^{131}I DAIRY COW UPTAKE STUDIES USING A SUBMICROMETER SYNTHETIC DRY AEROSOL (PROJECT SIP)

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Benjamin J. Mason, Stuart C. Black, and Delbert S. Barth
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ENVIRONMENTAL PROTECTION AGENCY

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This study performed under a Memorandum of
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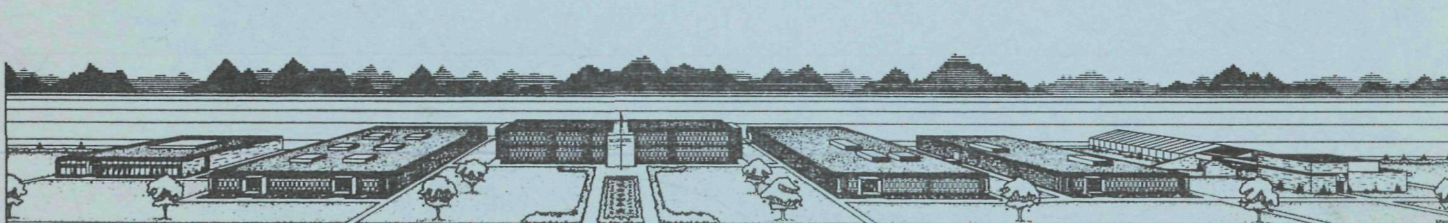

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ABSTRACT

This report covers the fourth controlled release study conducted by Radiological Research in a continuing program to define the mechanisms associated with the overall transfer of radioiodines from the environment to cow's milk.

A ^{131}I labelled aerosol of submicrometer size was released over a pasture and a corral containing 18 dairy cows. Six of the cows had hay in mangers for their consumption. Another group of six was fed green chop from the contaminated pasture while the remaining six cows received no other contaminated material. The pasture was contaminated to a level of 1.13 μCi/kg, and cows fed green chop from the pasture secreted a peak level of .07 μCi/liter in milk. The effective half-life of ^{131}I in milk during ingestion of contaminated forage was 5.2 $\pm$ 0.85 days which was nearly twice as long as the effective half-lives in previous experiments using aerosols of larger particle size.

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ABBREVIATIONS AND DEFINITIONS

CMD - count median diameter. The diameter of those particles in the size-frequency table at the point where the cumulative count is 50 percent of the total number of particles counted.

MMD - mass median diameter. As above, but based on mass rather than count.

σ_g - geometric standard deviation. The ratio of the 84 percent size to the 50 percent size.

$T_{\frac{1}{2}}$ - physical half-life. The decrease in activity caused by radioactive decay.

T_b - biological half-life. Decrease of radioactivity in living systems due to biological effects.

T_e - effective half-life. Decrease of radioactivity caused by a combination of $T_{\frac{1}{2}}$, T_b and other loss processes.

® - indicates a copyrighted name for a commercial product.

Green chop - fresh forage cut from a pasture by machine then placed in the cow's manger.

Milk/Forage Ratio - the peak average concentration in milk (pCi/liter) divided by the peak average concentration in forage (pCi/kg).

INTRODUCTION

The Radiological Research Program(RRP) in the Southwestern Radiological Health Laboratory utilizes controlled releases of a simulated fallout as one means of evaluating the passage of radioiodine through the air-forage-cow-milk-man food chain. Prior to the release discussed in this report, RRP had conducted two releases using dry aerosols (1, 2) and one release using an aerosol mist (3). The dry aerosols utilized ^{131}I tagged diatomaceous earth particles with a CMD greater than one micrometer. An evaluation of the results of these two dry aerosol releases, code named Hayseed (1), and Alfalfa (2), suggested that valuable information could be obtained by conducting an experiment which utilized an aerosol particle with a CMD of less than one micrometer.

This experiment, code named SIP*, was designed to accomplish the following objectives:

1. To measure the deposition and retention of ^{131}I on growing alfalfa as a result of dissemination in the form of a dry aerosol with a CMD of less than one micrometer.
2. To measure the secretion of ^{131}I in the milk from a group of dairy cows fed contaminated alfalfa green chop after first being exposed to the aerosol cloud. (Simulated summer feeding practices.)
3. To measure the secretion of ^{131}I in the milk from a group of dairy cows given a single feeding of contaminated hay while being exposed to the aerosol cloud. (Simulated winter feeding practice where the hay supply is protected.)
4. To measure milk secretion of ^{131}I from a group of dairy cows exposed to the aerosol cloud but not fed contaminated forage (air uptake).

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* an acronym for Submicrometer Iodine Particle

In the Great Basin, two of the primary sources of cattle feed are hay and fresh alfalfa green chop. Those dairies that feed green chop during the summer growing season normally use hay as a supplement to this fresh feed (4). These same dairies usually feed alfalfa hay during the winter months.

Comparisons of the results of objectives 2 and 3 should aid in determining the differences between ^{131}I levels in milk from dairy cows fed under a simulated winter feeding plan (i.e., single contaminated hay feeding) and in milk from cows fed under a simulated summer feeding plan (i.e., green chop from a contaminated pasture, plus hay).

PROCEDURES

A. Experimental Design

The experimental design for Project SIP was such that the only difference between the groups of cows was the type of forage which was fed. Table 1 shows the three treatments evaluated in this study, the cows assigned to the groups and the amounts of feed given to cows.

The assignment of cows to each group was based on milk production and days of lactation. There was a bias in selecting the cows for Group II in that several of the higher producers were placed in this group. This was done because milk from this group was required not only for the study presented in this report, but also for an ancillary study which is reported elsewhere (5). The milk production of the Group II cows dropped slightly and the Group I and III cows increased slightly between the time assignments were made and the beginning of the experiment. This change adjusted the average production per group so that there was no significant difference among groups as determined by Analysis of Variance (AOV).

About two hours prior to the release of the aerosol, all 18 cows were milked then placed in a pen erected downwind from the aerosol generators. The Group I cows were placed in a pen equipped with stanchions and a manger in which was placed 75 kg of hay.

This provided a feeding station similar to those encountered in the off-site area at the time of a radioactive cloud passage. The cows were allowed to feed in the manger starting two minutes prior to release and were left there until approximately 65 kg of the hay had been consumed. (All that remained was stem material and loose leaves.) The cows were decontaminated approximately 11-1/2 hours after the release, placed in a separate corral and fed alfalfa hay according to the schedule in Table 1. The Group II and Group III cows were placed in a pen adjacent to the Group I cows. These animals were not provided with

Table 1. Groups of Cows and Feeding Schedule

Group	Cow No.	Type of Feed	Remarks
I "Winter"	2, 18, 36, 47, 17, 87	Contaminated hay in field manger on D-day. Uncontaminated hay during rest of the experiment. Hay fed free choice. Approximately 10 kg per feeding.	Cows received no green chop from 30 May through 16 June 1967.
II "Summer"	11, 16, 28, 35, 45, 83	20 kg contaminated alfalfa green chop in A.M. - 10 kg uncontaminated hay in P.M.	Cows received contaminated green chop Land No. 5 - 6 June to 12 June. Land No. 6 - 13 June to 16 June 1967.
III "Control"	12, 25, 27, 29, 39, 48	Approximately 20 kg uncontaminated alfalfa green chop in A.M. and 10 kg uncontaminated hay in P.M.	Cows received green chop harvested from Land No. 1.

forage and were removed from the pens approximately four hours after the release. They were brought to the decontamination station, washed, then led to their assigned positions. The Group II cows were placed in individual pens and fed green chop from the contaminated pasture for ten days according to the schedule in Table 1. The Group III cows were placed in a separate corral and fed according to the schedule in Table 1.

The first milking of all groups was at 1500 hours on 6 June 1967 or about 13 hours after the aerosol release. Procedures for handling the feed, for milking and for animal care are outlined in SWRHL-55r (6).

B. Study Area

The study area for this experiment was located in Lands 5, 6, and 7 of the Environmental Protection Agency's Experimental Farm, Area 15, Nevada Test Site. Figure 1 shows the overall layout of the study area at the time of the release. Figure 2 is a detailed drawing showing the location of the air samplers, fallout collectors, plots, pens, etc.

C. Aerosol Generation and Measurement

The release of the aerosol was essentially the same as that used in Projects Hayseed (1) and Alfalfa (2). Basically the method involves the generation of a diatomaceous earth aerosol which has been ground, sieved and tagged with ^{131}I. The generation was accomplished by a line of 20 generators spaced at an interval of 4.75 meters along a line 7.5 meters upwind from the leading edge of the test field with the outlet tube of the generators 46 cm. above the ground. The aerosol was transported across the field by the normal drainage winds occurring at the farm.

Stainless steel 4.5-inch planchets coated with a non-setting alkyd resin were spaced at 7.5-meter intervals over a 60-by-22.5-meter section of the test field at a height even with the top of the growing alfalfa (approximately 46 cm. above the ground). Data from these were used to determine the deposition isopleths and as part of the deposition

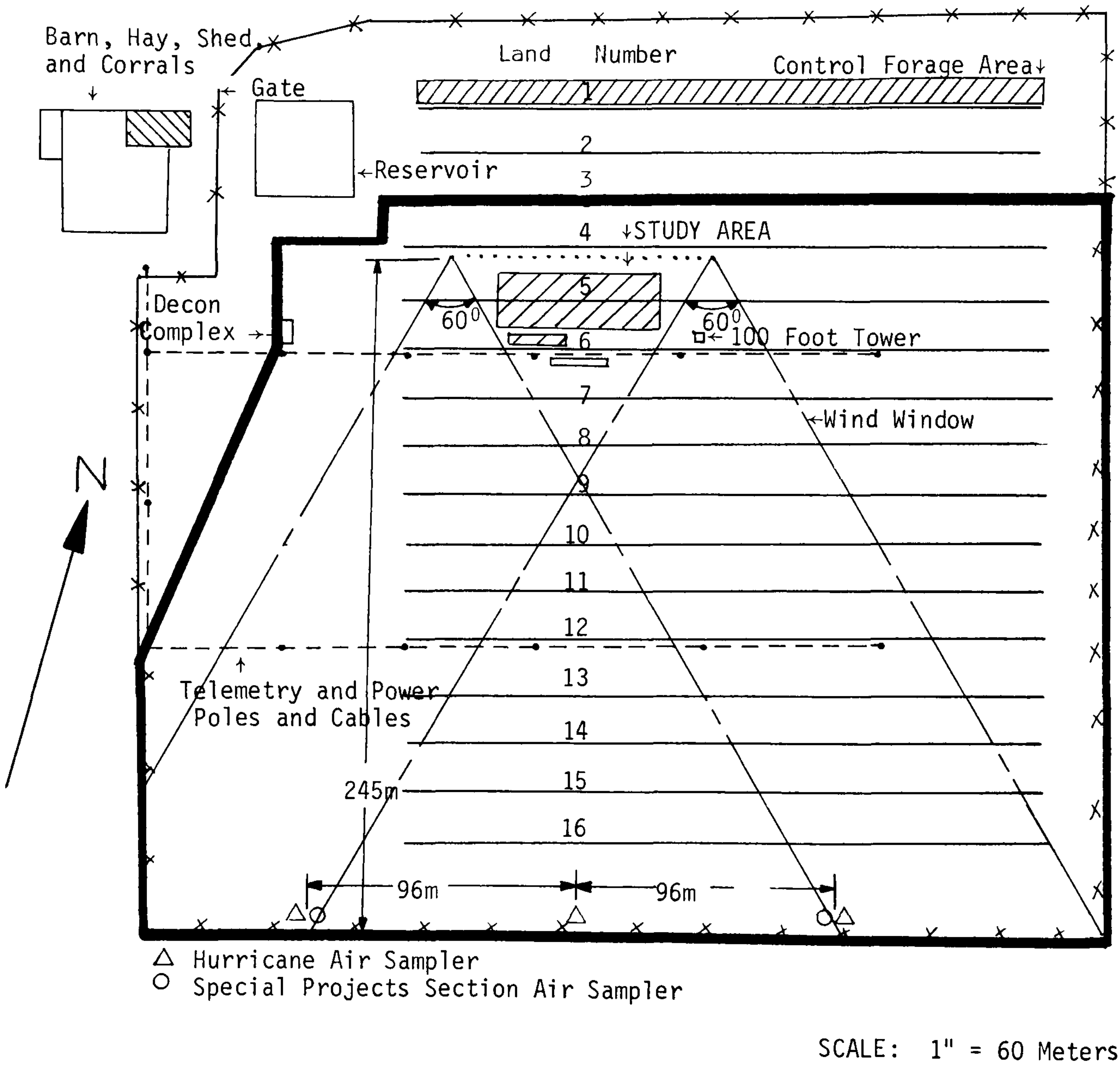

Figure 1. General Farm Layout for Project SIP

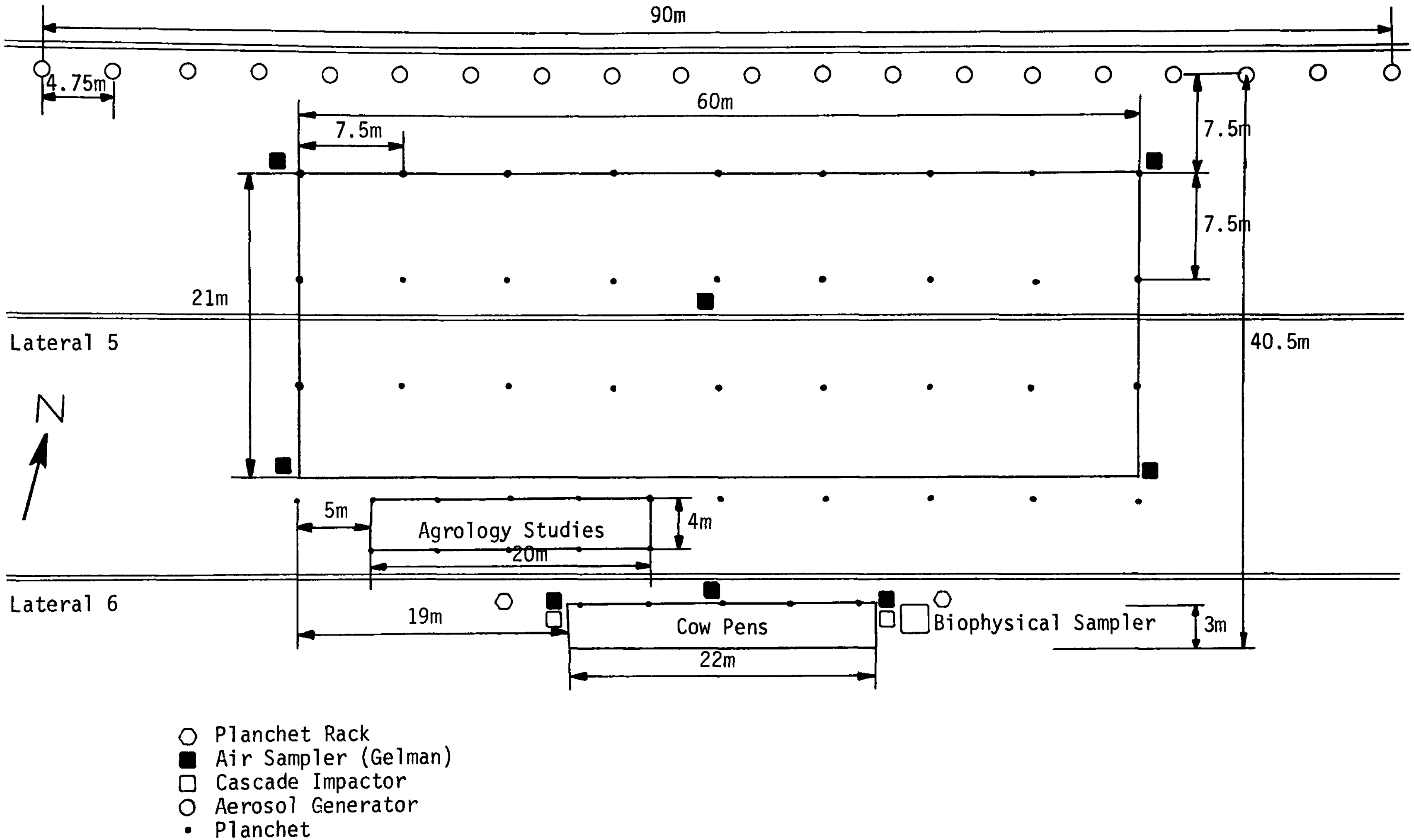

Figure 2. Detailed plan of Project SIP Layout

velocity calculations. Additional planchets were placed in the agrology study area to the rear of this section. Two racks containing a series of horizontally and vertically oriented planchets, located at ground, one- and two-meter levels, were placed at the rear of the study area on either side of the cow pens. These special racks were used both to determine the angle of deposition of the aerosol particles and to determine whether or not the aerosol cloud remained close to the ground.

Gelman Tempest air samplers were placed at various locations throughout the plot and adjacent to the cow pens to measure airborne concentrations of ^{131}I. These samplers contained Whatman 541 prefilters, MSA charcoal cartridges and Microsorban® postfilters. Glass slides (1 by 3 inches) were spaced evenly throughout the field and were used to determine the size distribution of the deposited aerosol.

To measure the mass median diameter of the aerosol cloud, two Unico cascade impactors were placed near the cow pens as shown in Figure 2.

D. Meteorological Data Collection

The particle size distribution expected for Project SIP was such that the meteorological conditions required for aerosol release were important. Evaluation of the results from Hayseed (1) and Alfalfa (2) indicated that a wind speed of less than five miles per hour and a wind direction with an azimuth somewhere between 315 and 15 degrees were required if sufficient deposition was to be obtained on the experimental area.

The various meteorological parameters which influence aerosol transport and deposition were monitored by meteorological sensors located in three fixed positions upwind from the line of generators. One station was located midway and one station was located at each end of the line of generators. The sensors were one meter above the ground level. From continuous recordings, average values were derived of wind speed and wind direction at two-minute intervals during and at 15-minute intervals following the release. The temperature, relative humidity, and precipitation were also recorded. In addition to these data, ambient temperature and the temperature gradient (ΔT 1-10 meter levels) were also recorded.

E. Agrology Study Area

In order to adequately evaluate the T_e of the submicrometer ^{131}I particles on growing alfalfa, a sampling area of three blocks was set up in the Agrology Study Area near the cow pens (Figure 2). Each block consisted of sixteen one-square-meter plots as shown in Figure 3. At each of eight sampling times, two randomly selected plot samples were taken from each block. The sampling times were at 0800 hours each day starting on the day of release and at 1, 2, 4, 6, 9, 14, and 20 days afterward. The samples were pressed into the standard vegetation geometry (1) and gamma counted for ^{131}I. The results of the ^{131}I analyses were evaluated according to the Analysis of Variance presented in Table 5 under the results section.

F. Sampling Techniques

The forage given to Group I cows was sampled by taking a composite of grab samples at several points and depths along the length of the manger. The feed for the Group II cows was sampled individually by taking a composite of a grab sample from each of the four corners and the bottom center of each of the plastic feed boxes. A number of grab samples was taken from the feed bunkers used for Group III. The samples taken from Group III provided a check on feed contamination from resuspension and other unknown releases of activity. The frequency of all of these sample collections corresponded to the feeding periods.

The forage samples were placed in plastic bags, the bags sealed and the samples transported to Sample Control where each sample was compressed into a 500-milliliter plastic container of standard geometry. This sample was then submitted for gamma analysis. The grain used as a feed supplement was sampled once daily. This single 500-ml. sample was taken from the grain storage bin inside the milking room.

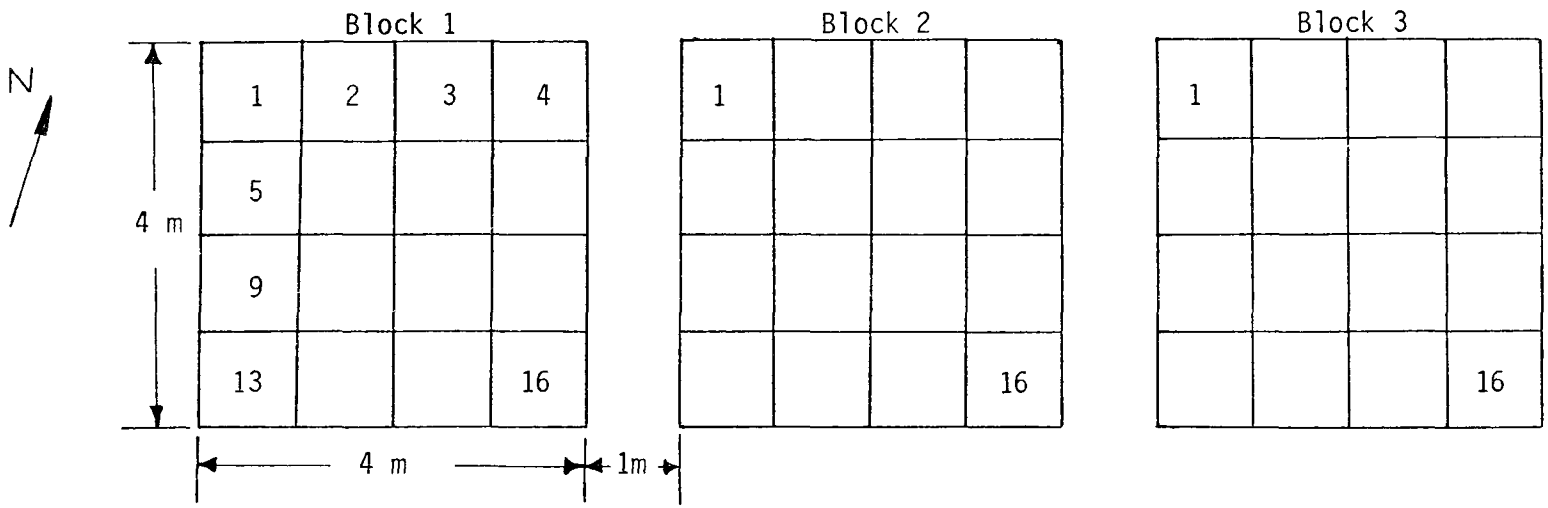

Figure 3 Layout of the Agrology Study Vegetation Plots - Project SIP

A one-gallon composite sample of water was collected daily from each group. The composite sample for Group II was made up of equal amounts of water from each cow's watering cup. The sample was submitted for analysis in a plastic Cubitainer®.

One-gallon samples of milk were collected at each milking. These samples were also submitted for analysis in plastic Cubitainers. At the time of collection ten milliliters of 37 percent formaldehyde preservative were added to each milk sample.

G. Sample Analysis

All of the planchets and air filters were analyzed for ^{131}I by using a system consisting of opposed 4-by 9-inch NaI (Tl) crystals and a 400-channel analyzer. This system has been described in detail in earlier reports (1, 2). The minimum sensitivities for the various geometries are outlined in Table 2.

Table 2. System Efficiency and Minimum Sensitivity for ^{131}I

Sample Type	Container	Efficiency	Minimum Sensitivity*
Milk and Water	4-liter Cubitainer	17.3%	10 ± 5 pCi/l
Grain	400 ml. plastic container	27.8%	80 ± 10 pCi/kg
Hay	400 ml. plastic container	28.1%	100 ± 15 pCi/kg
Green Chop	400 ml. plastic container	34.8%	80 ± 10 pCi/kg
Charcoal (from air sampler)	250 ml. plastic container	27.8%	30 ± 5 pCi/sample
Filter paper	100 ml. plastic container	48.0%	15 ± 5 pCi/sample
Fallout planchet	100 ml. plastic container	48.0%	15 ± 5 pCi/sample

* Based on a 40-minute count

Milk, water, grain, and vegetation samples were submitted to the Laboratory's Technical Services group for analysis. The analysis was done on systems using 4-by 4-inch NaI (Tl) crystals coupled to TMC Model 404-C pulse height analyzers calibrated for energies of 0-2 MeV.

RESULTS AND DISCUSSION

A. Aerosol Deposition

The release of the aerosol began at 0150 PDT, 6 June 1967, and was complete after an average generation time of approximately 22 minutes. During this time the wind was blowing from 309 degrees true azimuth at an average speed of three miles per hour. The temperature for this period averaged 39.4°F. and the average relative humidity was 58.6 percent.

Aerosol deposition across the test grid as measured by fallout planchets showed an average of 1.63 $\mu Ci/m^2$. Of the total amount of 51.78 mCi released, 4.3 percent was deposited on the study area. The isopleths drawn from the planchet data indicate that 96 percent of the test grid was contaminated at levels from 1-3 $\mu Ci/m^2$ and the remaining 4 percent at a level of 4.5 $\mu Ci/m^2$ (Figure 4). In the Agrology Study Area the average deposition was 0.98 $\mu Ci/m^2$. Data obtained from the special planchet racks, together with the respective "deposition vectors" are shown graphically in Figure 5. The "deposition vector" is defined as the resultant of the two vectors calculated from the activity on the horizontal and vertical planchets. These data demonstrate that the cloud was more concentrated below 2 meters. The vectors show that the particles were being deposited in a nearly vertical mode close to the ground, while at higher elevations the horizontal vector became stronger, probably due to the effect of winds.

The planchet rack data indicate that the active cloud remained close to the ground during transport across the experimental area. The uniformity of the individual values between the two planchet racks is remarkable.

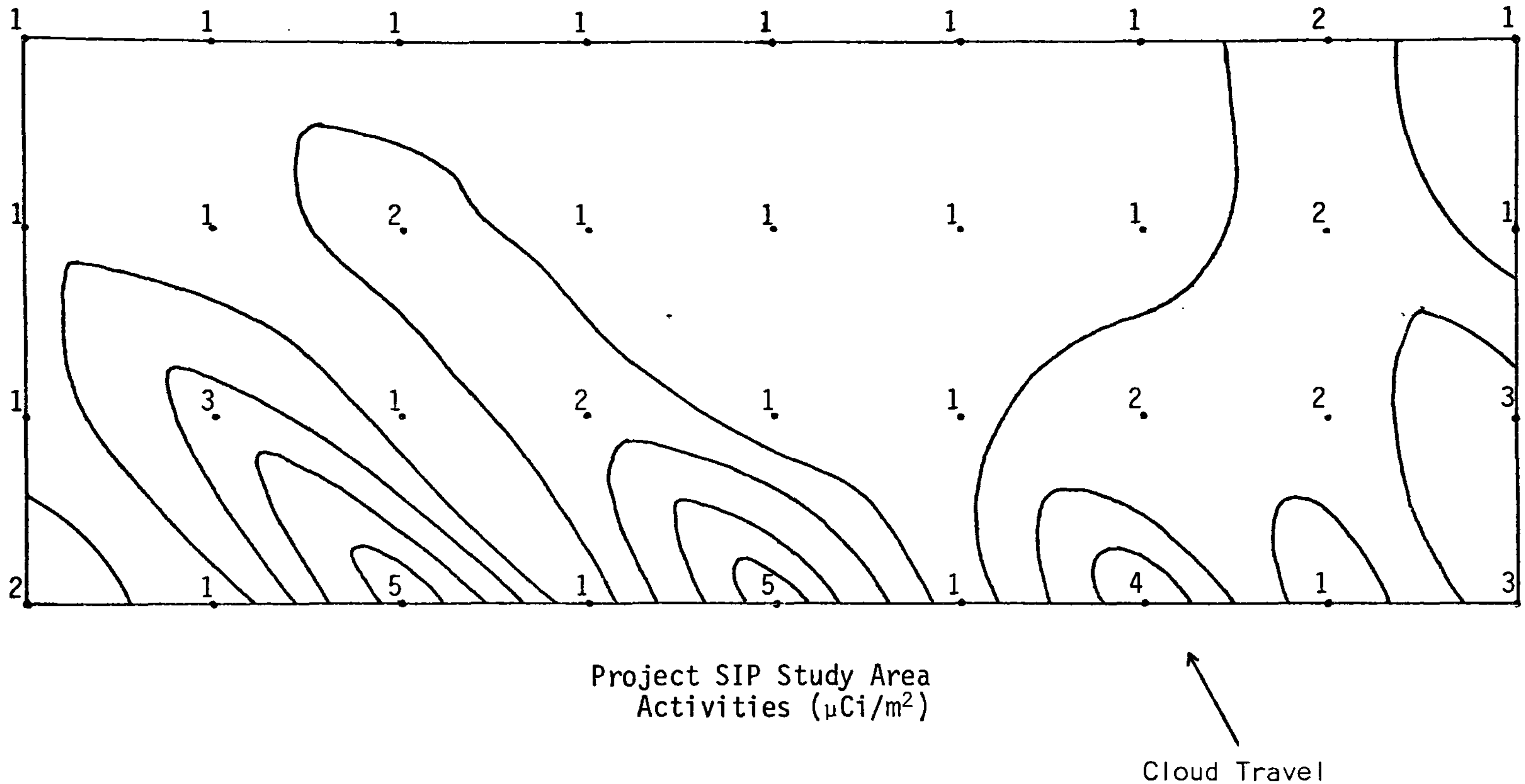

Figure 4. ^{131}I Activity Isopleths from Planchet Data

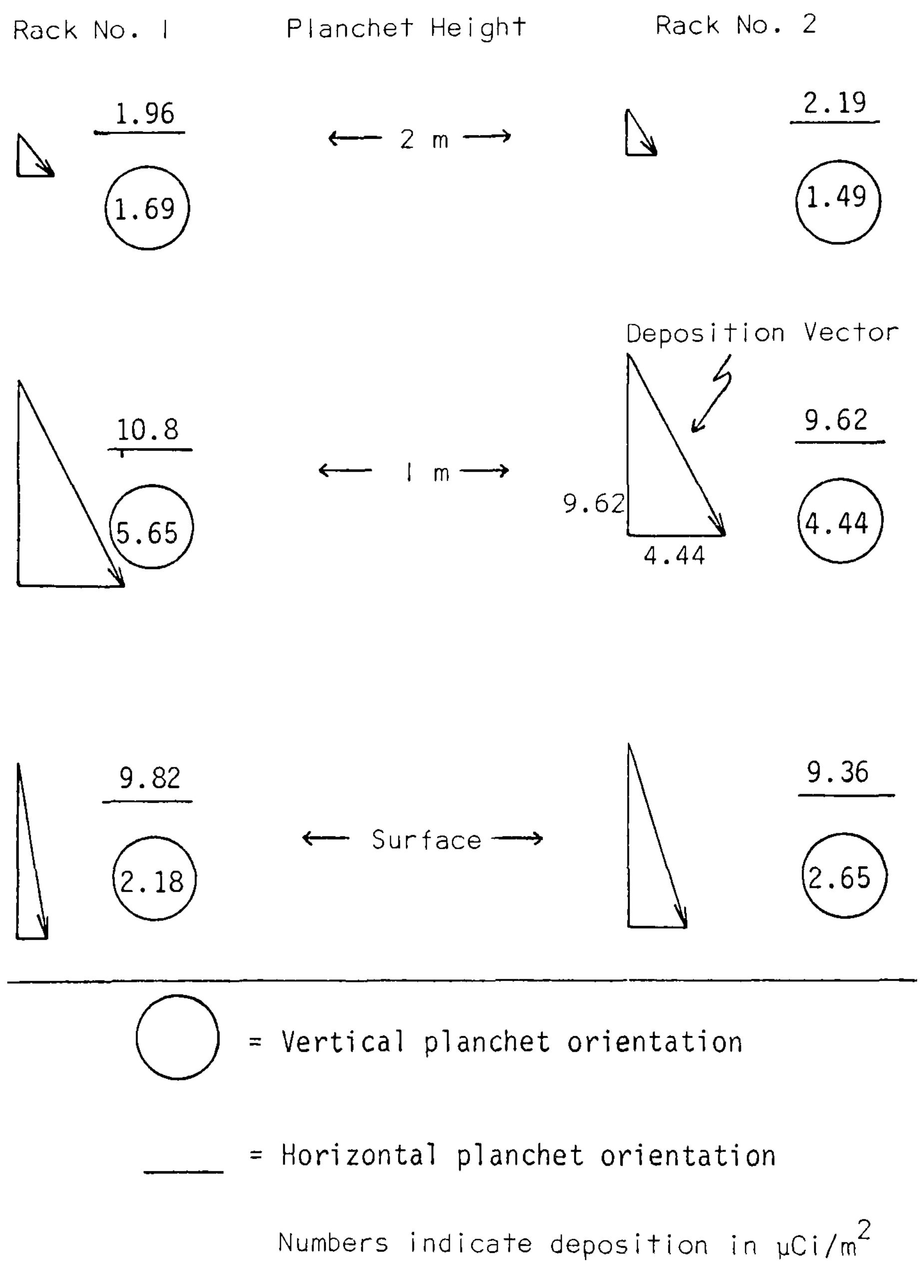

Figure 5. Planchet Rack Data and Deposition Vectors for the SIP Aerosol

Table 4 shows the cumulative size distribution of the aerosol particles. These data show that the CMD of the cumulative distribution was approximately 0.13 micrometers with a σ_g of 4.1. The two Unico cascade impactors located in the test area indicated an MMD of 1 and 2.6 micrometers respectively.

Table 5 shows the activity collected on each air sampler component and the deposition velocities, calculated from these data plus the planchet data. An average of approximately 70 percent of the activity was collected on the prefilters which had a mean pore size of from 3.4 to 5 micrometers.

B. Vegetation Contamination

The results of the Analysis of Variance for the radioactivity on the growing alfalfa are presented in Table 3.

TABLE 3. Analysis of Variance of ^{131}I Contamination of the Vegetation Study Area

Source of Variation	df	F
Block	2	3.27
Time	7	67.77**
Block x Time	14	1.36
Error	24	
TOTAL	47	

**Significant at 1% Confidence Level.

This analysis indicates that the deposition over the vegetation study area was quite uniform, that there was no difference in the effect of time on the different blocks and that the only significant variable was decay with time. Using the data from all three blocks, T_e's were calculated for the pasture. This calculation showed a two-phase loss of ^{131}I from the plants. The first phase, lasting 3-4 days, reduced the incident contamination by about 50%. This phase showed

Table 4. Particle size distribution for the aerosol released during Project SIP

Size (μm)	Count	Cumulative Count*	Cumulative Per Cent*	Size (μ)	Count	Cumulative Count*	Cumulative Per Cent*
<0.03	4959	4959	17.4	0.64	65	24600	86.1
0.03	3002	7961	27.9	0.66	131	24731	86.6
0.05	1936	9897	34.6	0.72	22	24753	86.6
0.08	1827	11724	41.0	0.80	479	25232	88.3
0.11	979	12703	44.5	0.82	22	25254	88.4
0.13	2001	14704	51.5	0.87	44	25298	88.5
0.16	914	15618	54.7	0.93	44	25342	88.7
0.19	761	16379	57.3	0.98	44	25386	88.9
0.21	935	17314	60.6	1.01	22	25408	88.9
0.24	783	18097	63.3	1.06	326	25734	90.1
0.27	3632	21729	76.1	1.33	371	26105	91.4
0.29	392	22121	77.4	1.80	321	26426	92.5
0.32	283	22404	78.4	2.90	767	27193	95.2
0.34	261	22665	79.3	3.90	206	27399	95.9
0.37	87	22752	79.6	4.90	72	27481	96.2
0.40	348	23100	80.9	10.10	357	27838	97.4
0.42	87	23187	81.2	15.60	169	28007	98.0
0.48	87	23274	81.5	20.80	70	28077	98.3
0.50	65	23339	81.7	24.70	36	28113	98.4
0.53	979	24318	85.1	29.90	49	28162	98.6
0.56	65	24383	85.3	35.10	36	28198	98.7
0.58	87	24470	85.6	40.30	27	28225	98.8
0.61	65	24535	85.9	45.50	73	28298	99.0

*Refers to amount $\leq$ stated size.

TABLE 5. ^{131}I Activity on Air Sampler Components and Deposition Velocities

Sampler Number	Whatman Activity (nCi)	Charcoal Activity (nCi)	Microsorban Activity (nCi)	Deposition* Velocity cm/sec
1	427	263	3.4	1.21
2	649	270	12.9	1.69
3	521	163	5.4	0.55
4	650	241	8.6	0.71
5	512	168	7.0	0.54
6	176	63	8.1	1.47
7	909	130	5.9	0.46
8	434	136	5.6	0.71

* $\mu Ci/m^2$ from planchet divided by the integrated air concentration in $\mu Ci\text{-}sec/m^3$

an average T_e of three days. The second phase of the activity curve had a 6.5-day half-life.

The T_e for this second phase did not reach the 8-day $T_{1/2}$ of ^{131}I probably because of growth of the alfalfa and also because of some additional loss of ^{131}I from the plants. However, plant growth was the most likely cause of the shortened half-life. This observation is borne out by the fact that irrigations on D + 6, D + 14 and D + 18 had no effect upon the activity levels. If particles were still being lost from the plant this application of water should have had some influence upon the activity levels. This observation is also supported by results of an ancillary study conducted with Project SIP. In this study, samples of the vegetation were vigorously washed in a 0.1% Joy® solution. After D + 4 this washing had no effect upon the activity levels in the vegetation. Thus the ^{131}I had either become more tightly bound to or had been absorbed by the plant. Therefore, the most likely cause of the reduction in contamination during the second phase is considered to be the growth of the plants.

C. Forage Contamination

In previous releases, (1, 2) the ^{131}I activity in the forage fed to the dairy cattle followed a different decay scheme than that in the growing alfalfa plot. This same observation can be made with the green chop fed during Project SIP. Table 6 shows the daily ^{131}I activity in the green chop fed to Group II cows. The activity had a calculated T_e of 4.1 days. The shorter effective half-life of green chop compared to that of the undisturbed growing alfalfa is considered to be a result of the dislodging of the contaminating particles during chopping and handling of the forage.

TABLE 6. ^{131}I Activity in Green Chop Forage

Date	Hour	^{131}I Activity $\mu Ci/kg$
6/6	0900	1.02±0.21
6/7	0700	1.13±0.06
6/8	0850	0.86±0.14
6/9	0800	0.68±0.09
6/10	0940	0.59±0.06
6/11	0900	0.51±0.07
6/12	0830	0.69±0.22
6/13	0830	0.27±0.03
6/14	0850	0.27±0.04
6/15	0800	0.26±0.03
6/16	0800	0.24±0.02

In some of the grain and water samples ^{131}I was detected at levels slightly above the minimum detectable activity. At no time were these additional sources of activity high enough to materially influence the results, i.e., <0.1% of the total intake.

D. ^{131}I Activity in the Milk

The average levels of ^{131}I found in the milk at each milking are shown in Figure 6. As can be seen from the curves, the ^{131}I levels in the milk from cows of Groups I and III showed the characteristic early peak resulting from air uptake. The Group I cows had a higher level of activity in their milk as a result of the longer time in the contaminated area and also as a result of eating the hay which was in their feed bins during aerosol generation. The effect of the uptake from the hay most likely caused the broadening of the peak seen in the data from the first two milkings.

In Groups I and III the activity in the milk began to drop immediately after the first milking. The curves of these data show T_e's of 1.05 and 1.52 days, respectively. The curve for the hay cows (Group I) follows a pattern similar to that seen in our

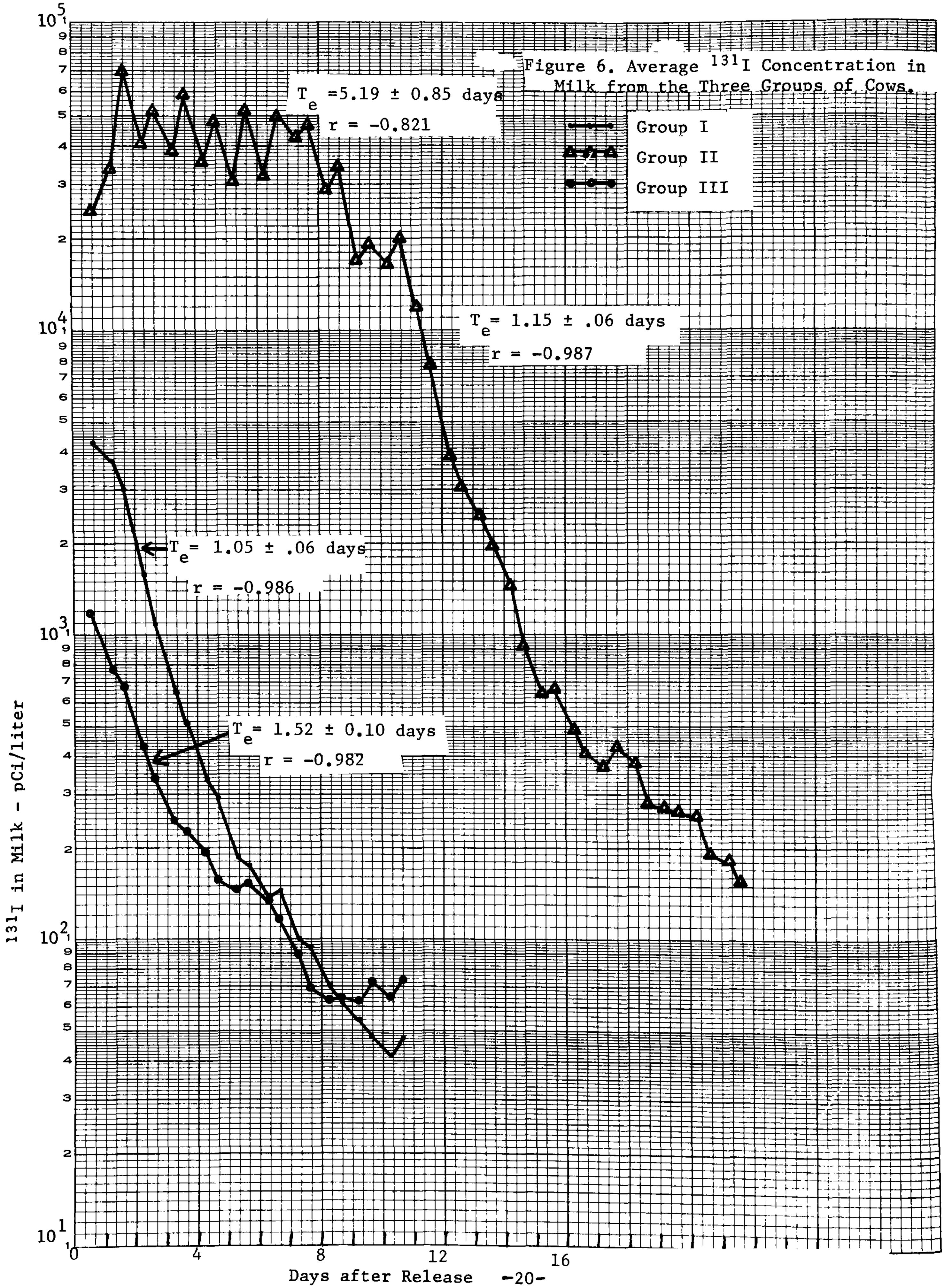
Figure 6. Average 131I Concentration in Milk from the Three Groups of Cows.
Group I
Group II
Group III
Te =5.19 ± 0.85 days
r = -0.821
Te= 1.15 ± .06 days
r = -0.987
Te= 1.05 ± .06 days
r = -0.986
Te= 1.52 ± 0.10 days
r = -0.982
131I in Milk - pCi/liter
Days after Release
0
4
8
12
16

previous studies after hay feeding was terminated. In both Group I and Group III, the peak milk values occurred at the first milking after contamination. The peak for similar treatments during Hayseed and Alfalfa occurred at one day.

The Group II cows exhibited a triphase curve that was similar to that seen in our earlier controlled releases where green chop was fed (1, 2). The half-life during feeding, however, was longer than that seen in those earlier studies. The T_e value of 5.2 days is approximately double that for Alfalfa and Hayseed. The peak milk values in the Group II milk occurred at 1.6 days.

In all three groups, the short effective half-life components of the milk secretion curves (T_e approximately one day) lasted about five days then was followed by a component with a T_e of 2-4 days. Apparently the ^{131}I on these small particles was retained on the forage longer than the ^{131}I from the larger aerosol particles. The fact that the T_e of the "after feeding" portion of the milk curves all exhibited half-lives in excess of one day, as compared to those of Alfalfa and Hayseed where the half-lives were less than one day, suggests that the ^{131}I on these small particles was retained in the cow longer or that there were some undetected differences in iodine metabolism among the three experiments. The average milk data for all three cow groups and standard deviations are shown in Tables 7-9.

An estimate of the milk/forage ratio for the group eating hay contaminated in their manger can be made by correcting for inhalation. If the average peak ^{131}I concentration in the milk of Group III cows is subtracted from that of the Group I cows, then the remainder should be due to ingestion of contaminated hay. Subtracting 1.17×10^3 from 4.32×10^3 leaves 3.15×10^3 pCi/liter due to ingestion of the hay. Since Group I cows ingested hay which had 7.98×10^4 pCi/kg of ^{131}I, the milk/forage ratio becomes .040. Similarly, since each cow ingested about 11 kg of the hay and since the average total secretion of ^{131}I in the milk of these cows was 2.11×10^5 pCi

Table 7. Group I Milk Data

Collection Date	Collection Hour	Days Lapsed	^{131}I-nCi/Liter Mean	^{131}I-nCi/Liter Sigma	Liters Mean	Liters Sigma	Total nCi Mean	Total nCi Sigma
6/ 6	1448	D+ 0.61	4.32	0.895	13.6	5.6	62.5	33.7
6/ 7	617	D+ 1.26	3.72	1.11	14.1	4.7	56.5	33.1
6/ 7	1542	D+ 1.65	3.00	0.935	8.6	3.5	27.9	19.0
6/ 8	651	D+ 2.28	1.58	0.669	12.2	4.9	21.4	16.0
6/ 8	1525	D+ 2.64	1.09	0.481	8.8	3.0	10.6	8.35
6/ 9	654	D+ 3.28	0.651	0.317	13.6	4.1	5.56	3.29
6/ 9	1522	D+ 3.64	0.512	0.282	8.8	3.3	4.76	3.96
6/10	717	D+ 4.30	0.336	0.149	13.6	3.5	4.75	3.24
6/10	1538	D+ 4.65	0.291	0.136	8.6	3.8	2.63	2.29
6/11	712	D+ 5.30	0.184	.082	12.4	3.6	2.30	1.36
6/11	1527	D+ 5.64	0.72	.058	8.8	3.4	1.57	1.07
6/12	717	D+ 6.30	0.137	.061	13.3	4.3	1.83	1.14
6/12	1554	D+ 6.66	0.144	.074	8.5	4.0	1.39	1.45
6/13	645	D+ 7.28	.099	.054	13.1	5.0	1.30	1.02
6/13	1522	D+ 7.64	.094	.040	8.9	2.1	0.866	0.530
6/14	642	D+ 8.27	.070	.033	12.9	5.3	0.997	0.885
6/14	1528	D+ 8.64	.062	.025	9.1	2.6	1.27	1.68
6/15	725	D+ 9.30	.054	.023	13.3	4.6	0.750	0.477
6/15	1530	D+ 9.64	.048	.016	8.5	3.5	0.422	0.286
6/16	649	D+ 10.28	.042	.013	12.0	4.3	0.505	0.269
6/16	1532	D+ 10.64	.048	.019	9.1	3.1	0.452	0.288

Table 8. Group II Milk Data

Collection Date	Collection Hour	Days Lapsed	^{131}I-nCi/Liter Mean	^{131}I-nCi/Liter Sigma	Liters Mean	Liters Sigma	Total nCi Mean	Total nCi Sigma
6/ 6	1519	D+ 0.63	24.5	11.7	14.5	4.8	361	217
6/ 7	654	D+ 1.28	33.3	8.99	14.9	5.8	507	266
6/ 7	1607	D+ 1.67	69.5	16.2	8.8	2.9	631	286
6/ 8	722	D+ 2.30	40.8	9.60	15.3	5.6	645	346
6/ 8	1556	D+ 2.66	51.7	15.8	9.3	4.5	483	289
6/ 9	723	D+ 3.30	37.8	14.2	16.0	6.5	621	370
6/ 9	1548	D+ 3.65	58.3	20.8	8.2	3.4	492	286
6/10	749	D+ 4.32	35.2	11.4	15.8	5.3	559	238
6/10	1602	D+ 4.66	47.7	18.5	8.8	4.0	433	272
6/11	749	D+ 5.32	30.6	11.4	16.0	6.4	492	243
6/11	1552	D+ 5.66	51.1	21.4	9.1	3.7	446	186
6/12	747	D+ 6.32	31.6	11.7	16.0	6.0	506	233
6/12	1630	D+ 6.68	49.2	18.9	8.9	3.6	435	213
6/13	722	D+ 7.30	42.2	14.7	14.8	5.2	651	353
6/13	1552	D+ 7.66	46.5	15.8	7.9	2.4	377	176
6/14	715	D+ 8.30	28.2	12.5	12.5	6.2	336	179
6/14	1556	D+ 8.66	33.9	15.9	8.0	3.8	258	124
6/15	751	D+ 9.32	16.6	5.24	14.0	8.3	231	148
6/15	1600	D+ 9.66	18.9	8.97	7.7	4.3	155	112
6/16	721	D+ 10.30	16.2	6.56	14.1	6.6	233	134
6/16	1602	D+ 10.66	19.9	7.83	7.2	3.6	153	100

Table 8. Group II Milk Data (continued)

Collection		Days	^{131}I-nCi/Liter		Liters		Total nCi	
Date	Hour	Lapsed	Mean	Sigma	Mean	Sigma	Mean	Sigma
6/17	722	D+ 11.30	11.9	4.87	14.5	5.6	177	95.5
6/17	1545	D+ 11.65	7.65	3.07	8.6	4.2	67.7	44.5
6/18	731	D+ 12.31	3.86	1.16	15.3	6.2	61.2	32.4
6/18	1556	D+ 12.66	3.02	0.986	7.5	3.1	22.9	12.1
6/19	724	D+ 13.30	2.43	0.872	13.6	4.5	34.5	19.7
6/19	1541	D+ 13.65	1.92	0.725	7.6	3.1	15.4	10.2
6/20	713	D+ 14.30	1.42	0.837	14.2	5.3	23.5	24.2
6/20	1547	D+ 14.65	0.918	0.351	8.3	3.6	7.92	5.40
6/21	713	D+ 15.30	0.634	0.274	13.5	6.1	8.56	4.77
6/21	1531	D+ 15.64	0.659	0.395	7.5	2.2	5.06	3.26
6/22	642	D+ 16.27	0.482	0.261	13.7	4.9	6.46	3.72
6/22	1515	D+ 16.63	0.406	0.269	6.3	2.7	2.26	1.25
6/23	1415	D+ 17.59	0.366	0.267	17.7	7.8	6.32	5.21
6/24	615	D+ 18.26	0.427	0.272	12.1	5.2	4.74	2.51
6/24	1515	D+ 18.63	0.372	0.108	6.9	2.8	2.47	0.914
6/25	615	D+ 19.26	0.275	0.152	15.0	6.8	3.95	2.18
6/25	1515	D+ 19.63	0.269	0.136	6.5	2.5	1.74	0.920
6/26	628	D+ 20.27	0.260	0.134	13.9	5.3	3.44	1.70
6/26	1518	D+ 20.63	0.251	0.121	7.9	2.6	1.96	0.972
6/27	627	D+ 21.26	0.188	0.116	13.9	5.4	2.48	1.43
6/27	1516	D+ 21.63	0.180	0.105	6.6	3.2	1.22	0.799
6/28	624	D+ 22.26	0.156	.072	13.9	4.5	2.13	1.00

Table 9. Group III Milk Data

Collection		Days	^{131}I-nCi/Liter		Liters		Total nCi	
Date	Hour	Lapsed	Mean	Sigma	Mean	Sigma	Mean	Sigma
6/ 6	1417	D+ 0.59	1.17	0.923	13.2	6.2	14.5	13.0
6/ 7	545	D+ 1.23	0.771	0.560	12.5	5.5	8.81	6.08
6/ 7	1507	D+ 1.63	0.672	0.496	7.6	3.3	4.77	3.29
6/ 8	622	D+ 2.26	0.427	0.334	11.9	5.8	4.47	3.07
6/ 8	1502	D+ 2.62	0.335	0.236	8.1	3.8	2.40	.43
6/ 9	627	D+ 3.26	0.245	0.119	12.8	6.2	3.03	1.81
6/ 9	1500	D+ 3.62	0.227	0.109	7.9	4.1	1.72	1.04
6/10	649	D+ 4.28	0.192	.085	13.0	6.2	2.39	1.46
6/10	1517	D+ 4.63	0.155	.071	7.7	3.8	1.24	0.806
6/11	643	D+ 5.28	0.146	.090	12.9	5.9	1.81	1.17
6/11	1503	D+ 5.62	0.151	0.115	6.8	3.5	1.05	0.804
6/12	646	D+ 6.28	0.133	.079	12.7	6.0	1.67	1.16
6/12	1515	D+ 6.63	0.115	.072	7.9	3.6	.960	0.704
6/13	607	D+ 7.25	.090	.043	11.6	5.8	1.04	0.707
6/13	1445	D+ 7.61	.070	.037	7.1	3.2	0.495	0.342
6/14	612	D+ 8.25	.064	.034	12.2	5.7	0.729	0.401
6/14	1504	D+ 8.62	.065	.031	7.4	4.2	0.451	0.266
6/15	654	D+ 9.28	.063	.032	11.9	4.6	0.708	0.431
6/15	1503	D+ 9.62	.073	.041	6.5	3.4	0.467	0.270
6/16	613	D+ 10.25	.065	.030	11.3	5.0	0.739	0.445
6/16	1507	D+ 10.63	.074	.034	8.5	3.2	0.628	0.301

(for 11 days), then the total percent in milk is calculated as 17.9. This is a relatively high percentage and may be due to the continued exposure to inhalation during their stay in the contaminated area. This latter fact also casts some doubt on the .040 milk/forage ratio.

E. Comparison of Results with other Aerosol Experiments

Comparisons among the three aerosol experiments (Hayseed, Alfalfa and SIP) are shown in Table 10. These data suggest several interesting differences among the three experiments. It had been postulated, from the results of Alfalfa, that the particle size of the deposited material may have a direct bearing on the transfer of radioiodine from forage to milk. A crude measure of this transfer is the milk/forage ratio which appears to be larger for the SIP experiment than for the previous two experiments. A graph of the milk/forage ratio vs. particle size is shown in Fig. 7 for two types of forage. The third point on the hay curves (Fig. 7) is missing because in SIP the cows had only a single feeding, i.e., the hay in the manger which was contaminated by the aerosol cloud, whereas contaminated hay had been fed to the cows for several days in the other two experiments.

In extrapolating this curve, it is reasonable to suppose that when the iodine-containing particles get large enough, they will fall off the forage and result in a zero milk/forage ratio. This should not occur at particle sizes indicated by a linear extrapolation of the curve to the right, therefor the line should curve here to approach the abscissa more slowly. At smaller particle size, the line may extrapolate toward the ordinate in several ways so a simple linear extrapolation is shown. Milk/forage data from other experiments can be entered on this line to indicate an "effective CMD" for the contaminating debris. Such data from green-chop-fed cows at the Habbart farm following the Pike Event(7) and at the Hiko farm following the Pin Stripe Event (8) yield an "effective CMD" of .011 and .023 respectively, which are not unreasonable values.

Table 10.

Summary of Milk Data from Aerosol Experiments

Experiment	Type of Intake	Duration of Ingestion Days	Time of Peak in Milk Days	T_e During ingestion Days	T_e After Ingestion Days	Milk/ Forage Ratio	CMD of Particles μm	Total % in Milk	Average Peak Value in Milk nCi/liter
SIP	Air+GC	10	1.6	5.2±0.8	1.15±0.06	.061	0.13	7.6±3.4	69.5
6/6/67	Air+ 1 hay	<1	1st Milk	-	1.05±0.06	.040		17.9	4.3
	Air		1st Milk	-	1.52±0.1	-			1.2
Alfalfa	GC	9	1.5	2.5±0.2	0.9 ±0.2	.029	2.0	12.5±7.8	109
6/21/66	Hay	8	1.0	8.2±1.3	0.9 ±0.1	.069		15.2±6.2	40
	Air		1st Milk	-	0.9 ±0.38	-			2
Hayseed	GC	6	2	3.0	<1	.0078	23	2.1±0.7	22
10/4/65	Hay	6	1	2.7	<1	.027		6.3±3.3	12
	Air		1st Milk	-	0.8	-			0.6

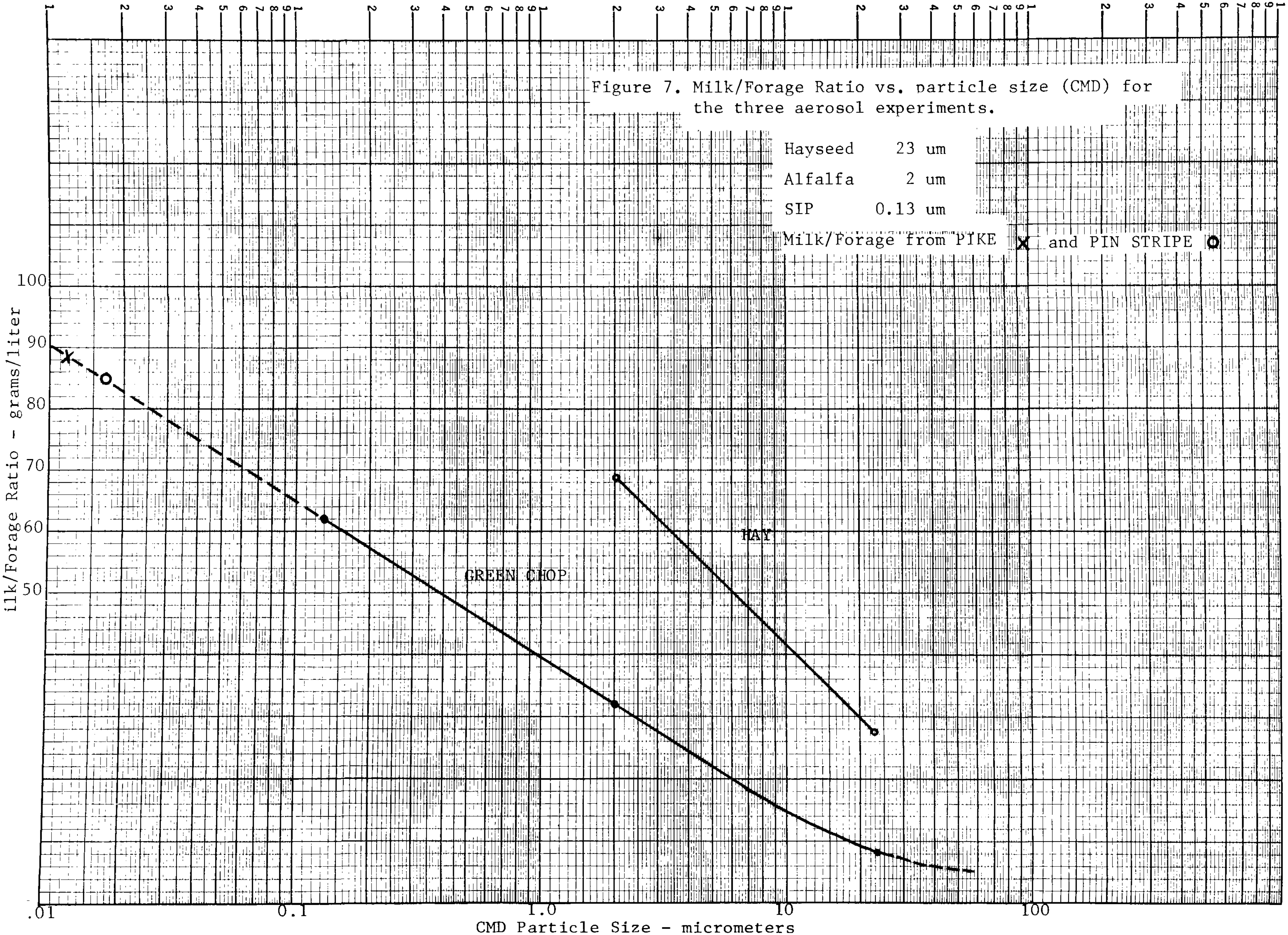

Figure 7. Milk/Forage Ratio vs. particle size (CMD) for the three aerosol experiments.

A puzzling difference between the data of SIP and Alfalfa is in the summary milk results for the green-chop-fed cows. In SIP both the T_e during feeding and the milk/forage ratio were greater than in Alfalfa yet the total percent secreted in milk was less for the SIP cows. A possible explanation of this is that one cow was widely variant from the average. Cow 12 was one of the green-chop-fed cows during Alfalfa and secreted more than twice the percentage of ^{131}I in her milk than any other cow in the group. Excluding Cow 12, the average percent secreted in milk of the group would have been 8.7%, which is not much different from the SIP value.

A third difference, as already discussed, is the longer effective half-life during ingestion in the milk of the green-chop-fed cows, and the longer T_e after ingestion in the milk of all three groups of cows. It seems unlikely that this would be an effect of particle size only as once the iodine gets into the cow the particle that carried it should be unimportant. A possible explanation is that there were some undetected differences in the cows' metabolism caused by the type of feed, season of the year, state of lactation or some other factor. This remains to be explored in future experiments.

CONCLUSIONS

The objectives outlined in the introduction were met by this study. Iodine-131 contaminated aerosol particles with a count median diameter of less than 1 micrometer were deposited on and retained by growing alfalfa forage. The ^{131}I activity disappeared from the alfalfa pasture with an initial effective half-life of approximately three days. After three to four days the T_e changed to 6.5 days. This suggests that the iodine on submicrometer particles was retained more tenaciously than that on the larger particles used in our previous studies.

The ^{131}I activity in milk from green-chop-fed cows (Group II) showed a pattern similar to that seen in our earlier studies. The principal difference was in the longer half-life during and after feeding.

A plot of the ^{131}I activity in milk from cows which acquired activity by being exposed to the aerosol during generation plus a single feeding of contaminated hay (Group I) showed little difference in shape from that of the cows exposed only to the aerosol (Group III). The difference was due to the higher amount of activity taken in by the Group I cows.

Comparisons between the Group I and Group II data indicate that cattle exposed to ^{131}I activity during a hay feeding regime similar to that used herein would secrete about 2.2 percent of the ^{131}I in their milk compared to cows fed on green chop over a 10-day period, provided conditions were similar to those encountered during Project SIP. Group III cows (air intake only) secreted about 0.6 percent of the ^{131}I as the green-chop-fed cows.

The milk/forage ratios for the green-chop-fed cows from the three aerosol experiments increased as the particle size decreased suggesting that the particle size used in SIP acts more like the debris deposited on dairy farms after the Pike and Pin Stripe events than did the larger particle sizes used in Hayseed and Alfalfa.

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