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JAN 25 1993

Pre-Decisional Draft

DETERMINATION OF THE CONTRIBUTION
OF LIVESTOCK WATER INGESTION TO
DOSE FROM THE COW-MILK PATHWAY

Hanford Environmental Dose
Reconstruction Project
Dose Code Recovery Activities
- Calculation 002

T. A. Ikenberry

December 1992

Prepared for the
Technical Steering Panel
and the Centers for Disease Control
Under Contract 200-92-0503 (CDC)/18620 (BNW)

Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

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1.0 INTRODUCTION

As part of the Hanford Environmental Dose Reconstruction (HEDR) Project, a series of calculations has been undertaken to evaluate the absolute and relative contribution of different exposure pathways to thyroid doses that may have been received by individuals living in the vicinity of the Hanford Site. These evaluations include some pathways that were included in the Phase I air-pathway dose evaluations (HEDR staff 1991, page xx), as well as other potential exposure pathways being evaluated for possible inclusion in the future HEDR modeling efforts. This calculation (002) examined the possible doses that may have been received by individuals who drank milk from cows that drank from sources of water (stock tanks and farm ponds) exposed to iodine-131 in the atmosphere during 1945.

Recommendations determined from scoping calculations are provided to the Technical Steering Panel (TSP) of the HEDR Project with the intent of providing a definitive technical basis to help the TSP decide whether specific exposure pathways should or should not be included in the HEDR dose estimation process for individuals.

2.0 TECHNICAL METHODS

Thyroid doses to adults and infants were calculated for the ingestion of milk from cows that had consumed water in stock tanks and farm ponds during 1945. The data on surface deposition are from the same source as those described in Calculation 001 (Ikenberry and Napier 1992, page 4) and for the same grid node (18, 25) in Franklin County Census District 4. However, in this calculation the average daily deposition rate, $\bar{D}$, was used rather than the month-ending surface deposition. The average daily iodine-131 deposition rate for each month was calculated from the time-integrated air concentration using the following equation:

$$\bar{D}_i \text{ (Ci/m}^2\cdot\text{d)} = \frac{X_i \text{ (Ci}\cdot\text{s/m}^3\text{)} * V_d \text{ (m/s)}}{(30 \text{ d/month})} \quad (1)$$

where X_i = the time-integrated air concentration in month i (Ci·s/m³);
varies monthly
value used: see Table 1

V_d = deposition velocity of iodine-131 (Ci/m² ÷ Ci·s/m³)
value used = 0.01 (Snyder et al. 1992, page V_d)

Table 1 shows monthly values of the time-integrated air concentrations and surface-deposition rates for 1945 used in these calculations.

There were three assumptions made to simplify the models used in making estimates of dose from the stock-tank and farm-pond pathways:

- There was continual deposition of radioactive material and continual ingestion of water.
- There were no losses of water or radioactive material from tanks or ponds except for radioactive decay and ingestion of water.
- The water level in the tank/pond remained constant (the tank/pond was replenished as necessary with uncontaminated water).

The area from which deposited iodine-131 can be collected into stock tanks and farm ponds is a function only of the surface area for tanks, while

for ponds it is a function of surface area plus any additional rainwater entering from the surrounding land:

TABLE 1. Monthly Time-Integrated Air Concentrations and Surface-Deposition Rates Used in the Scoping Calculations

Franklin County Census District 4 (Node 18, 25)		
1945	Time-Integrated Air Concentration $C_i \cdot s/m^3$	Surface Deposition Rate $C_i/m^2 \cdot d$
January	1.8×10^{-5}	6.0×10^{-9}
February	1.4×10^{-5}	4.7×10^{-9}
March	2.9×10^{-5}	9.7×10^{-9}
April	1.5×10^{-4}	5.0×10^{-8}
May	6.9×10^{-4}	2.3×10^{-7}
June	2.5×10^{-4}	8.3×10^{-8}
July	5.6×10^{-4}	1.9×10^{-7}
August	5.5×10^{-4}	1.8×10^{-7}
September	2.7×10^{-3}	9.0×10^{-7}
October	1.7×10^{-3}	5.7×10^{-7}
November	1.9×10^{-4}	6.3×10^{-8}
December	9.9×10^{-4}	3.3×10^{-7}

$$A_{\text{tank/pond}} = (\pi r^2) * n_{\text{area}} \quad (2)$$

where r = radius of the tank or pond (m)

n_{area} = a collection area factor to account for drainage from the surrounding land into the farm pond (unitless)
value used: 1 for stock tanks, variable for farm ponds.

The fractional flow rate of water out of the stock tank or farm pond can be calculated using methods described by Whicker and Schultz (1982, volume II, page 11). The outflow is dependent upon the consumption rate and the number of cows consuming water from the tank or pond. Therefore, the equation is

$$f_{\text{tank/pond}} = \frac{IR_{\text{cow}} * n_{\text{cows}}}{V} \quad (3)$$

where IR_{cow} = water ingestion rate of a dairy cow (L/d)
value used = 80 (Comar 1966, page 130)

n_{cows} = number of cows consuming water
values used: 1 - 25 for tanks and ponds

V = volume of water in the tank or pond (L);
tank values: 1900, 3800, 7600 (500, 1000, and 2000 gal)
pond values: calculated from pond depth and area.

The average daily concentration of radioiodine C (Ci/L) in a stock tank or farm pond was calculated as

$$C = \frac{D * A}{V} * \frac{1 - e^{-(\lambda_r + f)30}}{(\lambda_r + f)} \quad (4)$$

where λ_r = radiological decay constant (days⁻¹); value used: 0.086 for iodine-131 (Snyder et al. 1992, page 131) λ_r

Monthly thyroid doses were calculated for infants and adults who consumed milk produced by dairy cows that drank water from the stock tanks and farm ponds. There was assumed to be no holdup time between a cow's consumption of water and an infant's ingestion of milk from that cow. Infant thyroid doses were then calculated using the following equation:

$$\text{Dose}_{\text{Tank, Pond}_i} = C * IR_{\text{cow}} * TF_{\text{milk}} * IR_{\text{infant}} * 30 * DF_{\text{infant}} \quad (5)$$

where TF_{milk} = transfer coefficient for cow's milk (d/L) [Ci/L per Ci/d]
value used: 0.0092 (Snyder et al. 1992, page 131) $TF_{\text{milk_ind}}$

IR_{infant} = milk ingestion rate for an infant (L/d)
value used: 1.0 (Callaway 1992, page 19)

30 = number of days per month, a constant for continual ingestion

DF_{infant} = ingestion dose conversion factor for an infant
(rad [thyroid]/Ci); value used: 1.5×10^7
(Shindle et al. 1992, page 2.18).

The thyroid dose of an adult was calculated in a similar manner, but the appropriate variables were changed to represent adults rather than infants. The infant variables were changed to

IR_{adult} = milk ingestion rate for an adult (L/d)
value used: 0.5 (Callaway 1992, page 19)

DF_{adult} = ingestion dose conversion factor for an adult
(rad [thyroid]/Ci); value used: 1.8×10^6
(Shindle et al. 1992, page 2.18).

3.0 RESULTS/DISCUSSION

Adult and infant thyroid doses were calculated based on consumption of milk produced by cows drinking water from stock tanks and farm ponds in Franklin County Census District 4 during 1945. The results from cows using stock tanks are shown in Figure 1 for adults and Figure 2 for infants, for three sizes of stock tanks (500, 1000, and 2000 gal) and herd sizes ranging from 1 to 25 cows.

As shown by the three curves in these figures, use of larger-size stock tanks results in larger milk consumption doses. There is no limit to the amount of total water consumption from the tanks, because tanks and ponds are assumed to be continuously replenished with water. The depth of the stock tanks is fixed at 0.7 meters (approximately 2 ft deep), so only the tank diameter can increase to increase tank gallonage. Tank collection area increases as the square of the tank radius (πr^2), so larger tanks receive an increasingly large amount of iodine-131 deposition. As a larger number of cows consume the stock tank water, the doses from consuming milk produced by these cows decreases. This is because iodine-131 is consumed from the tank at increasing amounts with more cows and so it is not allowed to build-up. As more and more cows consume iodine-131, it reaches a smaller and smaller equilibrium level, that amount of iodine-131 in the tank where input from deposition equals the loss from water consumption and radioactive decay. For an equivalent number of cows, the dose received reaches a constant ratio between the three curves (sizes of stock tanks) based on the surface area of the tanks.

Farm ponds are much like stock tanks, except that neither the depth of the pond nor the overall collection area for iodine-131 entering the pond are fixed. Figure 3 shows the result of increasing the pond depth (and hence the pond volume) for three ponds with 20-, 40-, and 60-m diameters. As expected, increasing the depth decreases the dose received because the increasing volume and constant collection area result in a decrease in the iodine-131 concentration in the water ingested by the cows. Also, note that increasing the pond surface collection area has no effect on the dose received (e.g., the curves for all ponds are identical), because the increase in pond volume

FIGURE 1. Adult Milk Dose from Cows Drinking Water from Stock Tanks in Franklin County Census District 4, 1945

FIGURE 2. Infant Milk Dose from Cows Drinking Water from Stock Tanks in Franklin County Census District 4, 1945

FIGURE 3. The Effect of Farm Pond Depth on Milk Dose from the Water-Cow Ingestion Pathway in Franklin County Census District 4, 1945

is directly proportional to the increase in surface area. The increased surface area and volume essentially cancel one another out, resulting in the same pond-water concentration. The contribution of the water running off of the surrounding land and into the pond (n_{area} term in Equation 3) is unquantifiable for this scoping calculation, since it is highly dependent on the specific pond being examined. For this scoping calculation, additional contribution from run-off was assumed to be insignificant ($n_{\text{area}} = 1$). Increasing the number of cows drinking water from the pond has negligible effect (lowering the dose less than 0.1 rad for a 100-cow herd) because the amount of water consumed by the cattle is negligible compared to the volume of the pond.

Figures 1, 2, and 3 show that the infant thyroid dose from consuming milk from a backyard cow whose water source is a stock tank or farm pond could be above the dose-decision levels established by the TSP. However, this water consumption dose should be put into perspective with other exposure pathways, particularly the type of feed the cow eats, for a truer indication of the contribution of the water ingestion pathway.

Table 2 shows the addition of the water-ingestion pathway to the exposure pathways examined and reported in Scoping Calculation 001 (Ikenberry and Napier 1992) for Franklin County Census District 4. In this table the water ingestion dose to the infant thyroid is 9.4 rad, from ingesting milk from a single backyard cow consuming water from a 500-gal stock tank. For Feeding Regimes 1 and 2, the irrigated-land feeding regimes, water ingestion is not an important pathway. Water ingestion contributes 1.7% and 1.9% of the doses in Feeding Regimes 1 and 2, respectively, about the same as those contributed by alfalfa hay (1.1%, 1.2%), soil ingestion (1.6%, 1.7%), and deposition on stored feed (1.6%, 2.2%).

For the dryland feeding regimes, however, water ingestion is significantly more important. It is the fourth most important exposure pathway in Feeding Regime 3, contributing about 12% of the total feeding-regime dose. Water ingestion is the third most important exposure pathway in Feeding Regime 4, contributing about 19% of the total feeding-regime dose.

TABLE 2. Dose to Infant Thyroids and Percent Contribution for Each of the Components of the Milk Dose Pathway in Franklin County Census District 4^(a) for Four Dairy-Cow Feeding Regimes

PATHWAYS	THYROID DOSE (RAD) AND PERCENT CONTRIBUTION							
	FR 1		FR 2		FR 3		FR 4	
Pasture	470	86%	470	93%	-----		-----	
Silage	41	7.7%	-----		-----		-----	
Alfalfa hay	6	1.1%	6.2	1.2%	39	48%	-----	
Grass hay	-----		-----		-----		6.6	14%
Soil ingestion	8.6	1.6%	8.6	1.7%	14	18%	14	30%
Deposition on stored feed	8.6	1.6%	11	2.2%	17	21%	17	36%
Inhalation	0.9	0.2%	0.9	0.2%	0.9	1.1%	0.9	1.8%
WATER INGESTION	9.4	1.7%	9.4	1.9%	9.4	12%	9.4	19%
Total thyroid dose (rad)	540		500		81		49	

(a) Dose from dairy cow ingestion of grain is not included.

4.0 RECOMMENDATIONS

Scoping calculations were performed to examine the contribution to the cow-milk pathway from cows drinking water from stock tanks and farm ponds in Franklin County Census District 4 during 1945. This location and time period are considered to be the most exposed in the HEDR study. Based on results presented in Section 3.0, the following recommendation is made regarding exposure pathways and calculational methods for the calculation of individual doses for the HEDR Project:

EXPOSURE PATHWAYS

- The livestock water-ingestion pathway should be included in HEDR backyard cow-milk dose calculations. This pathway is estimated to contribute about 9 rad to the infant thyroid dose in 1945. Water ingestion is mainly of concern for dryland feeding regimes, where it was estimated to account for about 12% and 19% of the doses from Feeding Regimes 3 and 4, respectively, during 1945. This pathway could be omitted from irrigated-type feeding regimes, where it accounts for less than 2% of the dose in both Feeding Regimes 1 and 2.

5.0 QUALITY ASSURANCE

Quality assurance was undertaken in accordance with PNL-MA-70, Volume 1, Procedures for Quality Assurance Program, under PNL administrative procedure PAP-70-301, "Hand Calculations, General." Complete documentation of the calculation was prepared by the author, who prepared the calculational spreadsheet and performed the spreadsheet calculations. A thorough review was conducted by Bruce Napier, who is chief scientist for the HEDR Project. Independent technical review was conducted by a technical expert not associated with the HEDR Project. Spreadsheet documentation is on file with the author and available for review.

6.0 REFERENCES

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