An assay of thyroids from livestock indicates that radioactive iodine is accumulated and readily detectable in these glands following nuclear weapons testing. The levels found are an index of fission product contamination in the area.

Radioactivity in Animal Thyroid Glands

ARTHUR H. WOLFF, D.V.M.

A STUDY of radioactivity in animal thyroid glands was conducted to determine the feasibility of this technique in monitoring the environment for radioactive fallout. Thyroid glands of 412 animals from four States were assayed for evidence of fresh fission products from nuclear weapons testing which the United States began in the Pacific, May 5, 1956.

There are several radioisotopes of iodine which contribute significantly to the mixture of early gross fission products (*1*). Of these iodine–131 has the longest half-life—about 8 days—and it is the iodine isotope of most concern biologically. Radioactive isotopes of iodine assimilated by animal or man behave biologically just like the naturally occurring stable isotope of iodine and concentrate in the thyroid gland. If animals eat a gross mixture of fission products less than several weeks old, a significant portion of the I^{131} present would be concentrated in a small volume of thyroid tissue and would be readily detectable with appropriate instruments.

Thyroid concentration of fission-produced radioiodine may be associated not only with fallout from nuclear weapons tests but also with fission product waste from nuclear reactors. Hanson and Browning have found I^{131} in the thyroids of indigenous jackrabbits associated with stack discharge of radioactive wastes at the Hanford Atomic Products Operation (*2*). They have collected data since 1951, trying to derive ratios between concentrations of I^{131} in rabbit thyroids and the waste emission rate from the Hanford plant.

Dr. Wolff is senior veterinarian with the Radiological Health Medical Program, Division of Special Health Services, Public Health Service.

In 1953, I assayed thyroids from 10 sheep originating in 6 herds near Cedar City, Utah, and found concentrations averaging about 0.6 microcurie I^{131} per gram of thyroid tissue at the time of autopsy. There was evidence that these sheep had assimilated fission products falling out from a Nevada "shot" 2 or 3 weeks prior to the autopsy (*3*).

Since that time, other investigators have reported radioactive iodine in animal thyroids (*4–7*). The activity presumably was associated with nuclear weapons testing in all instances.

Methods

Single or partial lobes of thyroid glands from animals obtained between April 14 and October 18, 1956, were received in 10 percent formalin solution from Arizona, Ohio, Oregon, and Pennsylvania.

The specimens were individually prepared for beta counting. Each lobe or partial lobe initially was blotted, and, generally, a 1-gram portion from each specimen was placed in an individual flask to which a few drops of sodium iodide solution (20 mg. of iodide per ml.) and 5 ml. of 0.5 normal sodium hydroxide were added. The flasks were gently heated, usually 1 to 2 hours, until digestion was complete. Each digest was transferred to a stainless steel planchet cup (2″ by 3/16″) and thoroughly dried by infrared heating. The radioactivity of the residue in the cups then was counted in an alpha, beta, gamma, proportional counter (NMC Model PC–1). Activity, after the required corrections, was expressed as millimicrocuries (mμc.) per gram of wet (formalized) tissue, extrapolated to the date of slaughter or death of the animal. Preliminary studies indicated that the weight of thyroids after soaking in 10 percent formalin for several days was about 10 percent greater than fresh weight. The more active samples were checked periodically for decay, substantiating a half-life of about 8 days.

Specimens with an activity greater than 0.05 mμc./gm. were counted with a standard deviation of less than 10 percent. Those having activity of less than 0.05 mμc./gm. were counted with a standard deviation ranging from 10 to 50 percent. The lower limit of detection was 0.01 mμc./gm. ±50 percent.

Results and Discussion

Of the specimens received, 81 were from small animals, mostly dogs and cats undergoing postmortem examination in veterinary clinics in Ohio and Pennsylvania, and 331 were from livestock, mostly cattle and sheep. Pennsylvania livestock specimens came from the diagnostic laboratory, New Bolton Center, University of Pennsylvania Veterinary School. All other livestock thyroids came from slaughterhouses in Phoenix, Ariz., Columbus and Cincinnati, Ohio, and Portland, Oreg.

All thyroids from animals dying between April 14 and May 16, 1956, were considered pre-series specimens, thus arbitrarily allowing 11 days after the announced start of the United States Pacific test series for the occurrence of fallout in the United States and the assimilation of I^{131} by animals.

No I^{131} was detected in 33 pre-series thyroids from small animals. From the thyroids of 45 small animals dying between May 16 and the end of July, I^{131} was detected in only one thyroid: there was 0.04 mμc./gm. in a specimen from a cat in Pennsylvania.

It is thought that any activity found in small animal thyroids would be mainly attributable to inhalation and, to a minor extent, dietary intake, depending on the quantity of fresh milk consumed. Milk, as a possible vehicle for I^{131}, is discussed later in this report. The sensitivity of the equipment available for this study probably was too limited (0.01±50 percent mμc./gm.) to detect the low levels of activity expected in small animals in contrast with the expected concentrations assimilated by grazing animals. Livestock may graze daily many hundreds of square feet of pasture which serves as an efficient collector of fallout. On the basis of a report by Chamberlain (*8*) it is estimated that in an area with a given sustained atmospheric concentration of I^{131}, the thyroid I^{131} uptake by cattle as a result of grazing in the area would be several thousand times greater than what could be attributed to inhalation alone.

As anticipated, the thyroids from livestock revealed much more activity than those from nongrazing small animals. The total number of livestock specimens assayed during select sampling periods and the corresponding number in which activity was detected are summarized below.

Period	*Number of livestock specimens*	*Number with detectable I^{131} activity*
Pre-series	60	2
May 16–June 15	70	27
June 16–July 30	89	65
August 1–August 31	102	92
September 1–October 18	10	10

A progressive increase in the proportion of livestock thyroids with detectable activity is apparent following the onset of the United States tests in the Pacific. In view of the announced July 23 terminal date of these tests and the announcement of a Russian test series beginning on August 24, the activity in the last 10 specimens is thought to be associated with the Russian series.

Table 1 summarizes the numbers of thyroid specimens tested and the mean concentrations of I^{131} detected, according to the species, geographic origin, and period of collection. Table 2 summarizes the distribution of the individual samples with respect to the levels of activity according to period and species.

The indicated levels of activity for the Oregon specimens undoubtedly are lower than the actual values, since we were not able to determine the date of slaughter for most of the samples submitted from this State. The Oregon activity, therefore, was extrapolated to the date of mailing in instances of unspecified slaughter dates. Some of the specimens were shipped as much as 2 to 3 weeks following the date of collection.

Van Middlesworth has reported that sheep tend to concentrate greater amounts of I^{131} in the thyroid than do cattle (*4*). The limited data presented here tend to substantiate this observation when the mean levels of activity of the two species are compared during the same period and within the same State. The data for Oregon sheep and cattle during the last period would indicate the opposite. However, the quantitative significance of these data is questionable because, as previously pointed out, the slaughter dates and the proper extrapolation factors for these specimens are not known.

For the most part the specimens from Pennsylvania showed less activity than those from the other States. The livestock thyroids from this State originated in a veterinary diagnostic laboratory, and most of the source animals were moribund or dead when received by the laboratory, in contrast with the presumably healthy grazing animals serving as a source of thyroids in the other States. This is offered as a possible reason for the difference in activity.

Although I^{131} was readily detectable in thyroids of animals from widely varied locations after May 16, the estimated doses in the thyroid were quite low. The mean concentration of I^{131} in cattle thyroids in Ohio and Arizona, based on the combined data of these two States, from May 16 through October 18 was about 0.5 mμc./gm. The mean concentration for sheep in these same States was about 1.7 mμc./gm. If we assume that these mean values represent the average daily sustained concentrations of I^{131}, we can estimate the total integrated dose during the 150-day period of this study to be about 910 millirep (milliroentgens equivalent physical) and 3,100 millirep for cattle and sheep respectively. Stated in another manner, the average weekly thyroid dose would have been about 42 millirep per week and 144

Table 1. Average concentration of iodine-131 from 331 livestock thyroid glands, April 24 through October 18, 1956

Period and State	Cattle		Sheep		Other animal	
	Number of specimens	Mean activity [1]	Number of specimens	Mean activity [1]	Number of specimens	Mean activity [1]
Apr. 24–May 15 (pre-series)						
Arizona	21	(2)	15	(2)	0	
Ohio	12	0. 0041	0		0	
Oregon	0		0		0	
Pennsylvania	7	(2)	1	(2)	4	(2)
Total	40	. 0008	16	(2)	4	(2)
May 16–Aug. 15						
Arizona	36	. 25	9	2. 70	0	
Ohio	46	. 58	34	1. 37	9	0. 46
Oregon	24	. 11	19	. 33	0	
Pennsylvania	8	. 14	5	. 20	16	. 067
Total	114	. 34	67	1. 17	25	. 21
Aug. 16–Oct. 18						
Arizona	12	. 28	3	2. 15	0	
Ohio	14	. 80	0		0	
Oregon	18	. 30	18	. 12	0	
Pennsylvania	0		0		0	
Total	44	. 45	21	. 41	0	

[1] Activity is in millimicrocuries per gram of thyroid extrapolated to date of slaughter.
[2] Background or activity below limit of sensitivity (0.01 mμc./gm.).

Table 2. Distribution of iodine-131 concentration in livestock thyroids from Arizona, Ohio, Oregon, and Pennsylvania, April 24 through October 18, 1956

Period and species	Mean activity (mμc./gm.)	Highest activity (mμc./gm.)	Number of thyroid specimens				
			Back-ground	0.01–0.1 mμc./gm.	0.1–1.0 mμc./gm.	1.0–10 mμc./gm.	Total
Apr. 24–May 15 (pre-series)							
Cattle	0.0008	0.03	38	2	0	0	40
Sheep	(1)	(1)	16	0	0	0	16
Other	(1)	(1)	4	0	0	0	4
Total			58	2	0	0	60
May 16–Aug. 16							
Cattle	.34	2.5	53	19	27	15	114
Sheep	1.17	5.3	12	1	34	20	67
Other	.21	.87	6	6	13	0	25
Total			71	26	74	35	206
Aug. 16–Oct. 18 [2]							
Cattle	.45	4.20	6	11	20	7	44
Sheep	.41	2.50	1	6	11	3	21
Total			7	17	31	10	65

[1] Background or activity below limit of sensitivity (0.01 mμc./gm. ± 50 percent).
[2] Only cattle and sheep were assayed in this period.

millirep per week for cattle and sheep during the period of May 16 through October 18, 1956.

These values are in general agreement with the dosage levels reported in similar studies (*4–7*). These exposure levels are apparently harmless for livestock and probably would represent no acute hazard to animals even if exceeded by 1 or 2 orders of magnitude (*9*).

Van Middlesworth, since November 1954, has been conducting an extensive sampling program, testing 15 thyroids a week from cattle raised in the Memphis area (*4*). The mean weekly concentration of I^{131} found in these cattle for a 70-week sampling period was about 0.9 mμc./gm. If we can assume that these data, along with the Ohio and Arizona data given here, are representative of the rest of the country, we can estimate that the average concentration of I^{131} in cattle thyroids has been at least 0.5 mμc./gm., resulting in an average cattle thyroid dose of at least 42 millirep per week over the last 2 to 3 years.

Generally, it is accepted that body burden levels of radioisotopes found in grazing animals will be many times greater than those likely to be present among the adult human population in the same area. Comar found the I^{131} content in animal thyroids to be 18 to 85 times that found in humans in the same locale (*7*). Van Middlesworth reported maximum I^{131} activity in cattle to be 200 times the maximum activity in humans in the same area (*4*).

Thus, if cattle have been subjected to thyroid exposure levels in the order of 42 millirep per week, it appears that the general population has been subjected to considerably less. However, it should be pointed out that the thyroid dosage received by infants and young children may be considerably higher than that by adults because significant portions of I^{131} ingested by dairy cows will be secreted with the milk (*10, 11*).

According to data of Hunter and Ballou (*1*), limited evidence (*12–15*), and theoretical considerations (*16*), significant levels of various other fission product radioisotopes would be secreted into milk concomitantly with I^{131}. Although there has been extensive investigation (*17–18*) with respect to the levels of the long-life alkaline earth, strontium-90, in milk, human bones, and other biological material, to my knowledge there has been but limited investigation of the relative contribution of other fission products, particularly some of the shorter-lived radioelements, via the nutritional medium of milk.

The levels of animal thyroid activity in this study, though readily detectable, occurred for the most part in the absence of significant increases in gamma background and air activity as reported weekly by the Nationwide Radiation Surveillance Network (*19*). It is conceivable that for limited periods levels of fission product activity in milk could approach peacetime permissible levels with little or no perceptible increase in background levels (*16*).

Summary

Iodine-131 activity was readily found in thyroid glands from grazing animals in Arizona, Pennsylvania, Ohio, and Oregon within 2 weeks following the start of the 1956 United States Pacific atomic weapons tests. A progressive increase was noted in the proportion of samples which were active from mid-May to mid-October, at which time the study was terminated.

Based on the Arizona and Ohio data, the average weekly dosages from mid-May to mid-October to cattle and sheep were 35 and 120 millirep respectively, apparently harmless to the health of animals. It is suggested that the average cattle I^{131} level found in this study approximates the average continuously existing in United States cattle during the past 2 or 3 years.

Theoretical considerations indicate that with the levels of I^{131} found in cattle thyroids, detectable amounts of I^{131} would have been secreted with the fresh milk produced in these areas.

REFERENCES

(*1*) Hunter, H. F., and Ballou, N. E.: Fission product decay rates. Nucleonics 9: C2–C7, November 1951.

(*2*) Hanson, W. C., and Browning, R. L.: Biological monitoring. Biological Research—Annual Report 1955 (HW 41500). Richland, Wash., Hanford Atomic Products Operation, 1956.

(*3*) Public Health Service: Report of Public Health Service activities in the offsite monitoring program. Nevada proving ground—spring 1953. Washington, D. C., 1953. (For official use only.)

(*4*) Van Middlesworth, L.: Radioactivity in thyroid glands following nuclear weapons tests. Science 123: 982–983, June 1, 1956.

(*5*) White, M. R., and Dobson, E. L.: California cattle thyroid activity associated with fallout: 1955. University of California Radiation Laboratory Report (UCRL 3355). Berkeley, 1956.

(*6*) Gunther, R. L., and Jones, H. B.: Confirmation of radioactivity in thyroids of various animals—July 15 to September 10, 1954. University of California Radiation Laboratory Report (UCRL 2689). Berkeley, 1954.

(*7*) Comar, C. L., Trum, B. F., Kuhn, U. S. G., III, Wasserman, R. H., Nold, M. M., and Schooley, J. C.: Thyroid radioactivity after nuclear weapons tests. Science 126: 16–18, July 5, 1957.

(*8*) Chamberlain, A. C., Loutit, J. F., Martin, R. P., and Russell, S. R.: The behavior of 131_{I}, 89_{Sr} and 90_{Sr} in certain agricultural food chains. Harwell, England, Atomic Energy Research Establishment, 1955.

(*9*) Bustad, L. K., George, L. A., Jr., Marks, S., Warner, D. E., Barnes, C. M., Herde, K. E., and Kornberg, H. A.: Biological effects of I^{131} chemically administered to sheep. Hanford Atomic Products Operation Report HW 38757. Richland, Wash., Hanford Atomic Products Operation, 1955.

(*10*) Glascock, R. F.: The secretion of a single tracer dose of labelled iodine in milk of a lactating cow. J. Dairy Res. 21: 318–322 (1954).

(*11*) Tennessee, University of: Atomic Energy Commission Agricultural Research Program Semiannual Progress Report, January 1, 1955, to June 30, 1955 (ORO–145). Oak Ridge, 1955.

(*12*) Cohn, S. H., Rinehart, R. W., Gong, J. K., Robertson, J. S., Milne, W. L., Bond, V. P., and Cronkite, E. P.: Internal deposition of radionuclides in human beings and animals. *In* Some effects of ionizing radiation on human beings. U. S. Atomic Energy Commission Report, T.I.D. 5338. Washington, D. C., 1956, ch. 5.

(*13*) Tennessee, University of: Atomic Energy Commission Agricultural Research Program Semiannual Progress Report, July 1, 1955, to December 31, 1955 (ORO–150). Oak Ridge, 1956, pp. 30–31.

(*14*) Johnson, W. S., McClelland, J., and Skillern, C. P.: Monitoring of cows' milk for fresh fission products following an atomic detonation. *In* Los Alamos Scientific Laboratory Report LA 1597. Berkeley, 1953, pp. 1–13. (For official use only.)

(*15*) Lebedinsky, A. V.: Report to Scientific Committee on Medical Radiobiology of the Minister of Health of USSR. Moscow, 1956.

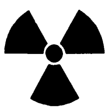
(*16*) Russell, S. R., Martin, R. P., and Wortley, G.: An assessment of hazards resulting from the ingestion of fallout by grazing animals. Atomic Energy Research Establishment, Harwell Berkshire, U. K., Report A.E.R.E. (ARC/ RBC5), Harwell, England, 1956. (For official use only.)

(*17*) Martelt, E. A.: The Chicago sunshine method, absolute assay of strontium 90 in biological materials, soil, water, and air filters. The Enrico Fermi Institute for Nuclear Studies, University of Chicago. U. S. Atomic Energy Commission Report AECU-3262. Chicago, 1956.

(*18*) Libby, W. F.: Radioactive strontium fallout. Proc. Nat. Acad. Sc. 42: 365-390, June 1956.

(*19*) Public Health Service: Summary reports of nationwide radiation surveillance network, April-September 1956, Radiological Health Program. Washington, 1956.

Radiation Protection in Industry



In interactions between advisory and official groups toward effecting the protection of workers against radiation hazards in industry, it is the employer who must provide the means for protection.

For the employer to have knowledge of the extent of potential radiation hazards, and for their proper evaluation, a chain of communication must be established between him and the manufacturer of a radiation source. The communication line, for other reasons, should extend to operators, to other employees, and perhaps to the public. Certainly the employees of an official agency having jurisdiction over protection practices must know that a hazard is present.

Registration of radiation sources is based upon the need to know where radiation hazards are present in industry. Connecticut, Delaware, New York (both health and labor departments), North Dakota, Pennsylvania, South Dakota, Texas, and Wisconsin require registration of radiation sources. The very act of registering a source provides a stimulus for conscious recognition of radiation hazards and their control by the employer.

We cannot, however, register all radioactive materials; our own bodies contain some amounts. And there is general acceptance that certain radiation sources containing measureable amounts of radioactive materials (such as radium dial wrist watches) may be allowed in general commerce without tight regulations. Large numbers of such items, on the other hand, in collecting points may bring into one spot enough radioactive materials to produce a hazard.

These quantities must be labeled. The pictured radiation hazard warning symbol—a purple, three-bladed "propeller" on a yellow background—has been adopted by the Atomic Energy Commission and several States.

Attempts are being made to standardize radiation protection in manufactured items and operations in industry. Standard shielding, installation, and maintenance will be the same for the strontium-90 thickness gauge wherever it may be located. Standards are being developed to apply to dental X-ray units, radioisotopic radiographs, and radium static electricity eliminators. The American Standards Association is developing standards aimed at the manufacture of sealed beta ray sources, and perhaps even "mass-produced" nuclear reactors, so that the hazard picture associated with any one unit can be repetitively characterized.

—Excerpts from an address presented by Saul J. Harris, assistant manager of technical services, Atomic Industrial Forum, Inc., at the Sixth Annual Health Conference of the Pennsylvania Department of Health, Aug. 21, 1957.