STAFF EXHIBIT 22

RAS 14589

6.2.9 Ingestion Rates of Home Produced Food, U_v (kg/y), U_a(kg/y) and U_f (kg/y)

6.2.9.1 Description of Ingestion Rates

The ingestion rates of homegrown produce, U_v (kg/y), and other home produced food, U_a (kg/y), and U_f (kg/y), as defined for Volume 1, represent the consumption rate of specific contaminated food. The dose model uses different constant values of U_v for "leafy" vegetables, "other" vegetables, fruits and grains, different constant values of U_a for beef, poultry, milk and eggs and a constant value of U_f for fish. U_v, U_a and U_f are behavioral parameters. Distributions therefore represent the diet of the average member of the screening group (i.e., residential and light farmers), and the default values are the average values of these distributions.

6.2.9.2 Use of Ingestion Rates in Modeling

Ingestion dose is linearly proportional to U_v, U_a and U_f. Therefore, the higher the values for U U and U the

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U_a = the inge by an in

$PPTF_{asij}$ = the partial pathway transfer factor for animal product type a, radionuclide j as a progeny of radionuclide i, for unit average concentration of parent radionuclide i in soil (pCi y/kg wet-weight food per pCi/g dry-weight soil for a year of residential scenario),

N_a = the number of animal products considered in the diet, and

N_v = the number of food crops considered in the diet.

The mathematical expression to evaluate the PFs for unit average concentration of a parent radionuclide in irrigation water is given in NUREG/CR-5512 (p. 5.52) as:

$$PF_{wij} = \Sigma_{(v=1,Nv)} U_v \, PPTF_{vwij} + \Sigma_{(a=1,Na)} U_a \, PPTF_{awij} \qquad (6.36)$$

where:

PF_{wij} = the agricultural pathway transfer factor for

TEMPLATE = SECY-027

SECY-02

STAFF EXHIBIT 22

6.2.9 Ingestion Rates of Home Produced Food, U_v (kg/y), U_a(kg/y) and U_f (kg/y)

6.2.9.1 Description of Ingestion Rates

The ingestion rates of homegrown produce, U_v (kg/y), and other home produced food, U_a (kg/y), and U_f (kg/y), as defined for Volume 1, represent the consumption rate of specific contaminated food. The dose model uses different constant values of U_v for "leafy" vegetables, "other" vegetables, fruits and grains, different constant values of U_a for beef, poultry, milk and eggs and a constant value of U_f for fish. U_v, U_a and U_f are behavioral parameters. Distributions therefore represent the diet of the average member of the screening group (i.e., residential and light farmers), and the default values are the average values of these distributions.

6.2.9.2 Use of Ingestion Rates in Modeling

Ingestion dose is linearly proportional to U_v, U_a and U_f. Therefore, the higher the values for U_v, U_a and U_f the higher the calculated dose. More specifically, the ingestion rates, U_v and U_a are used in the dose model to calculate the agricultural pathway transfer factors (PF). These factors are then used to calculate the annual dose from ingestion of home produced food. The mathematical expression to evaluate the PFs for unit average concentration of a parent radionuclide in soil is given in NUREG/CR-5512 (p. 5.51) as:

$$PF_{sij} = \Sigma_{(v=1,Nv)}\, U_v\, PPTF_{vsij} + \Sigma_{(a=1,Na)}\, U_a\, PPTF_{asij} \qquad (6.35)$$

where:

PF_{sij} = the agricultural pathway transfer factors for radionuclide j as a progeny of radionuclide i per unit initial concentration of parent radionuclide in soil (pCi ingested per pCi/g dry-weight soil for a year of residential scenario),

U_v = the ingestion rate for food crop type v by an individual (kg wet-weight/y),

$PPTF_{vsij}$ = the partial pathway transfer factor for food crop type v, radionuclide j as a progeny of radionuclide i, for unit average concentration of parent radionuclide i in soil (pCi y/kg dry-weight food per pCi/g dry-weight soil for a year of residential scenario),

U_a = the ingestion rate of animal product type a by an individual (kg wet-weight/y),

$PPTF_{asij}$ = the partial pathway transfer factor for animal product type a, radionuclide j as a progeny of radionuclide i, for unit average concentration of parent radionuclide i in soil (pCi y/kg wet-weight food per pCi/g dry-weight soil for a year of residential scenario),

N_a = the number of animal products considered in the diet, and

N_v = the number of food crops considered in the diet.

The mathematical expression to evaluate the PFs for unit average concentration of a parent radionuclide in irrigation water is given in NUREG/CR-5512 (p. 5.52) as:

$$PF_{wij} = \Sigma_{(v=1,Nv)}\, U_v\, PPTF_{vwij} + \Sigma_{(a=1,Na)}\, U_a\, PPTF_{awij} \qquad (6.36)$$

where:

PF_{wij} = the agricultural pathway transfer factor for radionuclide j as a progeny of radionuclide i per unit initial concentration of parent radionuclide in irrigation water (pCi ingested per pCi/L water for a year of residential scenario),

U_v = the ingestion rate for food crop type v by an individual (kg wet-weight/y),

$PPTF_{vwij}$ = the partial pathway transfer factor for food crop type v, radionuclide j as a progeny of radionuclide i, for unit average concentration of parent radionuclide i in water (pCi y/kg wet-weight food per pCi/L water for a year of residential scenario),

U_a = the ingestion rate of animal product type a by an individual (kg wet-weight/y),

$PPTF_{awij}$ = the partial pathway transfer factor for animal product type a, radionuclide j as a progeny of radionuclide i, for unit average concentration of parent radionuclide i in irrigation water (pCi y/kg wet-weight food per pCi/L water for a year of residential scenario),

N_a = the number of animal products considered in the diet, and

N_v = the number of food crops considered in the diet.

The ingestion rate of fish, U_f, is used in calculating the aquatic food ingestion factor (AF). AF is then used to calculate the annual dose from ingestion of aquatic foods. The mathematical expression for AF is given in NUREG/CR-5512, Vol. 1 (p. 5.60), as:

$$AF_{fj} = U_f \, t_f \, DFG_j \, BA_{jf} \left(C_{wj}/C_{wj}\right)/365.25 \qquad (6.37)$$

where:

- AF_{fj} = the aquatic pathway transfer factor for radionuclide j as a progeny of radionuclide i, per unit average concentration of radionuclide j in surface water (mrem per pCi/L for a year of the residential scenario),
- U_f = the ingestion rate of aquatic foods produced in contaminated surface water,
- t_f = the duration of fish consumption in days,
- DFG_j = the ingestion CEDE factor for radionuclide j (mrem pr pCi ingested),
- Ba_{jf} = the bioaccumulation factor for radionuclide j in aquatic foods, and
- C_{wj} = the average annual concentration of radionuclide j in water (pCi/L).

U_v and U_a are also used to determine the area of land cultivated, A_r. Section 5.4.1.2 provides a detailed description of the relationships among ingestion rates, crop yields, and the cultivated area.

6.2.9.3 Information Reviewed to Define Distributions for U_v, U_a, and U_f

The values used for U_v and U_a in NUREG/CR-5512, Vol. 1, are based on food ingestion rates found in the 1977–78 Nationwide Food Consumption Survey (USDA, 1983). The specific values are derived from mean values compiled by Higley and Strenge (1988) and Pao et al. (1985). These values are based on consumption data that represent all food sources and not just home grown food. The dose calculation described in Volume 1 uses a single parameter (DIET) to describe the fraction of homegrown food in each food category. This assumption requires, for example, that the fraction of domestically-produced beef in the diet equals the fraction of domestically produced leafy vegetables. This assumption is unlikely to be satisfied in general, and is not representative of the screening group. In this analysis, ingestion rates of homegrown food are estimated separately for each of the food product categories. The DIET parameter is therefore unneeded (see Section 6.2.1). This approach allows consumption patterns to be more accurately represented. In addition, redefining these parameters in this manner makes them consistent with the definition of U_f.

The default value used in NUREG/CR-5512, Vol. 1, for U_f was based on summary data presented by Rupp et al. (1980). The regional percentiles reported in Rupp et al. are based on the entire population, including those individuals who eat no fish, which is not representative of the screening group. To try to compensate for this inaccuracy, (i.e., Rupp et al. reported that over 85% of the population eat no freshwater fish), the value for the highest regional rate reported by Rupp et al. was used as the default value in NUREG/CR-5512, Vol. 1. In the dose calculations, U_f is not scaled by the DIET parameter, which implies that it represents the consumption of domestically-produced fish.

Table 6.20 displays the default values of ingestion rates for the eight food groups defined in NUREG/CR-5512, Vol. 1.

Table 6.20 NUREG/CR-5512 U_v, U_a and U_f default values

Food type	Consumption rate
Leafy vegetables (U_v)	11(kg/y)
Other vegetables (U_v)	51 (kg/y)
Fruit (U_v)	46 (kg/y)
Grain (U_v)	69 (kg/y)
Beef (U_a)	59 (kg/y)
Poultry (U_a)	9 (kg/y)
Milk (U_a)	100(kg/y)
Eggs (U_a)	10 (kg/y)
Fish (U_f)	10 (kg/y)

The most recent Nationwide Food Consumption Survey (USDA, 1993) was conducted in 1987–88 and is more reflective of long-term nationwide consumption trends compared to the 1977–78 survey data. Like the earlier survey, the individual survey data could not be used directly to measure consumption of home produced food because the source of the food item is not identified. However, EPA reports intake rates for various home produced food items (EPA, 1996) based on an analytical method that combined data from both the household and individual 1987-88 USDA survey components. The data is reported in the form of cumulative probability distributions. This data set provides estimates of U_v and U_a defined as rates of consumption of food from *on-site production.*

The data provided by EPA (1996) represent consumption of home-produced food, however the reported values do not directly correspond to the dose model parameters in some respects. Some additional assumptions are required to estimate parameter distributions from the reported data. First, the eight food categories have to be related to the EPA data. EPA reports intake rates that directly match the "other" vegetables, fruits, beef, poultry, eggs and fish categories. For the "leafy" vegetables category, it is assumed that this category is equivalent to EPA's "exposed" vegetables category. EPA defines the "exposed" vegetables category as those vegetables that are grown above ground. Therefore, assuming that the category of "leafy" vegetables is equivalent to EPA's "exposed" vegetable category is reasonable given the fact that all leafy vegetables are grown above ground, although it may overestimate this category since not all vegetables that are grown above ground are leafy. For the food grain group it is assumed that the EPA data for corn is appropriate, given that corn is the only grain for which data was reported. This assumption is consistent with the study by McKone (1994), where he also used corn to represent the grain category. The milk category is assumed to be equivalent to the EPA's dairy category. Again, this assumption is reasonable but conservative because the reported rates include dairy products other than milk.

EPA notes that the survey data were taken during a week long period, and therefore may not be representative of annual behavior (i.e., more home grown foods are typically eaten in the summer). EPA generated seasonally adjusted intake distributions for all meats, vegetables and fruits by averaging the corresponding percentiles of each of the four seasonal intake distributions reported. This same approach was used to generate seasonally adjusted distributions for the eight food group categories required for the dose model.

EPA reports ingestion rates indexed to the actual body weights of the survey respondents in units of mass ingested per time per respondent body weight. Although EPA does not recommend converting the intake rates into average ingestion rates of mass/time by multiplying by a single average body weight, they do indicate that if this is done, a weight of 60 kg should be used because the total survey population included children.

6.2.9.4 Proposed Distributions for U_v, U_a, and U_f

In order to use the EPA data to represent the average member of the screening group, the seasonally adjusted data were scaled by the percentile average of the ratio of the 20–39 age data to the total population data and then converted by multiplying by the body weight, 70 kg, of the average member of the screening group. This data adjustment assumes that the data scales linearly. EPA does not provide any information about whether or not this assumption is valid, but it is a reasonable approximation.

The homegrown food ingestion rate distributions reported by EPA are based on the amount of food "consumed" in an economic sense (i.e., food that has been brought into the house). EPA recommends converting these intake rates to reflect actual ingestion by decreasing the amounts by percent weight losses from preparing the foods. EPA provides percent weight losses for various meats, fruits and vegetables. Therefore, these losses were accounted for in deriving the distributions for U_v, U_a and U_f. However, losses were not reported for eggs and milk, so these losses were not accounted for in these two food categories.

Table 6.21 lists percentiles of the distributions for U_v, U_a and U_f for the members of the screening group, estimated from the values reported by the EPA as described above. Summary statistics are also listed, along with the equivalent values defined in Volume 1 (i.e., rates multiplied by the DIET parameter), and the 1995 total consumption rates, including both homegrown and purchased food (USDA, 1997a). Figures 6.17, 6.18, and 6.19 present the cumulative distribution functions for U_v, U_a and U_f, respectively. These cumulative distribution functions define the probability distribution functions for U_v, U_a and U_f.

Comparing the equivalent NUREG/CR-5512 default parameters (i.e., consumption rate default parameters multiplied by the default DIET parameter of 0.25) with the mean of the new distributions indicates that the mean of the new distributions are consistently higher than their 5512 equivalent, except for the grain category. However, given the differences in their derivations, the means and the Volume 1 default values are reasonably consistent. The Volume 1 default values typically fall between the upper and lower quantiles of the individual distributions. Poultry and egg consumption rates are notable exceptions: both Volume 1 default values are below their 0.01 quantile values. For both categories the ratio of the average homegrown consumption rate to the average total consumption rate is near 1, suggesting that domestic producers in these categories tend to derive most of their total consumption from domestic production. In this case the default Volume 1 DIET parameter value of 0.25 would be inappropriate for these categories.

6.2.9.5 Uncertainty in Ingestion Rates

The information collected in the Nationwide Food Consumption Survey as interpreted in EPA (1996) describes consumption rates for home-produced food items over a broad range of individuals. Rates were measured over a small time span, but these measurements were seasonally distributed. Estimating annual average ingestion rates for members of the screening

Table 6.21 Statistical characteristics of the distributions for U_v, U_a and U_f

Cumulative %	Leafy vegetables (kg/y)	Other vegetables (kg/y)	Fruits (kg/y)	Grain (kg/y)	Beef (kg/y)	Poultry (kg/y)	Milk (L/y)	Eggs (kg/y)	Fish (kg/y)
Ingestion rates of homegrown foods									
0.01	1.71(1)	2.23	1.93	1.41	2.42	3.85	6.59	2.80	1.85
0.05	1.04	4.15	3.64	2.22	7.03	4.18	6.86	4.50	1.92
0.10	2.40	5.95	5.08	3.22	8.20	5.94	7.67	5.30	2.84
0.25	5.90	11.27	9.48	4.83	13.26	9.57	58.63	8.23	3.68
0.50	11.68	26.64	20.48	8.20	28.79	19.85	148.56	12.36	7.77
0.75	24.58	55.57	45.36	15.80	48.41	38.22	294.81	21.35	16.14
0.90	46.27	77.07	125.96	31.78	76.75	50.83	554.94	35.90	39.08
0.95	66.03	145.57	190.05	44.01	105.71	58.52	721.00	47.35	79.05
0.99	135.52	301.49	460.84	84.78	220.06	72.81	1210.78	120.71	112.82
1.00	222.95	384.03	673.57	99.47	222.75	72.81	1210.78	120.71	852.06
Summary statistics									
Mean[1]	21	45	53	14	40	25	233	19	21
Equivalent 5512 value	2.8	13	12	17	15	2.3	25	2.5	10
1995 U.S. total ingestion rates	185(total)	185(total)	128	87	29	28.5	358	12	7
Ratio of homegrown mean to 1995 totals	(leafy + other)/total = 0.36	(leafy + other)/total = 0.36	0.41	0.17	1.4	0.89	0.65	1.6	2.9

[1] Estimated as average of 580 sample values

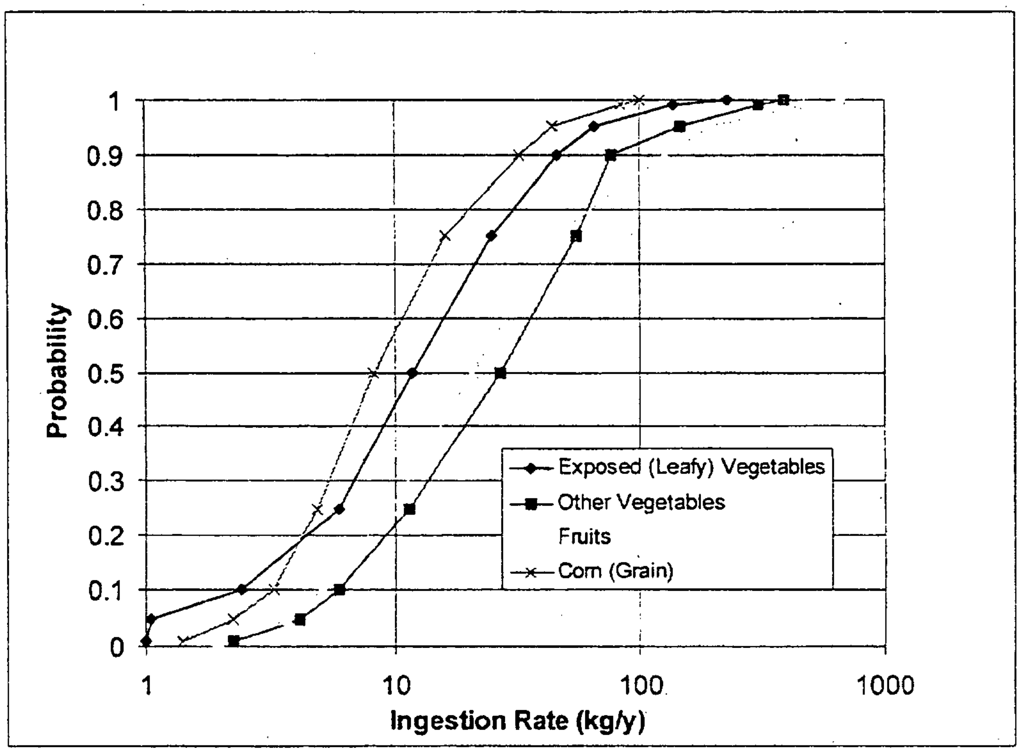

Figure 6.17 Cumulative distribution of U_v for exposed (leafy) vegetables, other vegetables, fruits, and corn (grain)

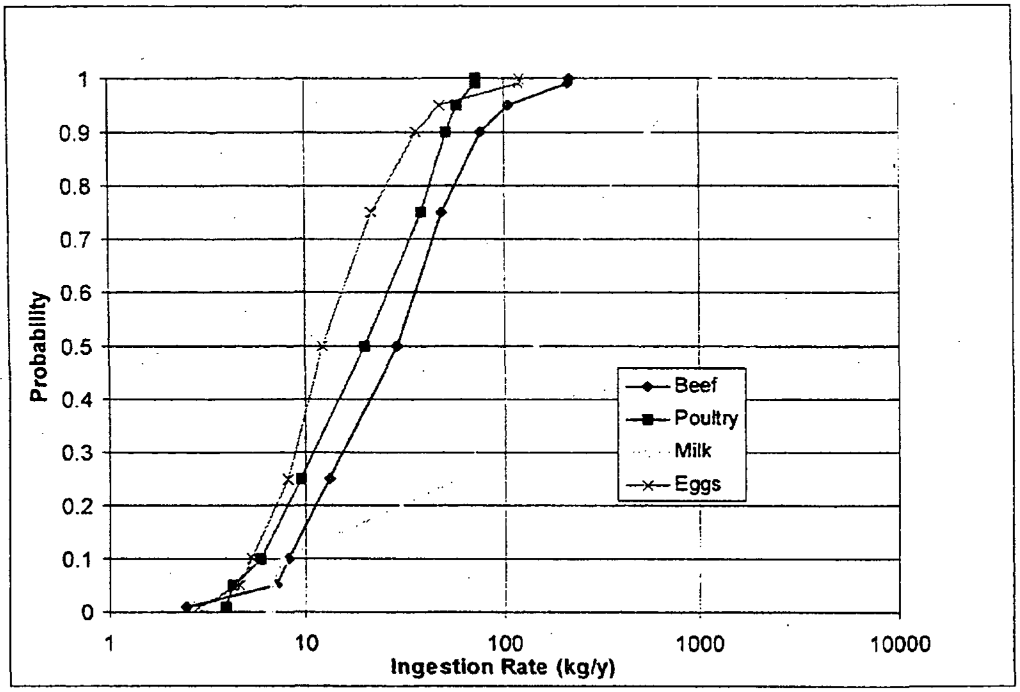

Figure 6.18 Cumulative distribution of U_a for beef, poultry, dairy (milk) and eggs

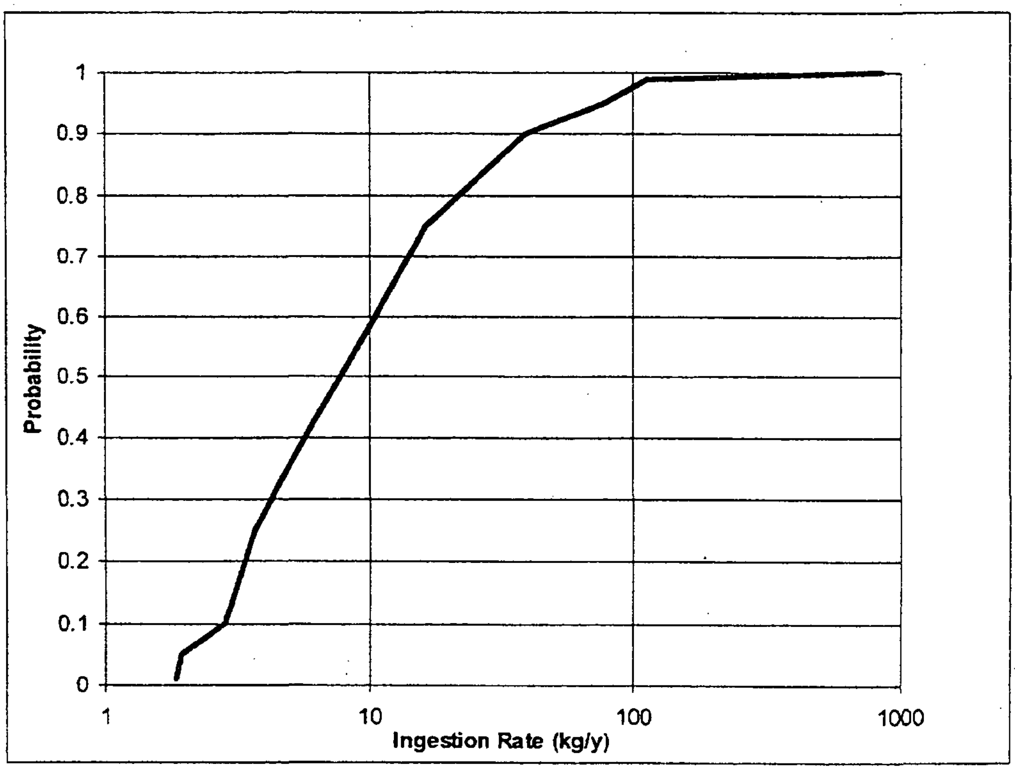

Figure 6.19 Cumulative distribution for U_f for fish

group requires assumptions about the variability of short term versus chronic consumption, the composition of the sample population versus the screening group, and the relative rates of ingestion versus economic consumption. These assumptions introduce some uncertainty about the distributions. We do not expect this uncertainty to be large relative to the mean parameter values, however, and these mean values are comparable to other estimates of ingestion rate.

6.2.9.6 Alternative Ingestion Rate Values

The proposed distribution functions presented above represent the behavioral variability of the members of the screening group and are not related to the physical characteristics of the specific site being considered. Site-specific values for these parameters, like other behavioral parameters, are established by defining a site-specific critical group. Some critical groups may have substantially different consumption rates, for example, groups that do not grow food in one or more categories.

6.3 Volumetric Breathing Rates (Metabolic), V_r, V_x, and V_g (m^3/h)

6.3.1 Description of Breathing Rates

The residential scenario defines three exposure situations or contexts for resident farmers: indoors, outdoors, and gardening. These exposure contexts are distinguished because the transport rates may differ significantly among them. The breathing rate parameters, in conjunction with the indoor resuspension factor, dust loadings, and isotope-specific inhalation CEDE factors, are used to calculate the average annual dose due to inhalation. The breathing rate parameters represent the annual average breathing rate of the average member of the screening group while indoors (V_r), outdoors (V_x) and gardening (V_g). As described in Section 3.2.2 above, default values for metabolic parameters are established by the average value for adult males in the general population.

The default value defined for each of the three breathing rates in NUREG/CR-5512, Vol. 1, is 1.2 m^3/h. This value corresponds to an average for the eight-hour work day assuming light activity for a person, as suggested in International Commission on Radiological Protection (ICRP) Publication 23 (1975). Revised default values for these parameters were defined based on a review of current literature on breathing rate.

6.3.2 Use of Breathing Rates in Modeling

Within each of the three contexts defined for the residential scenario (indoors, outdoors, and gardening), inhalation dose is directly proportional to breathing rate. The overall importance of breathing rate in determining dose depends on the relative contribution of inhalation dose to total dose, which in turn depends on exposure rates via alternative pathways, and on nuclide-specific dose factors.

The breathing rate parameters are used to calculate the committed effective dose equivalent, CEDE, resulting from inhalation of resuspended surface contamination. The relationship between the volumetric breathing rates and internal dose due to inhalation (DHRi) is described by the following (see NUREG/CR-5512, p. 5.55):

$$\begin{aligned} DEXR_i = & \left[24\ V_g (t_g/t_{tg})\ CDG\ C_{si}\ \Sigma_{(j=1,ji)}\ S\{A_{sij},\ t_{tg}\}\ DFH_j\right] \\ & + \left[24\ V_x (t_x/t_{tr})\ CDO\ C_{si}\ \Sigma_{(j=1,ji)}\ S\{A_{sij},\ t_{tr}\}\ DFH_j\right] \qquad (6.38) \\ & + \left[24\ V_r (t_i/t_{tr})\ (CDI + P_d RF_r)\ C_{si}\ \Sigma_{(j=1,ji)}\ S\{A_{sij},\ t_{tr}\}\ DFH \right. \end{aligned}$$

where V_g is the volumetric breathing rate for time spent gardening (m^3/h); V_r is the volumetric breathing rate for time spent indoors (m^3/h); V_x is the volumetric breathing rate for time spent outdoors (m^3/h), t_g is the time during the one-year exposure period that the individual spends outdoors gardening (d); t_i is the time in the one-year exposure period that the individual spends indoors (d); t_x is the time in the one-year exposure period that the individual spends outdoors, other than gardening (d); t_{tr} is the total time in the residential exposure period (d); CDI, CDO, and CDG are the dust loading factors for indoor, outdoor, and gardening activities (g/m^3); respectively, C_{si} corresponds to the concentration of parent radionuclide i in soil at time of site release (pCi/g dry-weight soil); J_i is the number of explicit members of the decay chain for parent radionuclide i; $S\{A_{sij}, t_{tr}\}$ is a time-integral operator used to develop the concentration time integral of radionuclide j for exposure over a one-year period per unit initial concentration of parent radionuclide i in soil (pCi*d/g per pCi/g dry-weight soil); $S\{A_{sij}, t_{tg}\}$ is a time-integral operator used to develop the concentration time integral of radionuclide j for exposure over one gardening season during one-year period per unit initial concentration of parent radionuclide i in soil (pCi*d/g per pCi/g dry-weight soil); DFH_j is the inhalation committed effective dose equivalent factor for radionuclide j for exposure to contaminated air (in units of mrem per pCi inhaled); P_d corresponds to the indoor dust-loading on floors (g/m^2); and RF_r is the indoor resuspension factor (m^{-1}). The resulting internal inhalation dose is directly proportional to the volumetric breathing rates for indoor, outdoor, and gardening activities.