE(goats)	"	"		Green Chop	147	1.1	8.7	0.089	18.0

*Count Median Diameter

Table 3. Percent of ^{131}I Secreted in Milk

Group	Exposure	Animal No.	Total intake μCi	Total in Milk μCi	% In Milk	Average %
I	Hay	2	108	11.6	10.7	
		27	107	16.1	15.0	
		35	98.7	10.1	10.3	11.4 ± 3.8
		43	125	9.35	7.5	
		86	127	21.5	16.9	
		87	101	8.07	8.0	
II	Green Chop	16	131	21.6	16.5	
		21	175	19.2	11.0	
		28	130	5.8	4.4	8.7 ± 4.4
		36	210	14.0	6.7	
		45	127	9.7	7.6	
		46	215	13.3	6.2	
III	Air	13		0.2		
		29		0.18		
		39		0.112		---
		44		0.136		
		47		0.161		
		84		0.175		
Goats	Green Chop	1	9.22	0.71	7.7	
		2	10.8	1.75	16.2	18.0 ± 8.9
		3	8.91	1.66	18.6	
		4	9.36	2.74	29.3	

would have extended the time to peak activity and increased the peak concentration in milk slightly but would not have affected the percent in milk. Furthermore, twice-daily feeding would have minimized the sawtooth effect on milk secretion of the iodine, cf. the smoother appearance of the curve for the cows fed hay.

The most common effective half-life (T_e) for decrease in iodine-131 concentration in milk from cows consuming fresh forage as quoted in the literature is about five days.[10] From the data in Table 2, a value near that (5.2 days in the SIP experiment) occurred only in the experiment where the aerosol had a count median diameter of 0.13 μm. Where the aerosol was larger the T_e was shorter and where ionic or molecular iodine was used the T_e was longer.

It can be hypothesized that the I^- or I_2 enters the plant more readily and becomes more firmly bound than is the case for iodine adsorbed on particles. Thus, if this longer T_e is not just peculiar for our experiments, and assuming all other variations were held constant, the thyroid dose to humans drinking milk produced by cows on a pasture contaminated by predominantly gaseous ^{131}I would be larger than would be the case if a T_e of five days were used.

CONCLUSIONS

For this experiment, cows and their forage were exposed to an aerosol plume which consisted of a predominantly gaseous (I_2) form of ^{131}I. The results of the experiment suggest the following conclusions:

1. The deposition velocity of gaseous iodine (0.51 cm/s) was ½ to 1/3 the deposition velocity measured with particulate aerosols.[2-4]

2. As in earlier experiments,[2-4] the cows ingesting contaminated hay secreted a higher percentage in their milk than cows ingesting contaminated green chop.

3. Cows exposed to the aerosol plume secreted a very small amount of ^{131}I compared to cows ingesting contaminated forage. The latter cows had a peak milk concentration about 44 times the air uptake cows and their total secretion in milk was about 80 times higher.

4. The time to peak concentration in milk, effective half-life during and after ingestion of contaminated forage and percent transferred to milk were similar to earlier experiments using other aerosols except for the case where Sudan grass was used.[2]

5. Gaseous ^{131}I is apparently bound to growing alfalfa more firmly than particulate ^{131}I aerosols.

6. Goats apparently absorb more ^{131}I from contaminated alfalfa than do dairy cows and secrete a higher percentage in their milk.

REFERENCES

1. Smith D.D. (1970), Status of the bioenvironmental research experimental dairy herd, Southwestern Radiological Health Laboratory Report SWRHL-67r, Las Vegas, NV.

2. Barth D.S. and Seal M.S. (1966), Radioiodine transport through the ecosystem air-forage-cow-milk using a synthetic dry aerosol, in Radioecological Concentration Processes, Pergamon Press, NY.

3. Stanley R.E., Black S.C., and Barth D.S. (1969), ^{131}I dairy cow studies using a dry aerosol, Southwestern Radiological Health Laboratory Report SWRHL-42r, Las Vegas, NV.

4. Mason B.J., Black S.C. and Barth D.S. (1971), ^{131}I dairy cow uptake studies using a submicrometer dry aerosol, Southwestern Radiological Health Laboratory Report SWRHL-39r, Las Vegas, NV.

5. Douglas R.L., Black S.C. and Barth D.S. (1971), ^{131}I transport through the air-forage-cow-milk system using an aerosol mist, Southwestern Radiological Health Laboratory Report SWRHL-43r, Las Vegas, NV.

6. McNelis D.N., Black S.C. and Whittaker E.L. (1971), Radioiodine field studies with synthetic aerosols, Southwestern Radiological Health Laboratory Report SWRHL-103r, Las Vegas, NV.

7. Barth D.S. and Veater J.G. (1964), Dairy farm radioiodine study following the Pike event, Southwestern Radiological Health Laboratory Report SWRHL-14r, Las Vegas, NV.

8. Barth D.S., Engel R.E., Black S.C. and Shimoda W. (1969), Dairy farm radioiodine studies following the Pin Stripe event, Southwestern Radiological Health Laboratory Report SWRHL-41r, Las Vegas, NV.

9. McFarlane J.S. and Mason B.J. (1970), Plant radioiodine relationships: a review, Southwestern Radiological Health Laboratory Report SWRHL-90r, Las Vegas, NV.

10. Thompson S.E. (1965), Effective half-life of fallout radionuclides on plants with special emphasis on iodine-131, Lawrence Livermore Laboratory Report UCRL-12388, University of California, Livermore, CA.

Appendix A-1 ^{131}I Concentration in Milk from Group I Cows (air uptake plus hay) - nCi/liter

Time*	Cow 2	Cow 27	Cow 35	Cow 43	Cow 86	Cow 87	Weighted Average
0.34	18.2	15.7	6.29	7.11	15.9	9.46	12.6
0.64+	21.7	15.5	7.32	7.14	16.7	9.73	12.4
1.28	14.0	10.1	4.33	4.39	11.4	6.45	8.56
1.65	9.08	3.66	1.49	3.76	8.31	5.06	5.24
2.29	5.13	4.19	2.06	2.07	5.49	2.82	3.76
2.63	3.84	3.43	1.86	1.79	4.31	2.40	3.12
3.32	3.06	2.28	1.41	1.00	3.32	2.18	2.20
3.64@	25.5	36.9	33.6	11.4	24.0	24.9	24.9
4.29	81.1	84.1	73.0	22.0	61.4	49.7	61.2
4.63	94.0	107	81.1	27.8	68.0	65.4	69.9
5.21	97.7	97.3	106	30.0	89.1	72.8	81.5
5.59	85.5	93.5	104	32.1	105	95.1	81.8
6.30	57.0	89.9	89.6	48.2	133	91.2	85.1
6.63	78.5	123	65.7	110	136	124	108
7.30	106	110	129	66.4	137	108	107
7.62	93.2	95.3	122	60.6	101	104	92.4
8.27	82.6	70.0	85.6	45.6	89.1	86.1	75.3
8.63	79.6	79.6	88.0	50.2	81.9	86.8	75.6
9.28	92.3	91.3	84.7	47.8	103	80.4	83.5
9.62	83.8	79.0	70.0	42.9	100	83.2	75.9
10.34	74.5	28.0	58.4	32.6	96.2	54.7	57.8
10.64	23.0	79.8	26.3	32.9	104	55.8	57.8
11.30	36.6	46.1	41.9	21.9	66.4	32.3	41.4
11.67	24.2	28.0	23.1	16.2	48.3	22.5	28.5
12.30	11.7	16.2	10.7	9.08	30.1	13.3	16.0
12.67	7.32	9.43	7.04	6.91	19.8	9.26	10.3
13.30	3.36	5.42	3.36	4.88	11.9	4.62	5.87
13.69	2.08	3.52	2.26	3.60	8.75	3.37	4.44
14.29	1.26	2.12	1.48	2.21	5.32	2.26	2.66
14.64	1.01	1.60	1.23	1.97	4.26	2.35	2.13
15.30	0.70	1.11	0.83	1.52	2.92	1.36	1.53
15.63	0.66	1.06	0.84	1.26	2.80	1.05	1.36
16.30	0.47	0.75	0.65	0.88	2.14	0.93	1.04
16.66	0.44	0.62	0.62	0.87	1.85	0.85	0.94
17.32	0.46	0.52	0.46	0.65	1.39	0.70	0.71
17.67	0.41	0.50	0.49	0.71	1.42	0.73	0.77
18.30	0.36	0.39	0.39	0.61	1.12	0.56	0.60
18.66	0.33	0.41	0.34	0.53	1.05	0.57	0.60
19.30	0.27	0.34	0.30	0.45	0.89	0.47	0.48

* Days after air exposure. Ate hay in manger during and after exposure.
+First feeding baled hay contaminated by the aerosol was at 0.42 days.
@ First feeding of contaminated pasture converted to hay and baled was at 3.40 days.

Appendix A-2 ^{131}I Concentration in Milk from Group II Cows (air uptake plus green chop) - nCi/liter

Time*	Cow 16	Cow 21	Cow 28	Cow 36	Cow 45	Cow 46	Weighted Average
0.36	4.02	2.66	2.59	3.62	2.55	2.77	3.06
0.66+	94.3	84.3	53.2	174	121	102	102
1.30	70.4	76.0	80.2	174	105	88.9	90.0
1.63	130	129	99.8	210	174	123	140
2.31	92.1	100	83.0	154	94.2	93.2	100
2.66	140	110	114	123	106	101	116
3.30	85.9	79.1	65.0	131	82.9	71.2	84.3
3.66	129	102	77.2	175	147	83.7	115
4.31	79.8	74.2	64.9	103	79.8	72.3	78.1
4.64	116	96.6	87.7	168	134	78.2	109
5.23	87.5	68.0	66.2	130	92.4	52.8	79.5
5.60	135	88.3	50.9	158	125	60.2	101
6.31	88.3	53.9	46.4	84.7	72.4	45.2	64.3
6.64	134	75.6	64.9	117	89.7	50.9	90.2
7.31	73.1	45.9	36.6	77.7	45.2	44.4	54.8
7.64	99.1	57.7	69.6	114	99.3	56.5	78.8
8.29	70.7	52.4	52.3	83.4	57.8	42.7	58.6
8.64	52.5	39.0	44.9	55.4	39.2	30.3	42.7
9.30	22.2	27.2	20.9	26.5	15.6	15.9	21.6
9.63	14.8	18.3	14.3	17.6	10.5	11.6	14.8
10.36	6.31	9.73	6.58	8.59	4.66	6.49	7.24
10.66	4.37	8.15	2.25	4.50	3.89	4.78	5.33
11.28	1.84	4.24	2.45	2.94	2.07	3.30	2.94
11.65	1.62	3.44	2.16	2.63	1.66	2.31	2.40
12.28	0.79	2.48	1.26	1.35	1.00	1.61	1.53
12.64	0.71	2.31	0.81	1.13	1.06	1.58	1.36
13.28	0.40	1.45	0.83	0.76	0.59	1.14	0.92
13.70	0.49	1.20	0.72	1.06	0.89	1.08	0.92
14.31	0.36	0.76	0.76	0.63	0.69	1.14	0.72
14.65	0.47	0.65	0.43	0.68	0.54	1.29	0.69
15.28							0.59 §
15.64							0.71
16.28							0.55
16.64							0.58
17.30							0.70
17.65							0.47
18.29							0.31
18.64							0.38
19.29							0.33

* Days after air exposure.
\+ First green chop feeding at 0.39 days after air exposure.
§ Composite samples.

Appendix A-3 ^{131}I Concentration in Milk from Group III Cows (air uptake) - nCi/liter

Time*	Cow 13	Cow 29	Cow 39	Cow 44	Cow 47	Cow 84	Weighted Average
0.37	3.40	4.44	4.71	2.55	4.28	2.98	3.58
0.63	3.49	4.68	4.76	2.37	4.25	3.42	3.56
1.27	1.95	2.37	2.06	1.05	2.41	1.93	1.90
1.62	1.40	1.43	1.24	0.86	1.69	1.33	1.30
2.27	0.75	0.81	0.85	0.53	0.96	0.70	0.73
2.61	0.58	0.66	0.72	0.45	0.78	0.53	0.58
3.27	0.35	0.38	0.42	0.24	0.43	0.35	0.35
3.62	0.30	0.41	0.53	0.26	0.57	0.37	0.39
4.27	0.27	0.30	0.45	0.21	0.62	0.34	0.34
4.61	0.24	0.23	0.32	0.17	0.57	0.29	0.29
5.19	0.19	0.20	0.28	0.16	0.42	0.19	0.23
5.58	0.16	0.25	0.27	0.19	0.30	0.29	0.24
6.28	0.12	0.15	0.22	0.25	0.14	0.20	0.18
6.61	0.12	0.16	0.26	0.17	0.28	0.20	0.19
7.28	0.12	0.12	0.27	0.14	0.19	0.16	0.15
7.61	0.10	0.16	0.30	0.17	0.24	0.16	0.18
8.26	0.084	0.14	0.25	0.10	0.18	0.12	0.13
8.61	0.098	0.12	0.18	0.099	0.16	0.11	0.12
9.27	0.065	0.078	0.16	0.067	0.10	0.079	0.084
9.61	0.064	0.095	0.10	0.090	0.096	0.086	0.087
10.32	0.037	0.053	0.060	0.043	0.080	0.058	0.053
10.62	0.050	0.078	0.076	0.067	0.088	0.075	0.072
11.26	0.053	0.039	0.061	0.080	0.071	0.080	0.065
11.63	0.073	0.072	0.070	0.10	0.10	0.14	0.093
12.26							0.086**
12.62							0.088
13.26							0.063
13.67							0.052
14.28							0.064
14.62							0.027
15.27							0.030
15.63							0.042
16.26							0.066
16.62							0.064
17.28							0.039
17.63							0.39
18.27							0.13
18.63							0.068
19.27							0.066

* Days after exposure (0000 hr 9/22/67)
** Composite samples.

Appendix A-4 ^{131}I Concentration in Cow Feed - μCi/kg

Hay for Group I Cows

Time*	Mean	S. E.**
0.33	0.096	0.012
0.67	0.034	0.011
1.29	0.009	0.002
1.62	0.102	0.025
2.32	0.078	0.029
2.62	0.047	0.027
3.33	1.44	0.22
3.62	1.00	0.12
4.29	0.911	0.17
4.62	0.956	0.06
5.25	1.01	0.19
5.58	2.11	0.67
6.33	1.49	0.13
6.58	1.69	0.14
7.33	0.586	0.12
7.58	0.613	0.14
8.33	0.955	0.13
8.58	1.22	0.18
9.33	0.424	0.056
9.62	0.589	0.110
10.33	0.568	0.071

Green Chop for Group II Cows

Time	Mean	S. E.
0.39	2.63	0.88
1.33	1.48	0.36
2.33	0.89	0.023
3.33	0.80	0.074
4.33	0.71	0.042
5.25	0.64	0.062
6.33	0.64	0.030
7.33	0.71	0.032

* Days after release when fed to cows
** Std. error of mean

Appendix B ^{131}I Concentration in Milk and Feed, Goat Study

	Milk - nCi/l					Green Chop - μCi/kg		
Time*	Goat 1	Goat 2	Goat 3	Goat 4	Weighted Average	Time Fed*	Mean	S.E.
0.67	25.4	53.5	111	204	83.6	0.54	1.65	0.13
1.34	36.0	88.9	165	307	135			
1.65	55.9	108	166	318	147	1.53	1.37	0.10
2.35	40.9	109	154	263	130			
2.65	45.9	109	163	293	124	2.50	1.36	0.044
3.35	28.0	85.0	98.7	153	85.8			
3.65	4.10	87.9	106	241	100	3.52	0.972	0.039
4.34	33.3	57.7	75.9	196	83.6			
4.66	37.3	76.5	74.5	243	86.9	4.51	1.02	0.050
5.35	26.1	64.2	47.2	126	62.6			
5.65	20.5	46.4	34.1	95.1	46.4	5.68	0.922	0.038
6.37	40.5	81.9	79.5	146	83.8			
6.65	57.2	74.1	144	241	113	6.50	0.692	0.022
7.34	26.3	55.6	103	137	72.8			
7.65	33.3	58.7	134	172	88.6	7.55	0.500	0.050
8.37	29.0	69.2	110	146	87.3			
8.65	22.2	44.5	85.1	112	57.4	8.51	0.00054	0.00002
9.35	11.8	26.0	39.1	48.8	28.6			
9.65	8.37	17.4	25.4	34.2	20.7	9.43	0.00047	0.00004
10.35	3.97	13.3	11.3	14.4	10.5			
10.65	3.29	7.58	8.76	10.7	6.96	10.40	0.00044	0.00002
11.35	1.39	4.14	4.42	5.05	3.60			
11.65	1.08	3.11	3.38	5.12	2.88			
12.36	0.59	1.85	2.31	2.95	1.77			
12.65	0.60	1.49	1.84	2.89	1.60			
13.35	0.37	1.08	1.82	2.20	1.22			
13.65	0.37	0.90	1.62	2.34	1.14			
14.34	0.28	0.70	1.24	1.64	0.91			
14.65	0.31	0.68	1.12	1.75	0.85			
15.34	0.22	0.72	1.05	1.59	0.85			
15.65	0.26	0.62	1.03	1.87	0.80			
16.34	0.24	0.77	1.01	-	0.64			
16.65	0.38	0.63	1.00	1.96	0.88			
17.35	0.32	0.65	0.92	1.48	0.77			
17.64	0.21	0.54	0.76	1.27	0.59			
18.35	0.25	-	0.64	1.23	0.62			
18.65	0.24	0.50	0.63	1.26	0.60			
19.35	0.19	0.44	0.48	1.11	0.51			
19.65	0.21	1.21	0.41	0.56	0.60			
20.34	0.15	0.39	0.53	0.91	0.44			
20.66	0.20	0.42	0.62	1.15	0.41			

* Days after aerosol release.

DISTRIBUTION

1 - 20 Environmental Monitoring and Support Laboratory, Las Vegas, NV

21 Mahlon E. Gates, Manager, ERDA/NV, Las Vegas, NV

22 Charles E. Williams, Deputy Manager, ERDA/NV, Las Vegas, NV

23 Bennie G. DiBona, ERDA/NV, Las Vegas, NV

24 David G. Jackson, ERDA/NV, Las Vegas, NV

25 Arthur J. Whitman, ERDA/NV, Las Vegas, NV

26 Elwood M. Douthett, ERDA/NV, Las Vegas, NV

27 - 28 Ernest D. Campbell, ERDA/NV, Las Vegas, NV

29 - 30 Paul B. Dunaway, ERDA/NV, Las Vegas, NV

31 - 32 Mary G. White, ERDA/NV, Las Vegas, NV

33 Roger Ray, ERDA/NV, Las Vegas, NV

34 Robert W. Taft, ERDA/NV, Las Vegas, NV

35 Leon Silverstrom, ERDA/NV, Las Vegas, NV

36 Richard C. Amick, ERDA/NV, Las Vegas, NV

37 John O. Cummings, ERDA/NV, Las Vegas, NV

38 Bruce W. Church, ERDA/NV, Las Vegas, NV

39 - 40 Technical Library, ERDA/NV, Las Vegas, NV

41 Chief, NOB/DNA, ERDA/NV, Las Vegas, NV

42 Martin B. Biles, DOS, ERDA/HQ, Washington, DC

43 Tommy F. McCraw, DOS, ERDA/HQ, Washington, DC

44 - 45 Major General Joseph K. Bratton, Assistant General Manager, DMA, ERDA/HQ, Washington, DC

46 Gordon F. Facer, DMA, ERDA/HQ, Washington, DC

47 James L. Liverman, Director, DBER, ERDA/HQ, Washington, DC

48 Robert L. Watters, DBER, ERDA/HQ, Washington, DC

49 John S. Kirby-Smith, DBER, ERDA/HQ, Washington, DC

50 L. Joe Deal, DOS, ERDA/HQ, Washington, DC

51 Charles L. Osterberg, DBER, ERDA/HQ, Washington, DC

52 Robert W. Wood, DBER, ERDA/HQ, Washington, DC

53 Harold F. Mueller, ARL, NOAA, Las Vegas, NV

54 Gilbert J. Ferber, ARL, NOAA, Silver Spring, MD

55 Wilson K. TAlley, Assistant Administrator for Research and Development, EPA, Washington, DC

56 William D. Rowe, Deputy Assistant Administrator for Radiation Programs, EPA, Washington, DC

57 William A. Mills, Director, Division of Criteria and Standards, ORP, EPA, Washington, DC

58 - 59 Floyd L. Galpin, Director, Field Operations Division, ORP, EPA, Washington, DC

60 E. David Harward, Director, Division of Technology Assessment, ORP, EPA, Washington, DC

61 Albert C. Printz, Jr., Director, Office of Technical Analysis, EPA, Washington, DC

62 Library, EPA, Washington, DC

63 Bernd Kahn, Chief, Radiochemistry and Nuclear Engineering, EPA, EMSL-Cincinnati, OH

64 Peter Halpin, Chief, APTIC, EPA, Research Triangle Park, NC

65 Paul DeFalco, Jr., Regional Administrator, Region IX, EPA San Francisco, CA

66 James K. Channell, Regional Radiation Representative, Region IX, EPA, San Francisco, CA

67 Charles Porter, Director, Eastern Environmental Radiation Facility, Montgomery, AL

68 K. M. Oswald, Manager, Health and Safety, LLL, Mercury, NV

69 Bernard W. Shore, LLL, Livermore, CA

70 James E. Carothers, LLL, Livermore, CA

71 Howard W. Tewes, LLL, Livermore, CA

72 Lawrence S. Germain, LLL, Livermore, CA

73 Mortimer L. Mendelsohn, LLL, Livermore, CA

74 Paul L. Phelps, LLL, Livermore, CA

75 John C. Hopkins, LASL, Los Alamos, NM

76 George E. Tucker, Sandia Laboratories, Albuquerque, NM

77 Harry S. Jordan, LASL, Los Alamos, NM

78 Arden E. Bicker, REECo, Mercury, NV

79 Savino W. Cavender, REECo, Mercury, NV

80 Carter B. Broyles, Sandia Laboratories, Albuquerque, NM

81 Melvin L. Merritt, Sandia Laboratories, Albuquerque, NM

82 Richard S. Davidson, Battelle Memorial Institute, Columbus, OH

83 Steven V. Kaye, Oak Ridge National Laboratory, Oak Ridge, TN

84 Leo K. Bustad, College of Veterinary Medicine, Washington State University, Pullman, WA

85 Leonard A. Sagan, Palo Alto Medical Clinic, Palo Alto, CA

86 Vincent Schultz, Washington State University, Pullman, WA

87 Arthur Wallace, University of California, Los Angeles, CA

88 Wesley E. Niles, University of Nevada, Las Vegas, NV

89 Robert C. Pendleton, University of Utah, Salt Lake City, UT

90 William S. Twenhofel, U.S. Geological Survey, Denver, CO

91 Paul R. Fenske, Desert Research Institute, University of Nevada, Reno, NV

92 Lloyd P. Smith, President, Desert Research Institute, University of Nevada, Reno, NV

93 Verle R. Bohman, University of Nevada, Reno, NV

94 Manager, Desert National Wildlife Range, U.S. Fish and Game Department, Las Vegas, NV

95 Supervisor, Region III, Nevada Fish and Game Department, Las Vegas, NV

96 Paul Lyons, Nevada Wildlife Research, Division of Archives, Capitol Building Annex, Carson City, NV

97 - 123 Technical Information Center, ERDA, Oak Ridge, TN (for public availability)