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LAWRENCE LIVERMORE LABORATORY
University of California/Livermore, California

BIO-MEDICAL DIVISION

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FROM EXPOSURE TO TRITIATED WATER VAPOR

L. R. Ansbaugh, J. J. Koranda, W. L. Robison, and J. R. Martin

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THE DOSE TO MAN VIA FOOD-CHAIN TRANSFER RESULTING
FROM EXPOSURE TO TRITIATED WATER VAPOR*

L. R. Anspaugh, J. J. Koranda, W. L. Robison, and J. R. Martin

Bio-Medical Division, Lawrence Livermore Laboratory
University of California, Livermore California 94550

INTRODUCTION

Efforts to predict the radiation dose to man as a result of food-chain exposure to tritiated water vapor have been severely handicapped by lack of knowledge concerning the behavior of tritium released to ecosystems, and by the lack of predictive models appropriate for tritium. Attempts to adapt models developed for ^{131}I and radionuclides contained in particulates have been unsuccessful (1).

Predictive failures were evident for Project Rulison, the second experiment in the stimulation of natural gas by nuclear explosives. Results of the Environmental Protection Agency's (EPA) environmental surveillance program (2) and the Lawrence Livermore Laboratory's (LLL) radioecology studies clearly indicate that preflaring estimates of dose resulting from exposure to tritiated water vapor were excessively conservative. Doses were overpredicted by as much as four orders of magnitude (1) due to a combination of conservative assumptions concerning

the source term and meteorological and ecological transport.

The purpose of this paper is to provide a more accurate, but simple model to predict doses to man resulting from food-chain contamination due to exposure to tritiated water vapor. It incorporates knowledge concerning the environmental behavior of tritiated water which was obtained during radioecology studies at Project Rulison (1) and controlled exposures at Livermore which have been discussed by Koranda and Martin (3). The model is specifically directed to the prediction of dose from the release of tritiated water vapor from a point source, but most of the model is applicable to any tritiated water vapor exposure.

Dose commitments via inhalation plus absorption and via the ingestion of vegetables, milk, and meat are considered. The model may be entered with a variety of input data; average values of the parameters needed to evaluate the model are provided, but other values more appropriate to a particular situation may be substituted readily.

Washout and rainout are not considered by the model. Theoretical calculations by Chamberlain and Eggleton (4) indicate that washout of tritiated water vapor is relatively unimportant beyond distances equal to a few effective stack heights. Data collected during Project Rulison confirm this prediction (1). If significant wet deposition of tritiated water should occur, the model may be used to predict dose commitments if the initial tritiated water concentration and residence time in the soil-plant system are known or assumed. A model developed by Kelly and Booth (5) may also

*This work was performed under the auspices of the U. S. Atomic Energy commission.

be used to predict doses arising from wet deposition, but its use may substantially overestimate the dose if significant loss of tritiated water by evaporation and transpiration occurs.

The model considers only the movement of tritiated water through the aqueous portion of the environment, as not enough information is available to model tritium incorporation and movement through the nonaqueous parts. However, several assumptions are made in the model in an attempt to compensate for the lack of treatment of the nonaqueous portion.

MODEL DEVELOPMENT

Average Concentration of Tritium in Ground-Level Air

For situations where tritiated water vapor is released from a point source at a rate of Q pCi/sec, the simplest means of predicting the average concentration of tritium in ground-level air $\bar{C}$ is the use of the equation (6, 7):

$$\bar{C} = \bar{K}Q$$

where $\bar{K}$ is the weighted mean dispersion constant with units of sec/m^3 , Bryant (7, 8) provides curves to evaluate $\bar{K}$ as functions of distance from the source and height of release. These values were calculated from data on the frequency of occurrence of meteorological conditions at eight sites in England and Wales. Three sites in Scotland were observed to have essentially similar frequencies of occurrence (8), and Barry (6) has presented arguments for the broad applicability of such data to any geographical site within the middle latitudes.

For a ground-level release, Bryant's values of $\bar{K}$ are 2×10^{-6} and $1 \times 10^{-7} \text{ sec}/\text{m}^3$ at distances of 1 and 5 km. Any increase in the height of release or distance from the source will reduce the value of $\bar{K}$, but the above values may be used to make conservative estimates of $\bar{C}$.

The use of $\bar{K}$ is only valid for continuous releases. Methods of calculating ground level concentration following short (a few minutes) or prolonged (6 hours) releases are also given by Bryant (8). If sufficient meteorological data are available, more detailed calculations may be made using methods and data compiled by Turner (9) or Slade (10).

Average Concentration of Tritium in Water of Vegetation

The average concentration of tritium in atmospheric moisture is $\bar{C}$ divided by the absolute humidity H of air in ml/m^3 . An essential feature of this model is that the concentration of tritium in vegetation water C_v cannot be higher than $\bar{C}/H$ as a result of exposure to an air activity of $\bar{C}$. While this is obvious, it should be pointed out that models used in the past have predicted values of C_v far in excess of $\bar{C}/H$.

Experimental results indicate that the concentration of tritium in plant water following exposure to tritiated water vapor is actually somewhat lower than $\bar{C}/H$. Koranda and Martin (3) exposed 8 species of plants to tritiated water vapor for periods of one-half or one hour and found that the ratio of tritium concentration in plant water to that in atmospheric water varied from 0.17 to 0.49. The average value was 0.31; no increase in the ratio was observed when the same species was exposed for one hour as opposed to one-half hour. Studies conducted in conjunction with

Project Rulison where tritiated water vapor was released to a natural environment provided similar results. Twenty-five exposures of grass were made over time periods of 23 to 51 hours. The average ratio observed was 0.38 (11). Several experiments of a reverse nature, i.e., where tritiated water has been supplied to the nutrient solution, have been reported. The movement of tritium between leaf water and atmospheric water is readily demonstrated here as well; the concentration of tritium in leaf water never equals that in the nutrient medium, but attains an equilibrium ratio of 0.45 to 0.65 (12, 13).

The uptake by leaves of tritium contained in atmospheric water is a rapid process. The results of Koranda and Martin (3) indicate that plateau levels are reached by one-half hour. Mason, Hop and Miller (14) indicate that plateau levels are attained within a few minutes.

For the predictive model, it is therefore assumed that

$$C_v^0 = \frac{0.5 \bar{C}}{H}$$

during exposure, and that this level is achieved instantaneously. The notation C_v^0 is used to indicate the value of C_v during exposure.

After exposure ceases, C_v has been observed to decrease with time in a rather complex manner which appears to depend upon factors such as metabolic activity, length of exposure period, and the extent of soil water contamination.

Several controlled exposure experiments have been conducted at Livermore to investigate the loss process. Exposure is achieved using a portable plastic chamber; air is circulated in the chamber through a bubbler containing tritiated water (15). After exposure ceases, the chamber is removed and the plant species are sampled over several days. Samples are immediately frozen on dry ice and subsequently lyophilized. Results observed following a one-half hour exposure of two plant species are shown in Fig 1. Both species exhibit similar behavior showing two component loss curves, but the concentration of tritium in the second compartment differs by nearly an order of magnitude between the two species. The results of a one hour exposure of burclover to tritiated water vapor are given in Figs. 14 and 15 of Koranda and Martin (3, This Symposium). Here, three components are clearly evident with the concentration of tritium in the second compartment 4.5 times larger than it was following a one-half hour exposure. Organically bound tritium is eliminated at the same rate as is the third compartment of tritiated water, although it is not clear whether the third tritiated water compartment is derived from organically bound tritium or tritiated soil water (3).

Table I summarizes data on the loss of tritium from vegetation water following exposure to tritiated water vapor. Data from the experiments illustrated in Fig. 1, in Figs. 14 and 15 of Ref. 3, and from those conducted in conjunction with Project Rulison (1) are included. These represent the only data known to the authors concerning the persistence of tritiated water in vegetation following exposure to water vapor containing tritium. Raney and

Vaadia (12) took excised leaves of sunflower plants grown in media containing tritiated water and exposed them to an atmosphere saturated with ordinary water vapor. They reported that tritiated water activity was lost with a half-time of about 3 hours with all activity lost before 24 hours had elapsed.

The data in Table I indicate that substantial variation in the integral half-time* of THO in vegetation water may be expected due to species variability, length of exposure, and season of the year as it affects metabolic activity. For the predictive model it is assumed that the integral half-time is 1 day; this substantially overestimates the measured values for all but the Project Rulison results which may have been atypical due to redeposition from the surrounding environment which contained higher concentrations of tritiated water. However, it appears likely that the concentration of tritium in the second compartment and therefore the integral half-time will increase as the length of exposure increases.

The level of C_v after exposure ceases is therefore given by

$$C_v = C_v^0 e^{-\lambda_p t'}$$

where λ_p = Disappearance rate of tritium in vegetation water, day⁻¹
 = 0.693/integral half-time

$$t' = t - T$$

t = Time since beginning of exposure, day

T = Time of exposure, day

*Defined as the half-time of a single exponential function that has the same integral as the sum of the integrals of the observed components.

Concentration of Tritium in Milk Resulting from Forage Contamination

The rate of change of the tritium concentration in milk C_m is given by

$$\frac{d C_m}{dt} = k W C_v - \lambda_m C_m$$

where k = Fraction of the cow's tritiated water body burden per liter of milk, ℓ^{-1} (k is the reciprocal of the volume of the cow's body water pool).

W = Daily volume of vegetation water consumed by a dairy cow, ℓ /day.

λ_m = Rate of disappearance of tritiated water from the cow, day⁻¹.

During exposure C_v is equal to C_v^0 . If exposure is continuous the level of tritiated water in milk at equilibrium, C_m^e , is

$$C_m^e = \frac{k W C_v^0}{\lambda_m}$$

If the exposure is discrete, C_m during exposure is

$$C_m = \frac{k W C_v^0}{\lambda_m} (1 - e^{-\lambda_m t})$$

and after exposure ceases at time T , C_m is given by

$$C_m = k W C_v^0 \left[\frac{e^{-\lambda_m t'}}{\lambda_m - \lambda_p} + \left(\frac{1}{\lambda_m} - \frac{e^{-\lambda_m T}}{\lambda_m} - \frac{1}{\lambda_m - \lambda_p} \right) e^{-\lambda_m t'} \right]$$

Concentration of Tritium in Meat Resulting from Forage Contamination

As the concentration of tritium is equal throughout the cow's body water pool (16), the equations used for the concentration of tritium in milk may also be used for meat with appropriate changes in the parameters k , W , and λ_m .

Concentration of Tritium in Milk and Meat Resulting from Bovine Inhalation and Skin Absorption

Bovine inhalation and skin absorption are additional pathways for the introduction of tritiated water into milk and meat. These pathways are not as significant as the ingestion of contaminated fresh forage. However, if cows are on stored, dry feed, they may be the only significant source of tritium in milk and meat.

During exposure the activity of tritium in milk or meat is

$$C_m = \frac{2 k B \bar{C}}{\lambda_m} (1 - e^{-\lambda_m t})$$

where 2 is the approximate skin absorption factor for cows (derived from data in references 17 and 18) and B is the bovine breathing rate in m^3/day .

The activity in milk or meat after exposure ceases is given by

$$C_m = \frac{2 k B \bar{C}}{\lambda_m} (1 - e^{-\lambda_m T}) e^{-\lambda_m t'}$$

Concentration of Tritium in Human Body Water

Inhalation and Submersion. The concentration, C_h , of tritium in human body water from inhalation and submersion during exposure is

$$C_h = \frac{2 B \bar{C}}{\lambda_e M} (1 - e^{-\lambda_e t}),$$

where 2 is the skin absorption factor for both adults and infants (19, 20), λ_e is the rate of elimination of tritium from human body water in day^{-1} , and M is the mass of the body water in grams. If exposure is continuous, the equilibrium value is

$$C_h^e = \frac{2 B \bar{C}}{\lambda_e M}.$$

For acute exposure, the level of C_h after exposure ceases is

$$C_h = \frac{2 B \bar{C}}{\lambda_e M} (1 - e^{-\lambda_e T}) e^{-\lambda_e t'}$$

Vegetables. The value of C_h from the consumption of vegetables during the period of exposure is given by

$$C_h = \frac{L_v C_v^0}{\lambda_e M} (1 - e^{-\lambda_e t}),$$

where L_v is the daily consumption of vegetables in g/day . The equilibrium level for continuous exposure is

$$C_h^e = \frac{L_v C_v^0}{\lambda_e M}.$$

For acute exposure, the level of C_h after exposure ceases is

$$C_h = \frac{L_v C_v^0}{M} \left[\frac{e^{-\lambda_p t'}}{\lambda_e - \lambda_p} + \left(\frac{1}{\lambda_e} - \frac{e^{-\lambda_e T}}{\lambda_e} - \frac{1}{\lambda_e - \lambda_p} \right) e^{-\lambda_e t'} \right]$$

Milk or Meat via Contaminated Forage. The concentration in human body water from consuming milk or meat during exposure is given by

$$C_h = \frac{k L_m W C_v^0}{\lambda_m M} \left[\frac{1}{\lambda_e} + \frac{e^{-\lambda_m t}}{\lambda_m - \lambda_e} - \frac{\lambda_m e^{-\lambda_e t}}{\lambda_e (\lambda_m - \lambda_e)} \right]$$

where L_m is the daily consumption of milk or meat in ml(g)/day. The equilibrium value for continuous exposure is

$$C_h^e = \frac{k L_m W C_v^0}{\lambda_m \lambda_e M}$$

and for acute exposure, C_h , after exposure ceases is given by

$$C_h = \frac{k L_m W C_v^0}{\lambda_m M} \left[\frac{\lambda_m e^{-\lambda_p t'}}{(\lambda_m - \lambda_p) (\lambda_e - \lambda_p)} + \frac{1}{\lambda_e - \lambda_m} \left(1 - e^{-\lambda_m T} - \frac{\lambda_m}{\lambda_m - \lambda_p} \right) e^{-\lambda_m t'} + \left(\frac{1}{\lambda_e} - \frac{\lambda_m e^{-\lambda_e T}}{\lambda_e (\lambda_m - \lambda_e)} + \frac{\lambda_p (\lambda_e - \lambda_p) - \lambda_m (\lambda_e - \lambda_m)}{(\lambda_m - \lambda_p) (\lambda_e - \lambda_m) (\lambda_e - \lambda_p)} \right) e^{-\lambda_e t'} \right]$$

Milk or Meat via Bovine Inhalation and Skin Absorption. The concentration of tritium in human body water from consuming milk or meat contaminated by these two combined pathways is given by the following equation for the time period when exposure is continuing

$$C_h = \frac{2 k B \bar{C} L_m}{\lambda_m M} \left[\frac{1}{\lambda_e} + \frac{e^{-\lambda_m t}}{\lambda_m - \lambda_e} - \frac{\lambda_m e^{-\lambda_e t}}{\lambda_e (\lambda_m - \lambda_e)} \right]$$

The equilibrium value for continuous exposure is

$$C_h^e = \frac{2 k B \bar{C} L_m}{\lambda_m \lambda_e M}$$

and for an acute exposure, C_h , after exposure ceases is given by

$$C_h = \frac{2 k B \bar{C} L_m}{\lambda_m (\lambda_m - \lambda_e) M} \left[(e^{-\lambda_m T} - 1) e^{-\lambda_m t'} + \frac{\lambda_m}{\lambda_e} (1 - e^{-\lambda_e T}) e^{-\lambda_e t'} \right]$$

Dose Rate from Continuous Exposure

If C_h^e for any pathway is in units of pCi/ml (or pCi/g), the dose rate, DR, in rem/year is simply

$$DR = 1.9 \times 10^{-2} E C_h^e$$

where 1.9×10^{-2} is a dose conversion constant with units of rem-g-dis/(pCi-MeV-yr). E is the average decay energy in MeV/dis, and the assumption is made that the relative biological effectiveness of the ^3H beta is 1.0 as recently recommended by the International Commission on Radiological Protection (21).

Infinite Dose from Acute Exposure

For acute exposures of duration T days, the infinite dose, D, in rems resulting from the exposure via each pathway is given by the following where A is 5.1×10^{-5} rem-g-dis/(pCi-MeV-day)

$$D = AE \int_0^T C_h(t) dt + AE \int_0^\infty C_h(t') dt'$$

The result of this calculation for each pathway is given below

$$\text{Inhalation: } D = \frac{2AEB\bar{C}}{\lambda_e M} T$$

$$\text{Vegetation: } D = \frac{AEL_v C_v^0}{\lambda_e M} \left(T + \frac{1}{\lambda_p} \right)$$

Milk or Meat

$$\text{via Forage: } D = \frac{AEkL_m W C_v^0}{\lambda_m \lambda_e M} \left(T + \frac{1}{\lambda_p} \right)$$

Milk or Meat

$$\text{via Inhalation: } D = \frac{2kAEB\bar{C}L_m}{\lambda_m \lambda_e M} T$$

The above dose equations include the dose commitment accumulated both during the exposure and after exposure ceases.

RESULTS OF THE PREDICTIVE MODEL

Typical values of the parameters necessary to use the model are listed in Table 2. Many of the values are well established and were taken directly from published compilations. However, only a few measurements of k and λ_m are available and very few have been reported for beef cattle (16, 22, 23, 24); substantial variations are also to be expected due to environmental

conditions (25). Therefore, to achieve results calculated upon a larger data base, an alternate approach was used. This utilized Comar's compilation of typical data for domestic animals which includes values for body weight, body water, and water intake (26). k is simply the reciprocal of the cow's total body water volume and λ_m is the daily water intake divided by the total body water volume.

As an illustration of the model predictions, calculations were made for a hypothetical situation where exposure to an air concentration of 10^3 pCi/m³ of THO vapor is continuous. A value of H of 5 ml/m³ was chosen to make the calculation. Equilibrium concentrations of tritium in the infant and adult are given in Table 3 as are the predicted yearly doses. The most significant pathways are shown to be inhalation plus absorption and vegetables for the adult, and milk and vegetables for the infant. Results of a more complex, non-equilibrium calculation are shown in Figs. 2-4. Calculations were again made with $\bar{C} = 10^3$ pCi/m³ and H = 5 ml/m³, but the exposure time was taken as 30 days. The predicted levels of tritium in the pertinent environmental media are shown in Fig. 2, both during the exposure and 90 days after the exposure ceases. The details of the contributions of each environmental pathway are shown in Fig. 3 for the infant and in Fig. 4 for the adult.

It is perhaps more interesting to compare the infinite dose predictions for acute exposure to those obtained using other available models. A typical model is that of Ng, et al. (31) which in conjunction with a deposition velocity of 1 cm/sec was used to predict the potential dose commitments arising from Project Rulison (32). The results of this comparison are given in Table 4 for a hypothetical one day exposure to air containing 10^3 pCi/m³ of tritium.

DISCUSSION

This model considers tritium moving through an ecosystem only in the form of THO and neglects the organic binding of tritium. However, all food consumed is assumed to be 100% water, and in the dose calculations it is further assumed that tritium is only distributed throughout body water. Under conditions of continuous exposure the specific activity in the organic portion of food stuffs would eventually approximate that of water (33, 34); the assumption that food stuffs are 100% water would then be realistic. The intake of tritium by cattle would be underestimated as only the water of forage is considered. All doses would be somewhat overestimated, however, as all tritium intake is considered to be distributed only in body water rather than the total hydrogen pool. Under acute exposure conditions the assumption that food stuffs are 100% water overestimates the dose as the specific activity of tritium in the organic compartment will not approach that in water. However, the tritium that is organically bound will leave the ecosystem at a slower rate (3, 16, 35, 36). These inaccuracies in the model are therefore compensating, but to an uncertain extent. There presently is not adequate knowledge to construct a model which would include the effects of organic binding throughout a natural, complex ecosystem.

The greatest uncertainty in predicting dose commitments for acute exposures appears to be the evaluation of the parameter λ_p . As already discussed, this parameter appears to vary widely due to biological diversity, metabolic activity, and length of exposure. The value used is probably conservative for very short exposures, but may underestimate the dose for relatively long exposures during periods of low metabolic activity.

Kirchmann, *et al.* (35), for example, observed half-times of disappearance of THO in vegetation of 1 day in summer but 5 days in winter following the application of THO in a liquid form. However, in this particular experiment only 0.7 to 2.6% of the tritium was still present after 24 hours indicating that the integral half-time is still less than one day. The nature of the decay curve following prolonged vapor exposure during periods of low metabolic activity is, however, an open question. Fortunately, the dose commitment does not vary as a function of $1/\lambda_p$ but as $(T + 1/\lambda_p)$, so as exposures become long and the true value of λ_p becomes questionable, the dose commitments calculated using the model would still be reasonably valid if $T > 1/\lambda_p$.

It appears that the model can be used without modification in rainout situations if the rainout is light, a few mm or less. Available data indicate that a one-day integral half-time in such situations is still conservative (1, 3, 35). If the rainout is sufficient to achieve a significant contamination of subsurface soil water, however, much longer half-times are to be expected. A discussion of such situations is beyond the scope of this paper; data pertinent to such situations may be found in Refs. 3, 5, 37-39.

Many of the parameters in Table 2 apply only to hypothetical receptors who are consuming only food which is continually being harvested from the exposed area. In most real situations this is an unrealistic assumption, and it is extremely unlikely that a substantial fraction of the predicted dose commitments via the vegetable, meat and milk pathways would ever be delivered following an acute exposure. It has also been assumed that all vegetable water achieves a tritium activity equal to one-half that of atmospheric moisture. Although data are lacking this is probably true only for leafy vegetables.

Although this model contains several conservative assumptions, the dose commitments predicted by using it are orders of magnitude lower than those predicted using other models. This is primarily because other models have used a deposition velocity approach and/or half-times in vegetation water of 14 days (31) or even 85 days (20). These conservative assumptions were made before adequate data were available indicating the very short half-life of tritium in vegetation. It is now obvious that the use of the deposition velocity approach for the "dry" deposition of THO vapor is inappropriate unless it is considered as a rate constant in competition with a high rate of loss. The greatly lower dose estimates predicted by the use of this model have been verified as conservative on the basis of environmental samples collected by EPA and LLL during the production testing of the Project Rulison well which released tritiated water vapor to the surrounding environment (1).

In all calculations we have neglected the radiological half-life of tritium. This does not introduce a significant error because it is extremely long (12 years) compared to the residence time in the ecological systems considered. This short ecological residence time also indicates that the infinite doses calculated for an acute exposure situation are actually delivered during a relatively short time period, certainly less than a year.

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Table 1. Loss parameters observed for the decrease of tritium concentration in vegetation water. The parameters were calculated assuming the loss curves may be represented by a sum of exponentials:

$$\frac{A}{A_0} = \frac{A_1}{A_0} \exp(-0.693 t/T_{1/2}^1) + \frac{A_2}{A_0} \exp(-0.693 t/T_{1/2}^2) + \cdots + \frac{A_n}{A_0} \exp(-0.693 t/T_{1/2}^n) .$$

The integral half-time is given by

$$T_{1/2}^{int} = \frac{A_1}{A_0} T_{1/2}^1 + \frac{A_2}{A_0} T_{1/2}^2 + \cdots + \frac{A_n}{A_0} T_{1/2}^n$$

and represents a single exponential compartment that has an integral equal to the sum of the integrals of each individual component that was measured.

Plant	Exposure Method	Exposure Time (hr)	$\frac{A_1}{A_0}$	$T_{1/2}^1$ (hr)	$\frac{A_2}{A_0}$	$T_{1/2}^2$ (hr)	$\frac{A_3}{A_0}$	$T_{1/2}^3$ (hr)	$T_{1/2}^{int}$ (hr)
Fiddleneck	Chamber	0.5	0.997	0.7	0.003	24			0.8
Burclover	Chamber	0.5	0.98	0.8	0.02	25			1.3
Burclover	Chamber	1.0	0.908	0.9	0.091	17	0.002	270	2.9
Grass ^a	Project Rulison	45.	0.25	0.4	0.75	70			53.

^a Exposure was late in the year when lower metabolic activity would be expected. Grass plugs were brought into the exposure area 45 hours before the THO release was stopped. Redeposition of THO from surrounding grass which was more highly contaminated may have significantly influenced these results.

Table 2. Numerical values of the parameters necessary to evaluate environmental concentrations and doses resulting from the exposure to tritiated water vapor.

<u>Parameter</u>	<u>Symbol</u>	<u>Value</u>	<u>Ref.</u>
Breathing rate			
Adult	B	20 m ³ /day	27
Infant	B	5 m ³ /day	20
Cattle	B	130 m ³ /day	26
Mass of body water			
Adult	M	43,000 ml	27
Infant	M	6,100 ml	a
Elimination rates			
Vegetation	λ	0.7 /day	Text
Cattle, dairy	λ^p	0.21 /day	26
Cattle, beef	λ^m	0.19 /day	26
Adult	λ^m	0.069/day	19
Infant	λ^e_e	0.22 /day	20, 28
Reciprocal of cattle body water volume			
Dairy	k	0.0028/l	26
Beef	k	0.0041/l	26
Cattle water intake via fresh forage			
Dairy	W	38 l/day	b
Beef	W	28 l/day	b
Average ³ H decay energy	E	0.0063 MeV/dis	29
Human food intake ^c			
Milk			
Adult (20-34 yrs)	L	260 g/day	30
Infant (< 1 yr)	L _m	700 g/day	30
Meat, poultry, fish			
Adult (20-34 yrs)	L	270 g/day	30
Infant (< 1 yr)	L _m	50 g/day	30
Vegetables, fruits, potatoes			
Adult (20-34 yrs)	L _v	400 g/day	30
Infant (< 1 yr)	L _v	220 g/day	30

Table 2 (Continued)

^a Assumes a 10 kg body weight with the same ratio of body water to body weight as that of an adult.

^b Assumes that dairy and beef cattle need 55 kg and 40 kg respectively of green forage per day (26), and that fresh forage is 70% water.

^c It is assumed for the purpose of dose calculations that each food category is continuously harvested in the exposed area, and is 100% water.

Table 3. Predicted concentrations of tritium in the body water of man at equilibrium resulting from continuous exposure to air containing 10^3 pCi/m³ of tritium as THO. An absolute humidity of 5 ml/m³ is assumed.

Pathway	³ H in Body Water (pCi/ml)		Dose Rate (mrem/yr)	
	Infant	Adult	Infant	Adult
Inhalation, absorption	7.5	13	0.89	1.6
Vegetables	16.	13	2.0	1.6
Milk, via Forage	26.	4.4	3.2	0.53
Milk, via Bovine Inhalation	1.8	0.30	0.22	0.036
Meat, via Forage	2.3	5.5	0.27	0.66
Meat, via Bovine Inhalation	0.21	0.51	0.025	0.061
Total	54.	37.	6.6	4.5

Table 4. Comparison of predictions for the infinite dose arising from a one day exposure to air containing 10^3 pCi/m³ of tritium as THO. An absolute humidity of 5 ml/m³ is assumed for the present model. The typical model used for comparison is that of Ng, et al. (31) with the deposition velocity of THO vapor taken as 1 cm/sec. The model described in this paper predicts the total dose commitment resulting from both the exposure and postexposure periods. The typical model considers the dose commitment only in the postexposure period.

Pathway	This Model		Typical Model ^a	
	Infant	Adult	Infant	Adult
Inhalation, absorption	2.4 μ rem	4.3 μ rem		
Vegetables	13.	11.		
Milk, via Forage	21.	3.5	8700 μ rem	1300 μ rem
Milk, via Bovine Inhalation	0.58	0.098		
Meat, via Forage	1.8	4.3		
Meat, via Bovine Inhalation	0.067	0.16		
Sum	39.	23.		

^a This model was not designed specifically for tritium, but is a general model developed to predict doses arising from the deposition of radionuclides.

FIGURE LEGENDS

- Fig. 1. Tritium (THO) loss curve for two species following a controlled vapor exposure of 0.5 hour. Results are very similar except the concentration of tritium in the second compartment is nearly an order of magnitude different for the two species.
- Fig. 2. Predicted levels of tritium (as THO) in pertinent environmental media beginning from the start of a 30 day exposure to air containing 10^3 pCi/m³ of tritium as THO vapor. An absolute humidity of 5 ml/m³ is assumed.
- Fig. 3. The predicted contribution from each of six pathways to the total tritium concentration (as THO) in the infant's body water. The hypothetical situation is the same as that of Fig. 2.
- Fig 4. The predicted contribution from each of six pathways to the total tritium concentration (as THO) in the adult's body water. The hypothetical situation is the same as that of Fig. 2.

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