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THE SIGNIFICANCE OF RADIONUCLIDE CONTAMINATION IN RUMINANTS*

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Ruminants may become contaminated by radionuclides released at the time of a nuclear detonation and to a very limited extent by radionuclides released by reactor accidents or by nuclear industry operation. In order to evaluate the contamination, we must consider the specific radioactive elements involved, their characteristics and behavior, and their probable route of entry into the animal and their transfer via animal products to man.

The primary and secondary fission products include more than 200 radionuclides. In addition, there are some radionuclides produced by neutron activation, such as carbon^{14} from nitrogen in the atmosphere and zinc^{65} from stable zinc^{64}. A list of some of the more important radionuclides, together with their characteristics, is presented in *Table* I. There are, of course, many short-lived nuclides of high fission yield of significance immediately after release, but they were omitted from the table for the sake of simplicity. Furthermore, only single isotopes or mother-daughter nuclides are shown; they are generally members of rather complex decay schemes. For illustrative purposes, the decay scheme for I^{131} is shown in *Table* II.

In *Figure 1* are shown the percentage contributions of several important radionuclides to the total fission product radioactivity following slow neutron fission.[32] During early times, of course, the total fission product radioactivity decreases rapidly because of the radioactive decay. This obtains since early fallout contains many short-lived isotopes. As a rule of thumb, the radioactivity decreases by a factor of 10 for every 7-fold increase in time after detonation or release; that is, if there were 1000 units at 1 hour, there would be 100 units at 7 hours, 10 units at 2 days, and 1 unit after 2 weeks.

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TABLE I

LIST OF IMPORTANT FISSION PRODUCTS AND THEIR CHARACTERISTICS

Fission product	*Half-life*	*Primary organ or organs irradiated*	*Source* *Fallout from nuclear explosion* local	tropo-spher-ic	strato-spher-ic	*Reactor* newly fueled	after oper-ation
I^{131}	8 d	thyroid gland	X	X		X	X
Sr^{89}	51 d	bone	X	X		X	X
Sr^{90}-Y^{90}	28 y, 64 h	bone		X	X		X
Ba^{140}-La^{140}	12.8 d, 40 h	bone	X	X		X	X
Zr^{95}-Nb^{95}	65 d, 35 d	whole body and gastrointestinal tract		X			X
Ce^{144}-Pr^{144}	285 d, 17.5 min	gastrointestinal tract and skin		X	X		X
Cs^{137}-Ba^{137}	30 y, 2.6 min	whole body			X		X

TABLE II

DECAY SCHEME[30] FOR IODINE 131

(Thermal neutron fission of U^{235})

Atomic number and element

49 Indium	50 Tin	51 Antimony	52 Tellurium	53 Iodine	54 Xenon*
1 sec →	3 sec →	23 min $\xrightarrow{95\%}$	25 min →	$\boxed{8.05 \text{ days}}$ $\xrightarrow{12\%}$	stable
			↑ 22% ↑ 78%		↑
		$\xrightarrow{5\%}$	30 hrs	$\xrightarrow{88\%}$	12 day

* Two isomeric states—one stable.

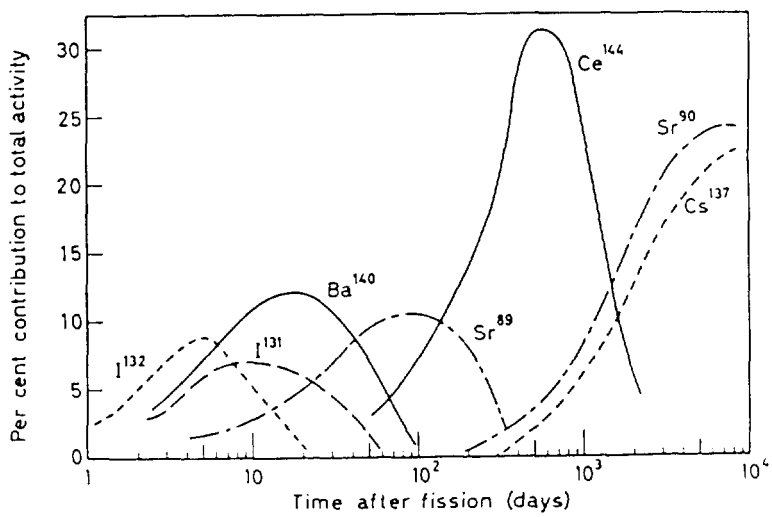

Fig. 1.—Relative contribution[32] of some important radionuclides to total fission product activity following slow neutron fission of U^{235}.

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Certainly, all of the 200 fission products are not of equal biological significance. In selecting those to be discussed, we took cognizance of the amounts present in various kinds of fallout, their physical half-lives, their metabolic behavior, their biological significance, the available data, and the tissue or organ involved. Regarding the latter category, we chose to discuss radionuclides that would be representative of poorly absorbed β-γ emitters that would irradiate principally the gastrointestinal tract and the skin, the bone-seekers, those that concentrate principally in a single organ such as the thyroid, and γ-emitters that irradiate the total body. Alpha-emitting isotopes are not included because they are generally poorly absorbed and are not concentrated in the milk.[42, 50] Although many of the radionuclides have not been studied in ruminants, general metabolic data are available in other species and have been recently reviewed.[58]

The effects of the various important radionuclides on ruminants will be discussed first and categorized according to the area of the body irradiated. This will be followed by a discussion of the significance of contaminated ruminants as a source of food for man and then examination of various methods of reducing the hazard to both animals and man.

GASTROINTESTINAL TRACT IRRADIATION

A grazing animal could receive a substantial dose of radiation to the mucosa of the digestive tract, primarily β-radiation from unabsorbed β-γ emitters such as Ce^{144}-Pr^{144}. The results of radionuclide feeding studies have shown that the lower large intestine usually receives the highest radiation dose.[46] An exception is suggested by the recent work of Bell[4] in which he fed high levels (20 mCi/day) of Ce^{144} to sheep. (Less than 0.05 per cent of an orally administered dose of Ce^{144} is absorbed.) He found that gross damage to the gastrointestinal tract was limited to the omasum and abomasum in most of the sheep. Yellow fibrous and necrotic infiltration was present in the omasal folds, some of which appeared to be sloughing. In one wether, seven months after the cessation of Ce^{144} feeding, the omasal folds were completely absent, the reticulo-rumen orifice was distended and the rumen appeared impacted.

In both the omasum and the lower large intestine the contents have a relatively long transient time and are quite concentrated,[20] both of which result in a high radiation dose from the contents. In addition, the high surface-to-volume ratio in the omasum is probably a contributing factor in explaining the pattern of lesions observed. The physiological state of the gastrointestinal tract, of course, could alter the intestinal dose by at least an order of magnitude (for example, if diarrhea or constipation occurred).[46] Irradiation, too, could modify absorption of material from the gastrointestinal tract.[3]

Some estimates were made by Nold and his colleagues[46, 48] on the effects of the β-emitter Y^{90} on the gastrointestinal tract of a goat and,

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by extrapolation, the effects on a cow. They estimated that each millicurie of Y^{90} ingested by the goat resulted in a dose of 17 rads to the lower large intestines. Single oral doses of more than 200 mCi which delivered between 3000 and 4000 rads to the so-called critical organ (the lower large intestines), failed to produce any evidence of hemorrhagic enteritis. Doses in excess of 5000 rads were estimated to be required to provoke the latter syndrome.

Under most circumstances involving a high-level fallout field, the contribution of the β dose to the gut would be relatively insignificant compared with the dose to whole body from γ-emitters on the ground and in and on the animal. Nold made estimates of the dose to the whole body and to the gastrointestinal tract for a 90-day period following a detonation that resulted in a fallout field that had dose levels of 100 r/hr at one hour (*Table* III).

TABLE III

COMPARATIVE 90-DAY DOSES TO THE WHOLE BODY AND GUT OF COWS GRAZING A FALLOUT FIELD[48]

	Cows start grazing immediately after attack	*Cows start grazing after 2 weeks*
90-day whole body dose	400 r	150 r
90-day gut dose	100 r	30 r

It was assumed that the animals that did not begin grazing until after two weeks were kept in a barn that provided a shielding factor of three, and during their confinement their ration was not contaminated. It should be noted in *Table* III that with a whole body dose that would be acutely lethal to most if not all of the cows (1000 r), the dose to the gut would only be about 10–15 per cent (250 r) of the dose required to produce minimal injury. This latter figure is based on the assumption that approximately 1 per cent of the significant radionuclides is retained on the grass and thus available for ingestion by the grazing animal. If the retention of the radionuclides on the forage consumed is greater than 1 per cent, then the dose to the gastrointestinal tract would be increased accordingly.

SKIN IRRADIATION

The deposition of fallout on the skin of animals can cause lesions often referred to as "beta burns" since they are due to the β component of β-γ emitting radionuclides. Gamma irradiation, of course, can cause a local reaction, but the effects are not confined to a localized area of skin. The most noticeable reaction to β-burns is a localized change in wool growth and in pigmentation as illustrated in the sheep exposed to a P^{32} plaque shown in *Figure 2*. We have found the skin response of sheep to Sr^{90} and P^{32} plaques to be similar.

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as one might expect due to the similarity of the β energies of P^{32} and the Y^{90} daughter. Short-term and long-term results of exposing sheep to P^{32} plaques are summarized in *Table* IV.[26] The reader is referred to the work of Lushbaugh and associates who have summarized well the early reaction of sheep skin to β-irradiation,[39] as well as reports by Tessmer[56] and Trum and Rust.[59]

Lethality in ruminants due to β-irradiation of the skin is unlikely because the levels of γ-irradiation would be limiting before overwhelming doses of β-irradiation would be received. Extensive "beta burns" of the skin have been seen in animals grazing near a nuclear test site, however, without their manifesting damage from excessive exposure to γ-irradiation.[10] The subject animals were Hereford cattle which were accidentally exposed to radioactive fallout from the first nuclear weapon test. The dose of radiation received by these animals was estimated to be 150 r of penetrating (γ) radiation and 40,000 rads from β and α emitters to the skin. The area of skin affected was principally the back region where dust easily settles.

A number of these exposed animals were shipped to Oak Ridge and later transferred to the University of Tennessee for a study of the effects caused by irradiation.

According to Brown,[10] the most significant and consistent damage associated with these cattle has been lesions on the skin, especially over the back and upper parts of the head and neck. These changes

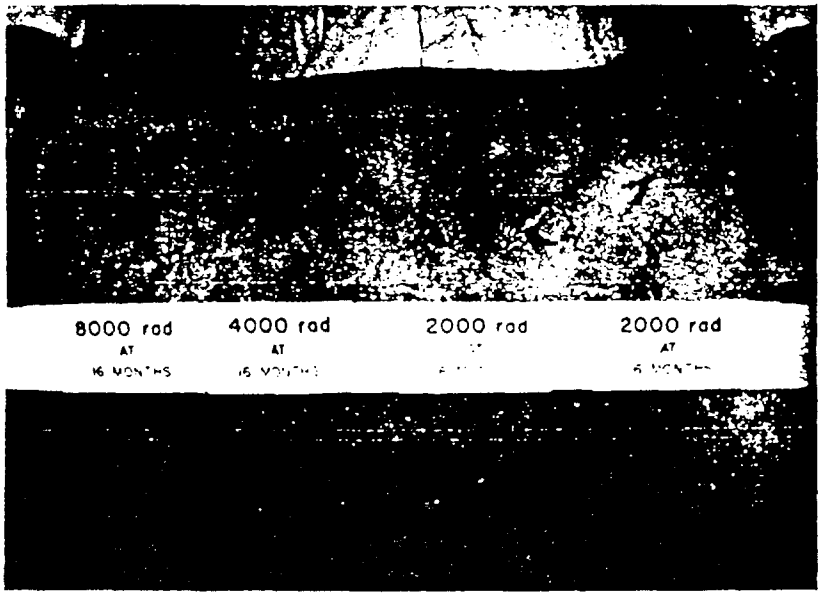

Fig. 2.—Sheep showing wool loss following exposure to 20,000 rads from a P^{32} plaque.

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were presumably caused by β-radiation from radioactive fallout. They consist of relatively prominent, irregularly distributed horny projections or plaques. Three animals which died (one in 1960, two in 1962) had cancerous growths in the area of these skin lesions. One animal succumbed to cancer which began in a "beta burn" lesion on the skin and spread to other tissues.[37] Perhaps the cause of death in this animal might be considered an exception to the common cause of death in cattle. This form of cancer is, however, common in the Hereford breed. Usually it develops about the eyes (cancer eye) but may occur in other areas of the body. There appeared to be no deleterious effect on the reproductive performance over a 14-year period. The overall conception rate was 94 per cent and one remaining cow has given birth to 16 calves in 16 years.

On the basis of the observations made on these cattle and other studies cited above, it is unlikely that β burns of ruminants will detract significantly from their food value or contribute to any substantial increase in the effects of accompanying external whole-body irradiation. Furthermore, the latency of neoplasms of the skin probably exceeds the economic life of most ruminants. The principal hazard from β particles on the backs of ruminants may well be to herdsmen and abattoir employees handling the contaminated animals.

TABLE IV

GROSS PATHOLOGIC CHANGES FOLLOWING BETA IRRADIATION OF SHEEP SKIN[38]

	2000 rads	*4000 rads*	*8000 rads*
Swelling	None	Onset immediate, severe, and diffuse. Duration about four days.	Onset immediate, very severe, diffuse (extending 1 *cm.* beyond the border of the irradiated area). Duration four days.
Redness	None	Obvious but not severe.	Severe initially. Duration about four days.
Sensitivity	Very slight	Onset immediate. Duration about four days.	Onset immediate and very severe. Duration about six days.
Pigmentation	Very slight, but persisted	First noted during second week, persisted.	Very dense black pigmentation in the irradiated area. First noted during second post-radiation week, persisted.
Wool changes	No cessation of wool growth. No wool loss.	Slight cessation of wool growth during first six weeks followed by normal growth. No wool loss.	Wool loss occurred during second and third post-radiation week, variable in extent and completeness. No regrowth until after the fourth month. New wool fibers did not attain the full length of normal wool fibers.

EFFECTS DUE TO BONE-SEEKING RADIONUCLIDES

In the long term, Sr^{90} is the nuclide of principal concern when discussing contamination due to bone-seeking fission products in a fallout field.[41] This obtains because it is readily absorbed from the

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gastrointestinal tract (5–15 per cent in adults and up to 70 per cent in the young), is concentrated readily in bone (~99 per cent), has a slow turnover in bone (>5 years for 50 per cent) and a 28-year physical half-life. Barium 140 and Sr^{89} are also bone-seeking isotopes, but the hazard is not as great since the physical half-lives are only two weeks and 51 days, respectively. (There could, however, be circumstances when shorter-lived nuclides may assume a position of importance because of their [or their precursors'] greater fission yield.)

Only limited studies have been performed on the effects of bone-seeking radionuclides in ruminants.[10, 12, 23, 34, 51, 55] In a study at Oak Ridge[10] two groups of sheep, one administered Sr^{90} intravenously and the other Ra^{226}, have been observed since 1954. The original experiment consisted of 16 animals dosed with Sr^{90}, 9 animals dosed with Ra^{226}, and 6 controls. (Ra^{226} was utilized in these studies because considerable data is available on its toxicity in man.[1]) Currently, 5 animals are surviving, including 1 control. Some pertinent data on these animals are summarized in *Table* V. Early deaths were

TABLE V

SUMMARY OF DATA ON SHEEP INTRAVENOUSLY ADMINISTERED EITHER Sr^{90} OR Ra^{226} IN 1954 AT UT-AEC AGRICULTURE RESEARCH LABORATORY[10]

Treatment group	*Number of animals in group*	*Number and type of tumors at necropsy*	*Remarks*
Sr^{90}			
0.11 μCi/kg	4	1 osteogenic sarcoma at 102 months post-injection	
5.6 μCi/kg	4	1 osteogenic sarcoma suspected in surviving animal	
55.5 μCi/kg	4	1 rhabdomyosarcoma at 55 months post-injection 1 osteogenic sarcoma at 93 months post-injection	
278 μCi/kg	4	none	acute radiation syndrome—average survival 25 days
Ra^{226}			
0.5 μCi/kg	3	none	
5.0 μCi/kg	3	1 osteogenic sarcoma at 33 months post-injection	
25 μCi/kg	3	none	blood dyscrasia with average survival of 5 months
Controls	6	none	

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associated with parasitism, infection, cardiac failure, traumatic pericarditis, and tumors.[10] The skeletal burden of Sr^{90} at death was about 5 per cent of the intravenously administered dose. On the basis of these data, the LD_{50} dose of Sr^{90} administered intravenously would be about 0.3 mCi/kg in sheep.[10] A somewhat higher figure (1.3 mCi/kg) was reported[55] for the goat using Sr^{89}.

Relative to strontium in milk, about 1–2 per cent of an orally administered dose will be secreted in the milk,[13, 24] while 10–27 per cent of an intravenous dose may be secreted in the milk in 5–8 days.[16, 23]

We estimate that if enough Sr^{90} is given to a pregnant cow or sheep in doses large enough to seriously injure the fetus, the dam will also be seriously injured or will succumb. Furthermore, since the economic lifespan of most farm animals is relatively short, it may be tentatively concluded that if an animal survives the acute phase, any long-term effects can probably be ignored.

WHOLE BODY IRRADIATION

The passage of a radioactive cloud or the accumulation of early or local fallout containing a large assortment of γ-emitters results in an exposure of the whole body to penetrating radiation from both the external and internal contamination. Our present state of knowledge indicates that the whole-body dose from γ-emitting radionuclides will be the limiting exposure from the standpoint of survival.

Gamma-emitting radionuclides which are readily absorbed from the gastrointestinal tract and distributed throughout the body may contribute significantly to the whole-body radiation dose. Of these radionuclides, Cs^{137} is the dominant one because it is readily absorbed from the gastrointestinal tract, has a relatively long biological half-life, and a 30-year half-life. Since it is metabolized in a manner resembling that for potassium, it, too, is distributed throughout the body.

TABLE VI

RELATIVE TISSUE CONCENTRATIONS OF RADIOCESIUM FOLLOWING DAILY ORAL ADMINISTRATION TO SHEEP AND GOATS

(20–30 days feeding)

	Cesium concentrations (% daily dose/kg tissue)	
	Sheep[43]	Goat[60]
Muscle	8	20
Kidney	10	36
Liver	6	19
Heart	8	—
Brain	—	5
Ovary	—	13
Testis	9	—
Blood plasma	0.5	1
Femur	1	—

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Ruminants absorb from 50 to 100 per cent of the Cs^{137} ingested and excrete relatively more in feces than in urine, although the fecal/urinary excretion ratio is higher in non-ruminants.[31, 33, 15, 14, 44, 43, 60]

The rate of loss of Cs^{137} from the body can be described mathematically by a series of exponential functions. Hood and Comar[31] observed that 75 per cent of an intravenously administered dose was excreted in the first month after administration. In sheep more than 50 per cent of a single administered dose is excreted within 10 days after administration.[43]

In *Table* VI are shown the relative tissue concentrations of radiocesium following daily oral administration to sheep and goats. Unpublished work in our laboratory with sheep has shown that body burdens 10–20 times the daily intake are reached after about three months of daily Cs^{137} feeding. Relative Cs^{137} concentration in the muscle of these latter animals is probably at least a factor of 2 higher than that observed in the sheep fed Cs^{137} for 20 days.

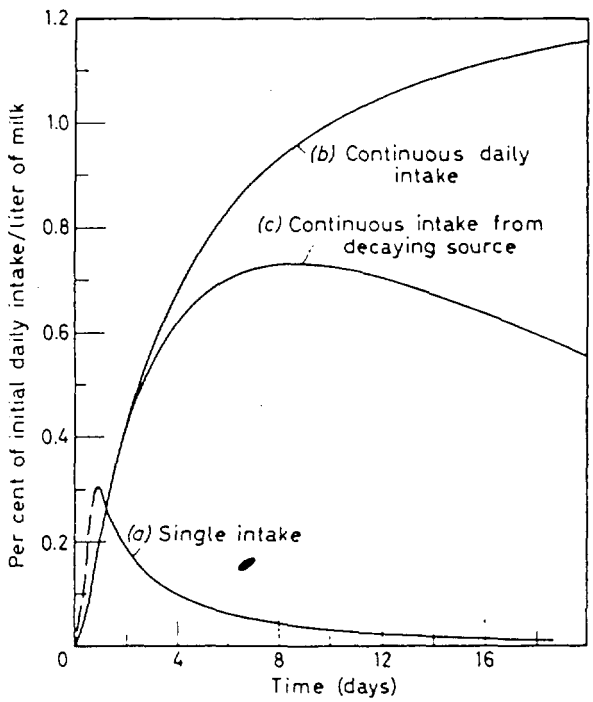

Fig. 3.—Change with time in percentage of initial daily intake of cesium-137 in milk following (*a*) a single oral dose of 1 μCi composite curve derived from data of Ilin and Moskalev[33] and Sansom,[49] (*b*) continuous intake at a constant rate equivalent to 1 μCi daily,[49] (*c*) continuous intake from a source decaying with a half-time of 14 days, the intake on the first day being 1 μCi, derived from curve *b*.

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Extrapolation of data from single dose studies to continuous daily intake indicates that the percentage of the daily dose found in the milk each day is 6–25 per cent and 6–11 per cent in the goat and cow, respectively.[31, 33, 15, 14]

In *Figure 3* are shown the changes in Cs^{137} concentration in milk with time following various exposure regimen.

RADIOIODINE AND THE THYROID GLAND

Radioiodine is considered one of the most biologically significant radionuclides because of: (1) its abundance in early fallout and in the gaseous effluent of certain nuclear facilities; (2) its high inventory in reactors; and (3) because it is so readily absorbed and concentrated in the thyroid gland and in the milk of ruminants. The thyroid uptake of radioiodine is dependent on the level of stable iodine and other constituents in the diet, as well as upon the age of the animal. Reported peak thyroid uptakes in ruminants on the second day following a single oral administration vary from 5 to more than 50 per cent.[8, 54, 18, 17, 21, 25, 7, 6]

The most practical case to consider when dealing with radioiodine is the situation in which animals ingest iodine from a decaying source as they would following a single contamination event. Several experimental studies have been performed in dairy cows in which a single contamination event was simulated.[21, 9, 36, 28] An idealized presentation of the results of such an experiment is shown in *Figure 4*. In

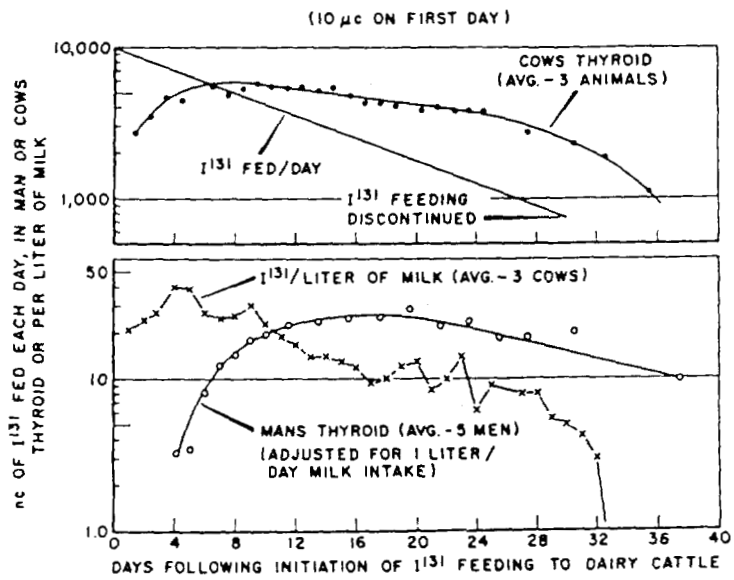

Fig. 4.—I^{131} in milk and in thyroid of cattle and man in a simulated contamination event study (feed pellets fed morning and evening were all spiked with 5 μCi/day on day one).

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this experiment, cows and sheep were fed, morning and evening, one pellet that had been spiked with 5 μCi each on day one. The approximate thyroid uptake curve for man drinking milk from these is also included. If cows were eating contaminated vegetation, the uptake values would probably be about 70 per cent or less of those shown because the effective half-life of fallout radioiodine on vegetation is closer to 5 days[40] than the 8-day half-life provided by physical decay alone in the study illustrated in *Figure 4*.

The relative concentrations of I^{131} at apparent equilibrium in various tissues, excretions, and secretions of cattle are shown in *Table* VII. Sheep usually show higher concentrations than cattle.[8, 7]

TABLE VII

CONCENTRATIONS OF I^{131} FOLLOWING DAILY ORAL ADMINISTRATION TO COWS (expressed as per cent of daily dose/g tissue, excretion or secretion $\times 10^4$)

Organ, tissue, secretion, or excretion	*% of dose/g* $\times 10^4$
Blood	1.7
Muscle	0.2
Spleen, pancreas	0.8
Kidney, liver	1.4
Ovary, salivary glands	1.0
Feces, milk	5.0
Thyroid	32,000

A cow may secrete in its milk about 0.5–1 per cent of the daily administered I^{131} dose per liter of milk.[25, 62, 37] Unlike the monogastric animals, considerable quantities of I^{131} are excreted via the feces.[54, 7]

A thyroid dose of several thousand rads appears to be necessary before any thyroid damage can be readily observed. Doses in excess of 50,000 rads appear to be required for ablation in sheep, and more than 100,000 rads are required in cattle. The effects of I^{131} in animals have been recently reviewed and are only summarized here.[19] The most spectacular effect is in the young animals which will fail to grow if the thyroid has been destroyed. Adult animals may appear fairly normal following thyroid ablation; however, lethargy, constipation, flatulence, and a dry skin develop. Such animals, however, may continue to conceive and reproduce, but they may encounter difficulties at parturition. The fetal thyroid is quite subject to damage since it concentrates up to three times as much as the ewe's and six times as much as the cow's.[2, 27] If a thyroid ablative dose is received by the fetus, the animal will not survive beyond the first week of life unless therapy is initiated.

If, in a pasture contamination event such as that described above, the initial concentration is 1 μCi of I^{131} per gram of dry vegetation eaten (20 per cent of this on succulent pasturage), the infinity thyroid dose will exceed 100,000 rads. Animals grazing such a pasture for 30

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days will show some evidence of a total-body irradiation syndrome and will probably have ablated thyroids.

The contributions of the short-lived isotopes of iodine (I^{132}, I^{133}, I^{134}, and I^{135}) to the dose of the ruminant in close-in fallout may approximate that due to I^{131} (with the tellurium precursors being the important sources of radioiodine, especially in the case of Te^{132}-I^{132}). The dose received by persons drinking milk, however, will be relatively insignificant, especially since a delay of a day or more between milking and consumption is usual[52, 11] and only small amounts of tellurium are secreted in milk.

INHALATION HAZARD

Animals exposed to lethal doses of external γ-irradiation from close-in fallout that originated from surface and underground shots had only insignificant amounts of fission products in their lungs.[48] Measurements made on animals exposed in the Marshall Islands and on indigenous animals at the Nevada Test Site showed very little contamination in the respiratory system. In addition to these field observations, it was estimated that a factor of 10^6 would have to be applied to the inhaled dose of radiation to place it in the same order of magnitude as that resulting from external γ-irradiation in a fallout field.[48] It would appear that in most cases the hazard of inhaled radioactive materials can be ignored for ruminants.

COMBINED EFFECT

In order to evaluate the acute effects from a combined dose of the important radionuclides, it has been assumed that the effects are additive and that the whole body dose is a sum of the doses for each individual radionuclide. The estimate of this dose is based upon the concentration of Sr^{90} in the blood and bone marrow, radioiodine in the blood, Cs^{137} in the muscle, and Ce^{144} in the gastrointestinal tract. Estimates of the whole-body dose are given in *Table* VIII. The lethal and damaging oral doses for adults and fetuses are shown in *Tables* IX and X, respectively.

TABLE VIII

WHOLE-BODY DOSE TO A SHEEP OR COW DURING THE FIRST WEEK AFTER A SINGLE INGESTION OF Sr^{90}, I^{131}, Cs^{137}

Radionuclide	*Dose* (rads/mCi ingested/kg body weight)
Sr^{90}	10 (400 for bone and 200 for bone marrow)
I^{131}	40
Cs^{137}	100

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TABLE IX

ESTIMATED ORAL DOSE TO ADULT SHEEP OF I^{131}, Sr^{90}, Cs^{137}, AND Ce^{144} THAT WOULD CAUSE SERIOUS INJURY OR DEATH

Radionuclide	*Oral Dose (mCi/kg body wt)* Lethal ($LD_{50/30}$)	Causing serious injury
I^{131}	15	0.2
Sr^{90}	10	1
Cs^{137}	5	0.5
Ce^{144}	8	4

TABLE X

ESTIMATED ORAL DOSE TO ADULT SHEEP OF I^{131}, Sr^{90}, Cs^{137}, AND Ce^{144} THAT MAY RESULT IN FETAL INJURY OR DEATH

Radionuclide	*Oral Dose (mCi/kg body wt)* Daily administration	Single administration
I^{131}	0.002	0.1*
Sr^{90}	0.015	†
Cs^{137}	0.020	0.2
Ce^{144}	0.5	4

* If administered in latter stages of pregnancy.
† Death of fetus is unlikely at doses that will not kill the dam.

CONTAMINATED RUMINANTS AS A SOURCE OF FOOD FOR MAN

In evaluating the effects of fallout or nuclear accidents or controlling them, it is the human population that must receive priority. One of the major routes of contamination for man, and particularly children, is the consumption of fresh milk. If acceptable limits are set for milk for man, the animal will be well protected. A comparative value for I^{131} will illustrate this point. A cow would have to ingest 70,000 times as much I^{131} to cause economic damage (~1.5 mCi/day) as would give milk-drinking man a permissible level of the nuclide in the milk (100 pCi/l in milk). Similar factors for Sr^{90} and Cs^{137} would be about 10,000 and 1,000; therefore, we assume there is no danger to grazing stock as long as the limits applied to the human population are met.

A summary of the fraction of orally administered doses of the four radionuclides that appear in the milk are shown in *Table* XI.

TABLE XI

FRACTION OF ORALLY ADMINISTERED DOSE OF Sr^{90}, I^{131}, Cs^{137}, AND Ce^{144} SECRETED IN MILK OF DAIRY COWS

Radionuclide	*Per cent of oral dose secreted in milk*	*Reference*
Sr^{90}	0.08-2	12,23
I^{131}	5-10	9,21,25,37
Cs^{137}	~10	14
Ce^{144}	<0.01	22

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It is highly unlikely that the meat from a contaminated ruminant surviving the acute phase will contain enough radioactivity to cause any acute deleterious effects upon the consumer.[48]

The methods applied in cooking will also have some effect and result in some loss of radionuclides. Bell and coworkers[5, 45] found that there was some leaching of Sr^{89} from bone into the contiguous meat in a roast during the cooking process, but it was of little significance. (More than 99 per cent of the Sr in an animal is in the bone.) With cesium these workers found that an oven-roasted loin retained about 80 per cent of its radioactivity, top round steak surface-braised with a small amount of water retained 57 per cent, and bottom round stewed with much water retained less than 50 per cent.

PROPHYLACTIC AND CONTROL MEASURES

In the event of large-scale contamination, a number of procedures can be initiated that will reduce the hazard both to ruminants and to man. Utilizing uncontaminated stored hay and grain can, of course, essentially eliminate the contamination problem.[35] There is also some work indicating fertilization of pastures will reduce the I^{131} transferred to milk.[53] Early hosing down of the backs of animals that have been exposed to close-in fallout will reduce significantly the possibility of "beta burns" on the skin.[48]

Iodine concentration can be reduced in a number of ways and they have been thoroughly reviewed by Lengemann[38] recently. We have found that increasing stable iodine content of the diet from 5 mg to 2 g/day reduced milk levels of I^{131} by 50 per cent and thyroid burdens more than 90 per cent.[9] The thyroidal uptake of adult volunteers drinking this milk was reduced by 50–80 per cent.[61]

A process for removing radionuclides from milk was developed to the pilot-plant stage at the Agricultural Research Center in Beltsville, Maryland under the cooperative sponsorship of the U. S. Department of Agriculture, the U. S. Public Health Service, and the U. S. Atomic Energy Commission. This adaptation of a continuous ion exchange apparatus has been under commercial scale testing by the Producers Creamery Company in Lebanon, Missouri. It is planned that about 12,500 lb of milk are to be processed each hour. The basic steps in the process involve acidifying to *p*H 5.2, passage through a cation resin bed where >95 per cent of the Sr and Cs is removed, thence to an anion resin which removes the iodine (more than 90 per cent) and hydrochloric acid.[29] The results of the commercial evaluation of the removal of radionuclides from milk, however, are not yet completed.[47]

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