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CALIFORNIA CATTLE
THYROID ACTIVITY ASSOCIATED WITH FALLOUT: 1955

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March 28, 1956

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ABSTRACT

Thyroids from cattle slaughtered in the San Francisco Bay Area were collected from February until September 1955 and followed for radioactivity.

A period of elevated radioactivity was noted, which lasted from the end of March until the end of July.

The total maximum beta-ray dose from the elevated activity during this time was approximately 1 rep. This was a maximum, not the average, dose delivered to the thyroid tissue of the cattle studied.

Evidence is presented which appears to indicate that the radioactivity was taken into the body of cattle through the food.

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INTRODUCTION

The thyroid gland presents an extremely sensitive monitoring device for detecting the presence of one of the most abundant products of nuclear fission. This gland concentrates a large proportion of the iodine intake of the body in a very small volume of tissue. I^{131} is near the top of the fission-yield curve, and since it has a relatively short half life the I^{131} radioactivity is very high in the mixed products of nuclear fission. This, combined with the ability of the thyroid to concentrate iodide ion, makes I^{131} readily detectable as a nearly pure radioisotope in the thyroid gland within a short time after animals come in contact with mixed fission products.[1]

The thyroid glands of cattle from several sources were studied throughout the 1955 nuclear tests in Nevada and for a period of six months thereafter. Previous studies from this laboratory have been reported by Gunther and Jones.[2,3,4]

METHODS

Thyroid samples from cattle were obtained from slaughter houses in and around the San Francisco Bay Area. The animals were raised for the most part within a 100-mile radius of San Francisco, but a few groups of animals were shipped into this area from Idaho and Utah. In all cases the tissues were prepared for counting within 24 hours after the death of the animal. In samples obtained between February 3 and March 7 the tissues were placed in the bottoms of 50-milliliter beakers which were centered over a sodium iodide crystal scintillator. This crystal had a background of approximately 70 counts per minute. With this geometry 1 millimicrocurie of I^{131} counted 334 counts per minute above background. Beginning on March 7, in order to increase the efficiency of counting and to make the geometry more readily reproducible, two well-type scintillation counters were used. One millimicrocurie of I^{131} counted 479 counts per minute above background on one of these and 561 counts above background on the other (backgrounds were approximately 60 and 70 respectively). In all except a few samples obtained in February the samples were counted for a minimum of 1600 counts. The root-mean-square counting error for the sample plus background was therefore no greater than 2.5%. For use in the well counters, tissues were chopped in small pieces and placed in 2-dram vials (6 to 7 ml), the level of tissue in the vials being brought up to a point even with the top of the well. The amount of tissue in each vial was accurately weighed. The samples ranged in weight from 3.5 to 4.5 grams, depending on how tightly the tissue packed. Usually about half a lobe of the thyroid gland was used, and an effort was made to have the sample that was counted represent both the middle and outer areas of the lobe.

It was found that neck muscle samples, prepared and counted in the same manner as thyroid samples, counted a few counts above background, and that this slight activity did not measurably change with time. In order to ascertain whether or not this activity could be due to the potassium content of the tissue, a solution was made up to contain the same potassium concentration as that of muscle.[5] When the raioactivity of this solution was determined it was found to be approximately the same as that of the muscle samples. While this does not prove that the slight radioactivity found in the muscle samples was due to natural potassium, it certainly strongly suggests that it was.

RESULTS

Figure 1 is a linear plot of the radioactivity per gram of thyroid tissue as a function of the date of death of the animal. The activity was calculated as millimicrocuries of I^{131}. In the preparation of the data for this graph it was assumed that the thyroid potassium concentration was probably about the same as muscle potassium concentration. Therefore a neck muscle sample from each animal (with the exception of three groups of animals collected in February) was counted and used as a background sample for the thyroid counts. This muscle background was subtracted before correcting the samples for decay (time of counting to time of death). Samples plotted in the area of

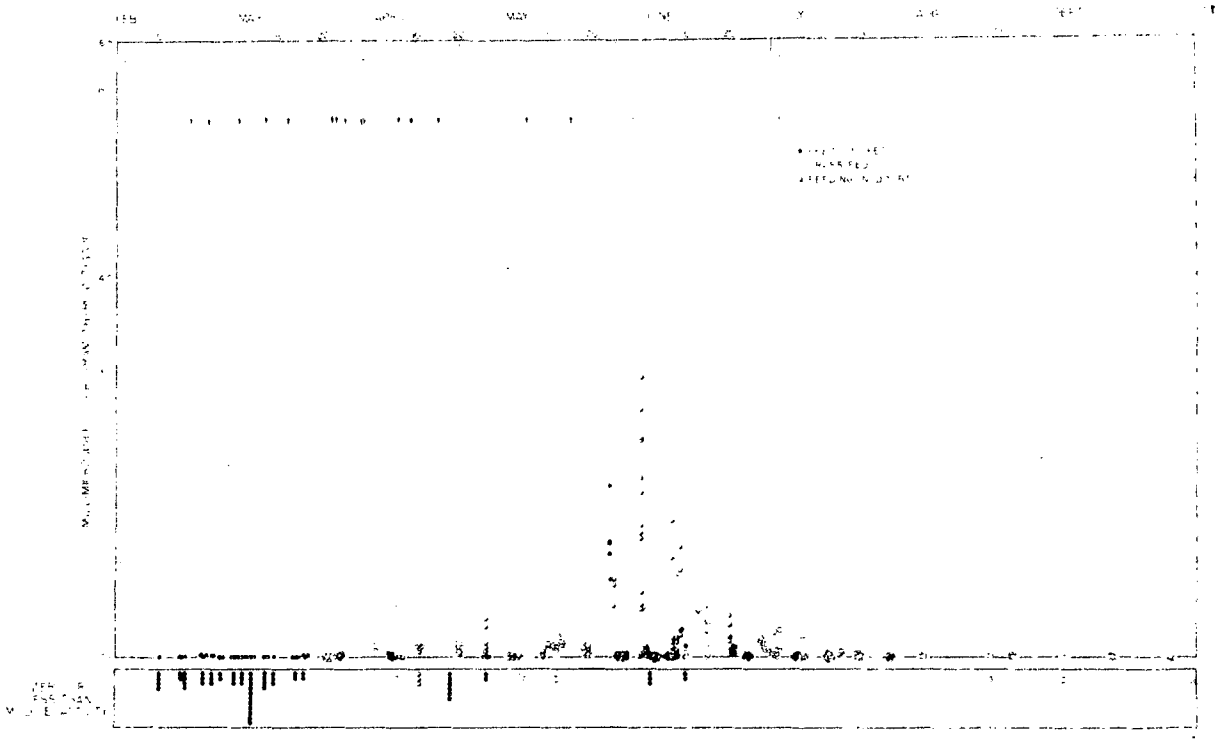

Fig. 1. Linear plot of radioactivity per gram of thyroid tissue as a function of date of death of the animal. The radioactivity is expressed as millimicrocuries of I^{131} Neck muscle tissue was used as background. The arrows at the top of the figure indicate the dates of explosion of nuclear devices. The heavier arrow on March 29 indicates two explosions on the same date. These data include a small number of animals raised in Idaho and Utah as well as those raised in California (these are separated in Figs. 4 and 5).

the figure below zero had either the same amount of radioactivity as muscle or slightly less. Arrows at the top of the graph indicate the dates of explosion of nuclear devices in Nevada.

Because of the possible influence that rainfall might have on fallout experiments, the rainfall data for the period and area being considered are represented in Fig. 2.

All samples were followed for radioactive decay. A few examples are illustrated in Fig. 3. These have been selected to show the characteristics of the decay curves obtained from samples with widely varying initial amounts of radioactivity. They are plotted with only counter background subtracted, therefore they include any natural potassium radioactivity present.

In Fig. 4 the thyroid radioactivity data are plotted on a logarithmic scale as a function of the date of death of the animals. Since zero and negative values cannot be indicated on a logarithmic scale, the muscle background was reincorporated into the data from Fig. 1 before plotting. The average muscle count and the standard deviation of muscle samples were calculated, and these came respectively to 0.0020 millimicrocuries per gram and ± 0.0012 millimicrocuries per gram. The heavy line (C-D) at 0.0056 millimicrocuries per gram indicates the sum of the mean muscle activity plus three standard deviations. Presumably any sample above this line can therefore be considered with almost complete certainty (probability = 0.999) to have more than the natural amount of radioactivity. Arrows at the top of the figure again, as in Fig. 1, indicate dates of explosion of nuclear devices.

Figure 5 shows a few groups of animals that were shipped from Idaho and Utah to the San Francisco Bay Area slaughter houses. It will be seen that the pattern of these samples is generally the same as that of the Northern California samples shown in Fig. 4.

DISCUSSION

The level of radioactivity does not follow a pattern that appears to be well correlated with the dates of explosions of nuclear devices in Nevada (Fig. 1). The thyroid activity content did not rise significantly above background until about a month after the start of the Nevada tests (however, most of the animals during the first month were feed-lot-fed; see discussion below). There were no significant peaks of activity until the very sharp one which appeared during the week of May 25 and which was about 10 days after the date of the last nuclear explosion. The amounts of activity seen in any given area would, of course, depend on many factors. Some of these are the amount of nuclear material exploded, the distance from the ground at which the device was exploded, prevailing winds, rainfall, and like factors.

It would appear that the peak seen in the latter part of May was mainly due to activity from the last explosion, or at least to a limited number of explosions that were significantly larger than the rest. The radioactive

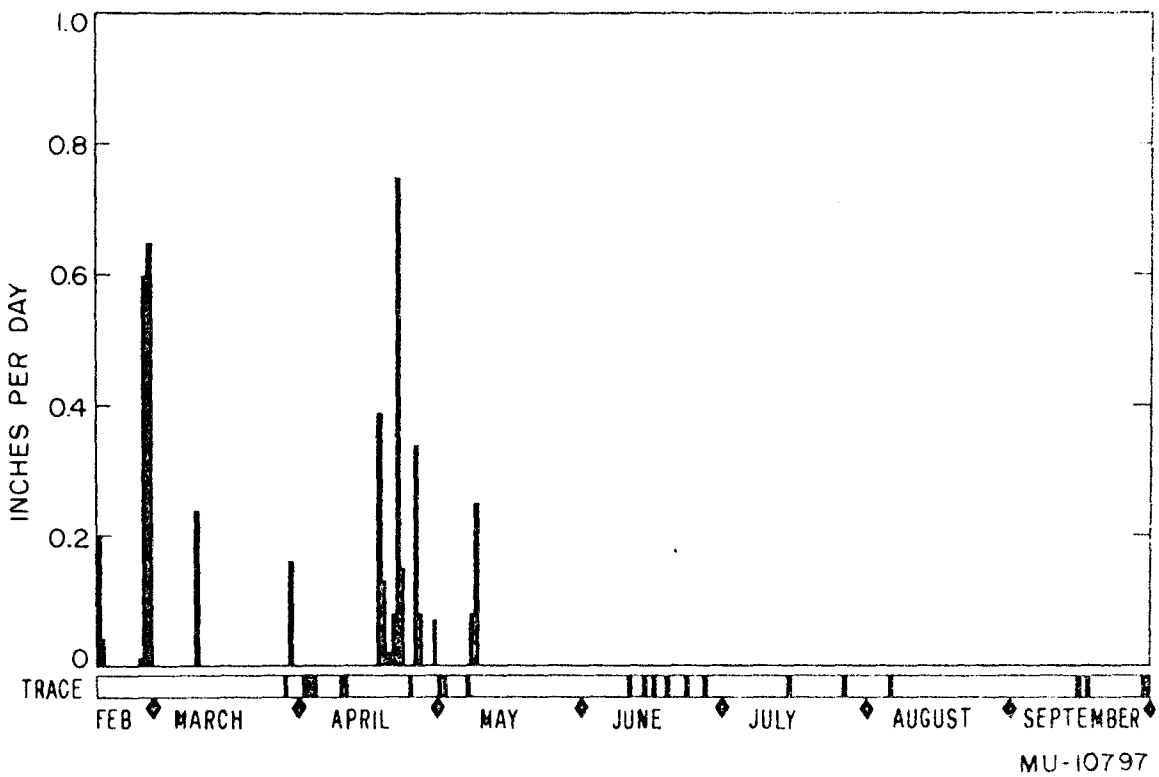

Fig. 2. Rainfall data for the San Francisco Bay Area. Note that there was essentially no precipitation from early May through September.

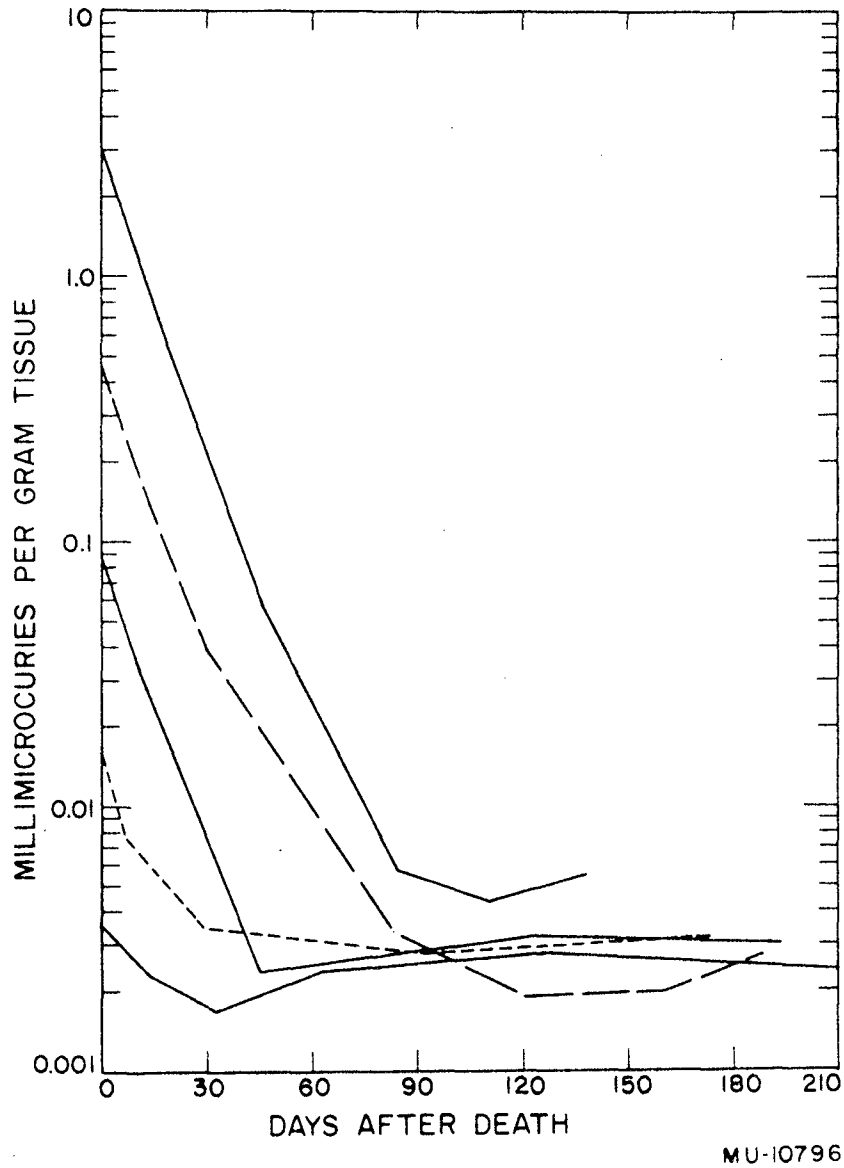

Fig. 3. Radioactive decay of five individual thyroid samples. These were selected to show characteristics of decay from tissues with widely varying initial amounts of radioactivity. They are plotted with only counter background subtracted and therefore include any long-lived potassium activity present. The fluctuations in the tail portions of the curve and in the curve that had the lowest initial activity are probably due to counting error, since there are only a few counts above background.

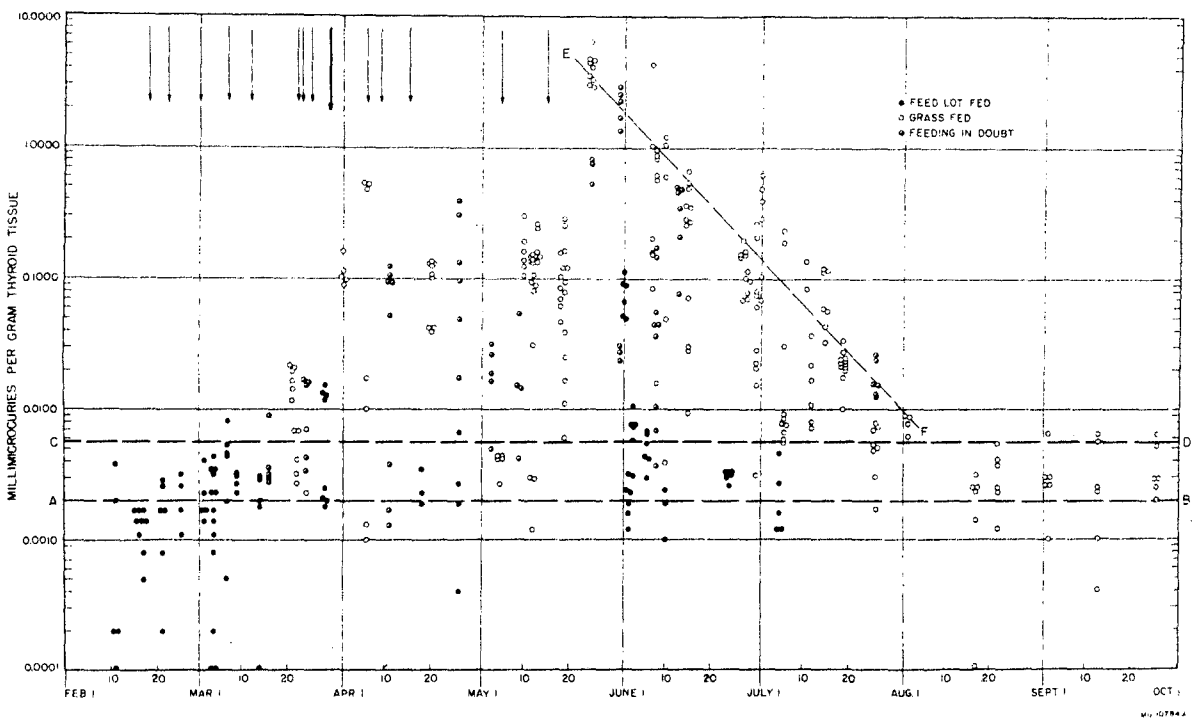

Fig. 4. Semilogatrithmic plot of radioactivity per gram of thyroid tissue as a function of the date of death for animals raised in California. The radioactivity is expressed as millimicrocuries of I^{131}. The data are the same as those of Fig. 1 with the following exceptions: (1) Because zero and negative values cannot be indicated on a logarithmic scale, the muscle background was reincorporated into the data after they were corrected to the time of death for I^{131} decay. (2) They exclude those animals raised in Idaho and Utah. Line A-B indicates the average muscle activity. Line C-D indicates the average muscle activity plus three standard deviations. Line E-F is an 8-day half-time decay line.

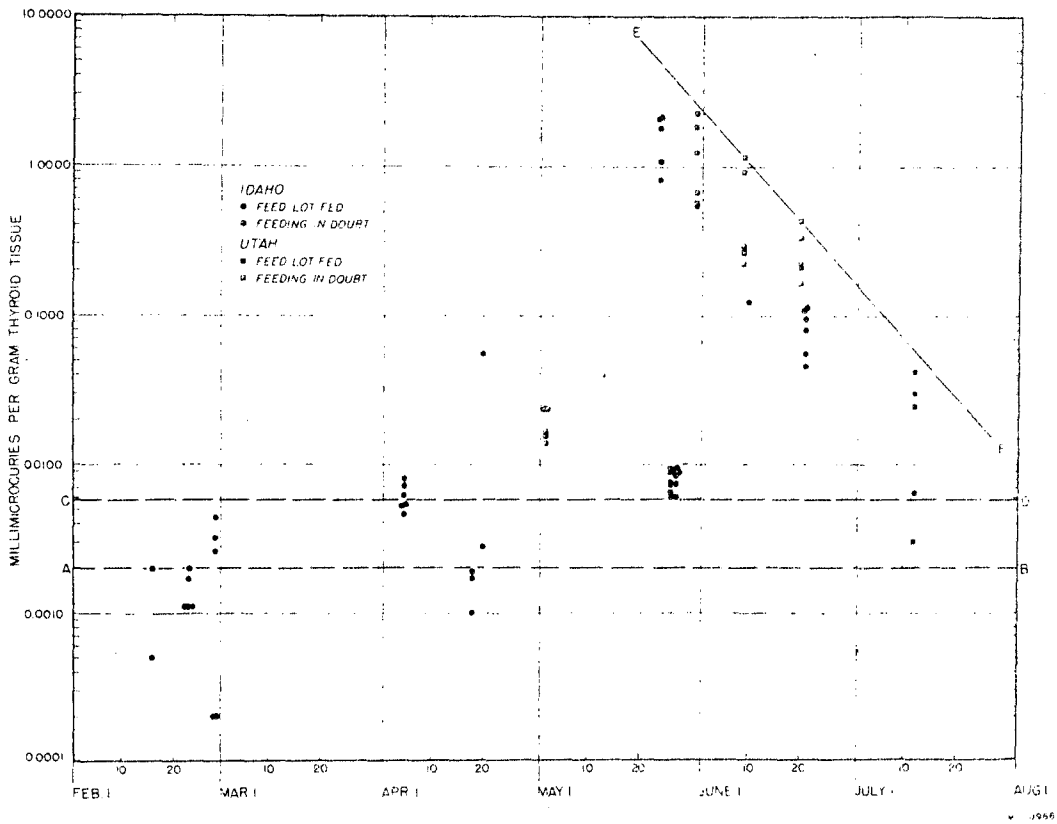

Fig. 5. This figure represents the same type of information as Fig. 4 except that the animals were raised in Idaho and Utah rather than California. Note that they follow the same general pattern as the California samples.

material that caused this peak apparently fell out over a very short period of time. Had it been due to an accumulation of activity from all the tests one would have expected the rise to be more gradual and the period of elevated activity to be more prolonged.

It will be noted from the decay curves of Fig. 3 that there appear to be two radioactive components. The small component or tail of radioactivity did not decay appreciably and was the same in absolute magnitude (mμc/g of tissue) regardless of the initial level of activity. Furthermore, this final activity level was the same as that found in muscle. It was therefore concluded that thyroid tissue had a small amount of radioactivity present normally, the most logical source of this being the naturally occurring isotope K^{40}. When muscle background was subtracted (correction for K^{40} content) all thyroid samples with sufficient activity to follow over an extended period decayed with a halftime of eight days. It was therefore assumed that the elevated activity seen in thyroid tissue during the period of the study illustrated in Fig. 1 was essentially all due to I^{131}.

A maximum total dose of radiation to the thyroid tissue of cattle in this western area due to this series of tests may be calculated. This can be done by multiplying the total exposure by the rate at which energy is liberated within the tissue, after converting to dose units.

The exposure is the number of millimicrocurie-days to which each gram of thyroid tissue is subjected. A maximum value of this quantity can be obtained by integrating the curve drawn through the maximum daily activity level in Fig. 1. This area, obtained by planimetry, is 95 millimicrocuries per gram times days.

The average energy for the beta rays of I^{131} is 0.189 Mev.[6] Therefore, one millimicrocurie of I^{131} will give 0.97 ergs per day.[a] The dose rate for I^{131} would then be 0.0104 rep per day per millimicrocurie per gram of tissue.[b] Since the integrated exposure was 95 millimicrocurie-days per gram of thyroid tissue, the total beta-ray dose is approximately 1 rep.[c] It should be noted that this is a maximum, not the average dose, and that it is limited to the thyroid tissue.

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[a] $37 \text{ dis/sec} \times 8.64 \times 10^{4} \text{ sec/day} \times 0.189 \text{ Mev/dis} \times 1.6 \times 10^{-6} \text{ ergs/Mev} = 0.97 \text{ ergs/day}$

[b] $\dfrac{0.97 \text{ ergs/day/m}\mu\text{c}}{93 \text{ ergs/g of tissue/rep}} = 0.0104 \text{ rep/day/m}\mu\text{c/g of tissue}$

[c] $95 \text{ m}\mu\text{c/g} \times \text{days} \times 0.0104 \text{ rep/g of tissue/day/m}\mu\text{c} = 0.99 \text{ rep}$

In addition to the total dose, a maximum dose rate may be calculated from the maximum activity level recorded on May 25. This is 6.4 millimicrocuries per gram of thyroid tissue, which gives a maximum dose rate of 0.06 rep per day.[d]

No attempt was made to include the gamma-ray dose. It would be very small compared to the beta-ray dose, owing to the relatively low absorption of the gamma rays and the geometry of the cattle thyroid.

There was a great deal of variation in the level of activity within a given group of animals. This can partially be explained by biological variation, but might also be explained on the basis of one grazing area's having a larger amount of fallout on it than another area close by, because of differences in wind currents during fallout. Another factor that may have contributed to this large variation comes from the fact that even though the whole group may have been allowed to graze, part of the animals may have obtained a larger proportion of their food from supplemental feeding (see discussion of feeding below).

The veterinarians at the slaughter houses were asked to estimate the ages of the animals. It was found that the estimated age could not be correlated with the level of activity per gram of thyroid tissue.

An attempt was made to find out what type of feeding each group of animals received just prior to death. The answer to this was not always available or reliable, because the animals were sometimes bought by the slaughter houses from stockyards and their exact sources were unknown. In many cases, however, fairly reliable information was available, and this is indicated in the figures. During the period of elevated activity the groups of animals that were feed-lot-fed had, in general, much lower activity than those animals which were grazed. This would appear to indicate that most, if not all, of the activity picked up by the animals at this time was in their food (the food used in feed lots probably being more protected from fallout than were grazing areas).

Additional evidence implicating the food as the principal source of radioactivity is derived from further consideration of Fig. 4. The line E-F in this figure points out that the maximum daily activities observed decrease exponentially with time. This exponential decrease starts with the maximum activity observed on the 25th of May and falls through three cycles with a halftime of approximately eight days. This would appear to indicate that biological turnover is not a factor in the loss of activity by the gland and that the animals must, during this time, be in equilibrium with a source of activity which is decaying at the same rate as the activity in the gland and to which no new activity is being added. The most likely source of this activity would be the food. Since, in this area, there were only traces of rainfall during this period (see Fig. 2), it is not likely that the activity was

[d] 6.4 mμc/g x 0.0104 rep/day/mμc/g = 0.064 rep/day

washed off the grass, and the animals were probably eating any fallout present on the grass at a relatively constant rate. It is hardly conceivable that air polution would remain constant over such a period of time. If the source of radioactivity were a deposit of material in the respiratory tract which was gradually being absorbed by the blood stream, this would probably be entering the blood stream at an exponential rather than at a constant rate.

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