Thyroid Radioactivity after Nuclear Weapons Tests

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In 1954 it was shown that nuclear weapons tests had produced radioactive materials (primarily iodine-131) that were accumulated and detectable in the thyroid glands of livestock in the United States (*1*). Further survey values for both man and animals have been presented in U.S. Atomic Energy Commission reports and in the open literature (*2–4*). The magnitude and pattern with time of radioactivity levels in the thyroids are of interest because (i) there is provided an alert to any build-up of potentially hazardous levels; (ii) as relationships are developed, radioiodine measurements could serve as a sensitive monitoring system for other fallout nuclides less easily detected in the biosphere; (iii) information may be obtained on the movement of radioiodine particularly in the biological system; and (iv) there could be an interference with medical diagnostic tests that employ low levels of radioiodine. This paper (*5*) summarizes the information that has been obtained on the levels of iodine-131 in human and cattle thyroids and presents an estimate of milk levels in the United States during the period from January 1955 to December 1956. Correlation with known bomb tests is noted, and some inferences are drawn about routes of exposure.

Procedure

Human thyroids from autopsies were submitted by pathologists from locations as noted by acknowledgment (*6*). In general, the thyroids were predominantly from persons more than 50 years old, and it was necessary to determine whether the radioiodine content was affected by the age of the person. Samples from the New Orleans area permitted comparisons of thyroid radioactivity in various age groups; thyroids from older persons showed slightly higher values than those from younger, and the few samples from children were not generally higher than those from other age groups. In addition, no differences were observed between samples from accident cases and those from patients hospitalized for a matter of weeks prior to autopsy. Thus, the sampling was considered as conservatively representative of the total population. Cattle samples were taken at the slaughter house, usually from calves or yearlings.

All thyroid glands were shipped in formalin and were processed in a standard manner upon receipt. The thyroids were washed, blotted dry, trimmed of extraneous tissue, cut into small pieces, placed in a tared aluminum cup, and weighed. The samples were dried for several hours at 100°C, reweighed, and then pelleted in a Carver laboratory hydraulic press into a cylinder about 16 millimeters in diameter. The pellet was placed in a test tube for counting. The dried pellets gave more uniform samples than did fresh tissue and permitted more sample to be presented to the sensitive volume of the detector. Recovery experiments showed that losses during processing did not exceed 10 percent; formalin-fixed weights were about 5 percent higher than wet weights. The results are expressed as millimicrocuries per gram of tissue (fresh weight) (mμc/g) calculated back to the date of death. The counting was usually done between 1 and 2 weeks after death. The samples as counted represented, on the average, about 10 to 15 grams of fresh tissue, ranging from 3 to 30 grams for both man and cattle.

For the most part, a commercial well crystal (background, 300 counts per minute; 1 millimicrocurie of iodine-131, 909 counts per minute) was employed, although some samples were counted with a 3-inch crystal and a single-channel analyzer (background, 10 counts per minute; 1 millimicrocurie of iodine-131, 394 counts per minute). Counts were considered significant when the counting rate was 2 to 3 times its standard deviation. As a rule, the counting rate was not significant when the sample contained less than 0.005 millimicrocurie of iodine-131. The usual calibration and standardization procedures were employed. Occasionally, the gamma-ray spectrum and half-life were determined and were found to be in agreement with the characteristics of iodine-131. Muscle samples showed no detectable activity under the conditions of measurement that could not be ascribed to radiopotassium.

Results

The over-all results are presented in Fig. 1 and represent the human and cattle samples averaged by 2-week periods. The curves were drawn by inspection to aid in the visualization of the general pattern; broken lines indicate periods during which samples were not taken. All the human samples were averaged except those from the Salt Lake City station. The cattle samples up to June 1955 represent averages of all continental stations listed in Table 1 except those from the Nevada-Utah area; thereafter, collections were made only from Omaha, Nebraska.

It is first noted that the pattern of levels is correlated with known weapons tests. The peak in mid-1955 was undoubtedly a result of the United States continental tests in the spring of 1955. The smaller rise with a peak near January 1956 presumably reflected a contribution from Soviet tests. The general rise during the latter half of 1956 could have resulted from United States, British, and Soviet activities.

From comparison of the pattern of cattle and human values, there seems little question about the common source of radioactivity. The cattle values were significantly greater than those of man ($P < 0.01$) and were increasingly higher at the higher levels. An indication of the route of entry of the radioiodine into cattle is given in Table 2. Through the cooperation of George K. Davis of the Florida Experiment Station, it was possible to obtain thyroids from six animals that had been barn-fed in central Florida for about 3 months on feed that could have contributed only small amounts of iodine-131. For comparison, thyroids were sent from two animals that had been allowed to graze normally on nearby pastures. It is apparent that at least 70 percent of the iodine-131 in the grazing animals had been contributed by the pasture. This observation is in disagreement with other reports (*2*) that suggest inhalation as the major source of contami-

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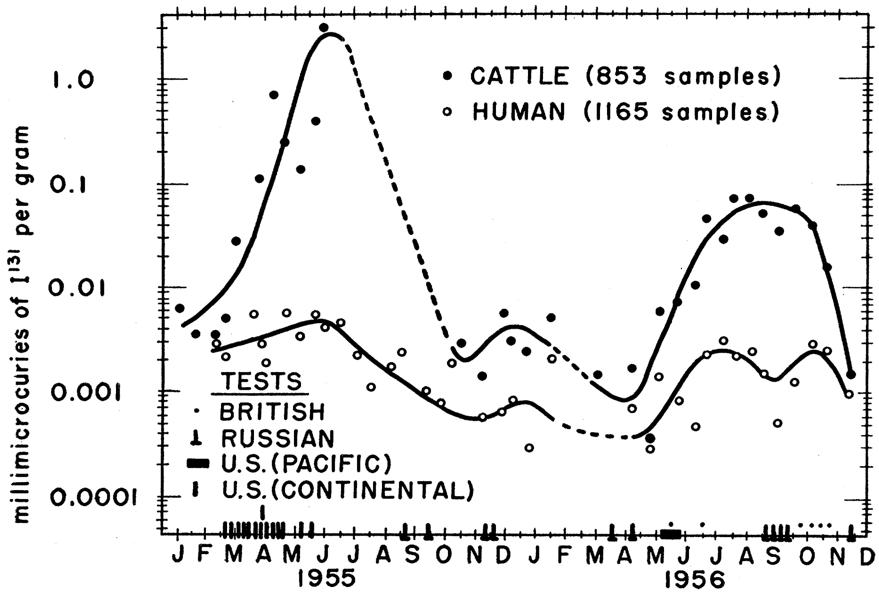

Fig. 1. Summary of iodine-131 levels in human and cattle thyroids as correlated with nuclear weapons tests during 1955–1956.

nation for cattle; indirect evidence (*3*) implicating food as the principal source of iodine-131 in cattle provides support for the findings presented in this paper.

A comparison of cattle values shown in Table 2 and the average human level is of interest. If the concentration in the thyroids of the barn-fed animals is corrected by a factor of 5 to account for the difference in respiratory tidal volume between the two species, a value of 0.0024 millimicrocurie per gram is obtained. As noted from Fig. 1, this is in fair agreement with the human values for this period (late June 1955). Since it is reasonable to assume that the iodine-131 burden in the barn-fed animals resulted primarily from inhalation, this supports the idea that the human burden may in large measure result from inhalation.

Table 1 presents the data for May 1955, a peak month. For ease of interpretation, the results have been lumped by geographical regions. Despite the fact that generalizations about regional differences are not particularly meaningful because of arbitrary factors, some trends are apparent. As expected, the levels from the region near the Nevada test site were higher than those from the rest of the country. The human values were essentially the same all over the country except for the Nevada-Utah area. The cattle samples, in contrast, appeared to show more differences between regions, with lowest values from the West Coast and highest from the Southwest. This may be related to the different routes of assimilation of fallout iodine-131 by man and grazing animals. Cattle samples from abroad were generally low.

Particular attention is called to the large spread of values. This is illustrated in Table 3, which presents the percentile distribution of samples for May 1955 and August 1956, two peak months. For instance, during the May peak, 30 percent of the human samples had less than 0.0008 millimicrocurie per gram, whereas 11 percent had more than 0.01 millimicrocurie per gram; the spread was even greater for the cattle samples. As a further example, out of ten cattle samples during the period 1 to 15 October 1956, eight ranged between 0.004 and 0.09, whereas the other two samples were 1.6 and 2.0 millimicrocuries per gram. There are obvious reasons for variations within sample groups; however, the occurrence of occasional high values requires further study to determine how much reliance can be placed on the ideas of uniform distribution or uniform accessibility of fallout materials. Similar interpretation of occasional high values could not be made for the human samples because any such value was automatically suspect on account of the widespread medical uses of iodine-131; in compilation, such values were eliminated from averages after the institution of origin confirmed that the individual had been treated with iodine-131.

Milk

It seemed important to consider milk as a route by means of which fallout radioiodine could be transmitted to the human population, especially to children, since appreciable amounts (up to 6 percent) of radioiodine ingested by the dairy cow appears in the milk (*7*). Samples of milk (100 milliliters) from the same areas as the sources of the cattle thyroids were collected from February to June 1955. No activity was detectable in these milk samples, indicating that the concentration of iodine-131 must have been less than about 0.01 millimicrocurie per 100 milliliters when the milk was secreted. From some unpublished experiments by F. W. Lengemann, it was shown that in two dairy cows receiving iodine-131 every day there was, at steady state, 0.74 and 1.3 percent of the daily dose per kilogram of milk and 30 and 65 percent of the daily dose in the thyroid gland, respectively. It is estimated from these values that the levels of iodine-131 in milk from dairy cows

Table 1. Iodine-131 content of human and cattle thyroid glands during May 1955.

Location	Human (mμc/g)	Cattle (mμc/g)
Nevada-Utah (eight human samples from Salt Lake City; two cattle samples from Nevada and southern Utah)	0.030	46; 0.15
West (27 human samples from Los Angeles and Portland; five cattle samples from California and Washington)	0.0048	0.086
South and Southeast (39 human samples from Louisville, Oak Ridge, and New Orleans; nine cattle samples from Louisiana, Tennessee, Texas, and Florida)	0.0055	0.46
North and Northeast (37 human samples from Minneapolis, Chicago, Boston, and New York; six cattle samples from South Dakota, Missouri, and Massachusetts)	0.0032	0.18
Abroad		
Panama (two cattle samples)		0.10; 0.082
Hawaii (two cattle samples)		0.11; 0.081
Germany (two cattle samples)		0.0019; 0.0056
Greece (one cattle sample)		0.013
French Morocco (one cattle sample)		0.047
Tokyo, Japan (one cattle sample)		0.0092

Table 2. Contribution of pasture to iodine-131 burden of cattle.

Animal number	Millimicrocuries of I^{131} per gram of tissue (fresh weight)
Barn-fed cattle	
3	0.0092
5	0.012
13	0.012
100	0.013
101	0.013
102	0.011
	Avg. 0.012
Pasture-fed cattle	
16	0.042
18	0.039
	Avg. 0.041

having the thyroid levels shown in Fig. 1 should have been about 0.2 millimicrocurie per 100 milliliters at the 1955 peak and averaged about 0.02 for the whole period. These values are higher than those found, probably because dairy cows usually consume older feed than do the cattle reported in this article. The data in this article do not permit estimations of the contribution of iodine-131 carried in milk, although the low milk levels found and the fact that the levels in younger age groups were not significantly higher would indicate this route to have been of minor importance. The contribution of milk is, of course, decreased by the physical decay between the time the fall-out is deposited on the forage and the time the dairy product is consumed. This may be an important factor and should be looked at more carefully under situations where milk from grazing animals is consumed within a matter of days after secretion.

Table 3. Examples of spread in iodine-131 levels in human and cattle thyroids. All continental samples except from Nevada-southern Utah area.

	May 1955	August 1956
Human		
No. of samples	101	60
Percentage of samples with		
Less than 0.0008 mμc/g	29	62
Betweeen 0.0008 and 0.01 mμc/g	60	35
More than 0.01 mμc/g	11	3
Cattle		
No. of samples	20	22
Percentage of samples with		
Less than 0.001 mμc/g	10	0
Between 0.001 and 0.1 mμc/g	40	86
More than 0.1 mμc/g	50	14

Thyroid Doses

It is of interest to estimate the radiation dose received by the thyroid glands of the human and cattle populations during the period of this study. The level of iodine-131 in an individual at any given time represents a balance between the intake, perhaps from several tests, and the biological and physical removal rates. This makes it difficult to calculate infinity dosages in the usual way (*8*). By integration of the area under the curves in Fig. 1 and estimation that 1 millimicrocurie of iodine-131 per gram of tissue delivers about 0.012 rep per day, it is calculated that the total dose from the iodine-131 beta rays, delivered over the 23-month period to the thyroid gland, was about 3 rep for cattle and 0.01 rep for man. In considering thyroid dosages, it is necessary to take into account the contribution of short-lived isotopes of iodine. This situation has been analyzed by Dunning (*8*), who shows that, up to 10 hours after detonation, the short-lived radioiodines may contribute about 4 times the iodine-131 dose and by 2 days about equally, but that after 10 days the contribution of the short-lived activities becomes negligible. It is not possible to correct the over-all dose of iodine-131 for the contribution of the short-lived activities, but in any event the total dose could not have been greater than 4 times the average dose from iodine-131 (4×0.01 rep) for man and was probably much less.

There seems to be little question that the levels of radioiodine introduced into the biological cycles by weapons tests during 1955 and 1956 are far below those that are expected to produce any observable effects. This can best be demonstrated by comparison of levels found with the official maximum permissible values and with findings on the lowest levels of radiation or of iodine-131 that could possibly have produced detectable changes. Such a comparison follows.

1) Average peak level observed in man, 0.005 millimicrocurie per gram.

2) Maximum permissible level in man for continuous exposure (*9*), 15 millimicrocurie per gram.

3) Estimated peak level in milk, less than 0.01 millimicrocurie per 100 milliliters.

4) Maximum permissible concentration in water for continuous exposure (*9*), 3 millimicrocuries per 100 milliliters.

5) Estimated average dose to human thyroid from radioiodine during the period January 1955 to December 1956, less than 0.04 rep.

6) External dose to neck area in infants and children that has been suggested as cause of later thyroid malignancy (*10*), 200 to 725 roentgens.

7) Dose to thyroids of sheep on daily intake of iodine-131 at which no damage was observed (*11*), 936 roentgens (3 roentgens per week for 6 years).

8) Dose to thyroid of sheep on daily intake of iodine-131 at which minor physiological change occurred (*11*), 3000 to 5000 roentgens (over 2½ years).

References and Notes

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5. This work was performed at the Medical Division, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn. under contract with the U.S. Atomic Energy Commission.
6. Cattle thyroids and milk samples were supplied through R. Miller, Omaha, Nebr., and with the cooperation of the Army Veterinary Corps, Office of the Surgeon General, and the Department of Defense. Human thyroids were received from Nicholas J. Chetta, Orleans Parish, New Orleans, La.; John H. Childers, University of Texas; T. H. Cochran, University of Utah; James R. Dawson, Jr., University of Minnesota; David Freiman, Beth Israel Hospital, Boston, Mass.; Nathan B. Friedman, Cedars of Lebanon Hospital, Los Angeles, Calif.; Marvin Kuschner, Bellevue Hospital Center, New York, N.Y.; Kenneth P. McConnell, Veterans Administration Hospital, Louisville, Ky.; Hans Popper, Cook County Hospital, Chicago, Ill.; Leopold Reiner, Beth Israel Hospital, Boston, Mass.; Vinton D. Sneeden, Emanuel Hospital, Portland, Ore.; and Walker B. Sorrell, Tulane University. The cooperation of these persons is gratefully acknowledged—it is emphasized that the success of this program depended largely on the procurement and prompt handling of uncontaminated samples.

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