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Radiological Dose Assessment of Department of Energy Pinellas Plant Waste Proposed for Disposal at United States Pollution Control, Inc. in Tooele County, Utah

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ABBREVIATIONS AND ACRONYMS:

DCF	dose conversion factor
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
HDPE	high-density polyethylene
ICRP	International Commission on Radiological Protection
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NRC	U. S. Nuclear Regulatory Commission
RCRA	Resource Conservation and Recovery Act
RESRAD	RESRAD computer code, Version 5.60
USPCI	U.S. Pollution Control, Inc.

UNITS:

Bq	becquerel
°C	degrees Celsius
Ci	curie
cm	centimeter
ft	foot/feet
°F	degrees Fahrenheit
g	gram
in.	inches
K	kelvin
km	kilometer
m	meter
ml	milliliter
mm Hg	millimeters of mercury
mol	mole
mrem	millirem
mSv	milliSievert
ppm	part per million
s	second
y	year
yd	yard

ABSTRACT

The U.S. Department of Energy (DOE) Pinellas Plant in Largo, Florida is proposing to ship hazardous sludge, listed as F006 waste, to the U.S. Pollution Control, Inc. (USPCI) hazardous waste landfill in Tooele County, Utah for disposal. This sludge contains radioactive tritium in concentrations of about 28 pCi/g. The objective of this study is to assess the possible radiological impact to workers at the USPCI facility and members of the public due to the handling, processing, and burial of the DOE waste containing tritium. Listed below are the estimated doses to workers from waste handling activities and to the pubic from disposed waste. The doses are compared to natural background and applicable regulatory limits. The results of this highly conservative dose assessment reveal extremely low annual doses that are far below natural background radiation exposure and regulatory limits. Note that the estimated doses are incremental doses above background or other sources of radiation exposures.

Summary of radiological doses

Exposure scenario	Dose (mrem/y)[a]	Fraction of natural background[b]	Fraction of regulatory limit[c]
Waste sampling	4.7×10^{-6}	1.6×10^{-8}	9.4×10^{-10}
Waste stabilization	6.0×10^{-6}	2.0×10^{-8}	1.2×10^{-9}
Waste burial	9.8×10^{-4}	3.3×10^{-6}	2.0×10^{-7}
Public exposure[d]	1.2×10^{-5}	4.0×10^{-8}	1.2×10^{-6}

[a] Waste sampling and waste stabilization are from short-term exposure scenarios that occur within one year. Because the doses are so low, no acute radiation effects are anticipated. Therefore, the most reasonable comparison is to annual background and annual occupational dose levels. The waste burial and public exposure scenarios are from longer-term exposures that are also compared to annual background and annual occupational doses.

[b] Annual average individual natural background level is 300 mrem.

[c] Occupational limit = 5000 mrem/y; public limit = 10 mrem/y.

[d] Peak annual exposure occurs about 14 years after placement of waste.

1. INTRODUCTION

The U.S. Department of Energy (DOE) Pinellas Plant in Largo, Florida (Pinellas) is proposing to ship hazardous sludge to the U.S. Pollution Control, Inc. (USPCI) hazardous waste landfill in Tooele County, Utah for disposal. This sludge, listed under the Resource Conservation and Recovery Act (RCRA) regulations as F006 waste, contains radioactive tritium. RCRA F006 waste is defined as wastewater treatment sludges from electroplating operations [40 *Code of Federal Regulations* Part 261.30]. Because the waste contains tritium, DOE requires the preparation of a radiological dose assessment prior to shipment and disposal to ensure the protection of workers and the public from radiation hazards. A radiological dose assessment is necessary to meet the requirements of DOE to allow for an exemption from the department's moratorium on the off-site shipment of radioactively contaminated wastes. This assessment is modeled after a similar one conducted for Pinellas sludge that was sent to the a facility in South Carolina in 1992 (M. H. Chew & Associates 1994).

The objective of this study is to assess an upper-bound radiological impact to workers at the USPCI facility and members of the public due to the handling, processing, and burial of the DOE waste containing tritium. Beta radiation (i.e., electrons resulting from the conversion of a neutron to a proton in the nucleus of an atom) from the tritium could result in radiation exposure to workers or members of the public. The potential off-site public dose is calculated as an upper bound for the hypothetical maximally exposed off-site individual. The study also compares the calculated doses with background radiation levels and applicable federal regulatory limits. Finally, associated health effects are discussed.

The remainder of this report is organized into three sections: (1) a description of the disposal facility and operations; (2) the dose analysis, including the methodology for calculating doses to workers and the public; and (3) a discussion of the results.

2. FACILITY DESCRIPTION AND OPERATIONS

2.1 Facility Location and Description

The USPCI landfill facility is located in Tooele County, Utah. Tooele County is a rural area with a 1987 population of approximately 28,600 persons, located approximately 80 km (50 mi) west of Salt Lake City (NRC 1993). The closest population center to the landfill facility is the town of Wendover, on the Utah/Nevada border. Wendover is approximately 64 km (40 mi) west of the facility and has an approximate population of 1,100 persons (1990 census) (Fig. 2.1). The Tooele Army Depot is located approximately 80 km (50 mi) to the southeast. Tooele County encompasses over 1.8×10^6 ha (4.4×10^6 acres) of land. The federal government owns and controls 82% of the county, the State of Utah administers 6%, and approximately 12% is privately owned. In 1988, the Tooele County Commission established the West Desert Hazardous Industry Area, which incorporates the USPCI landfill site. This designation limits the future uses of land in the vicinity of the site by prohibiting residential housing. The climate is arid with an average rainfall of approximately 13 cm (5 in.) per year (NRC 1993).

USPCI operates the Grassy Mountain Treatment, Storage and Disposal Facility. This facility contains six RCRA disposal landfill cells. Figure 2.2 shows the facility plan of the USPCI landfill. The Pinellas waste would most likely be disposed of in RCRA Cell 5, with the possibility of using RCRA Cell 4. No other cells are currently available. The size of RCRA Cells 4 and 5, without a cover, are listed below:

- RCRA Cell 4 - 144 m x 362 m x 5.5 m = 286,000 m^3 (157 yd x 396 yd x 6 yd = 376,000 yd^3)
- RCRA Cell 5 - 114 m x 109 m x 22 m = 273,000 m^3 (125 yd x 119 yd x 24 yd = 363,000 yd^3)

The RCRA cells consist of a 0.9-m (3-ft) compacted clay liner with a permeability of less than 10^{-7} cm/sec, a secondary 60 mil high-density polyethylene (HDPE) liner, a secondary leachate detection/collection system, a primary 60 mil HDPE liner, a primary leachate/ collection system, a non-woven geotextile fabric, a 0.6-m (2-ft) soil protective cover, a tertiary 80 mil HDPE liner, a tertiary leachate detection/collection system, a non-woven geotextile fabric, and a 0.6-m (2-ft) protective soil layer (Fig. 2.3). Leachate is removed via a detection and collection system that drains into sumps. The leachate is transported off-site for treatment.

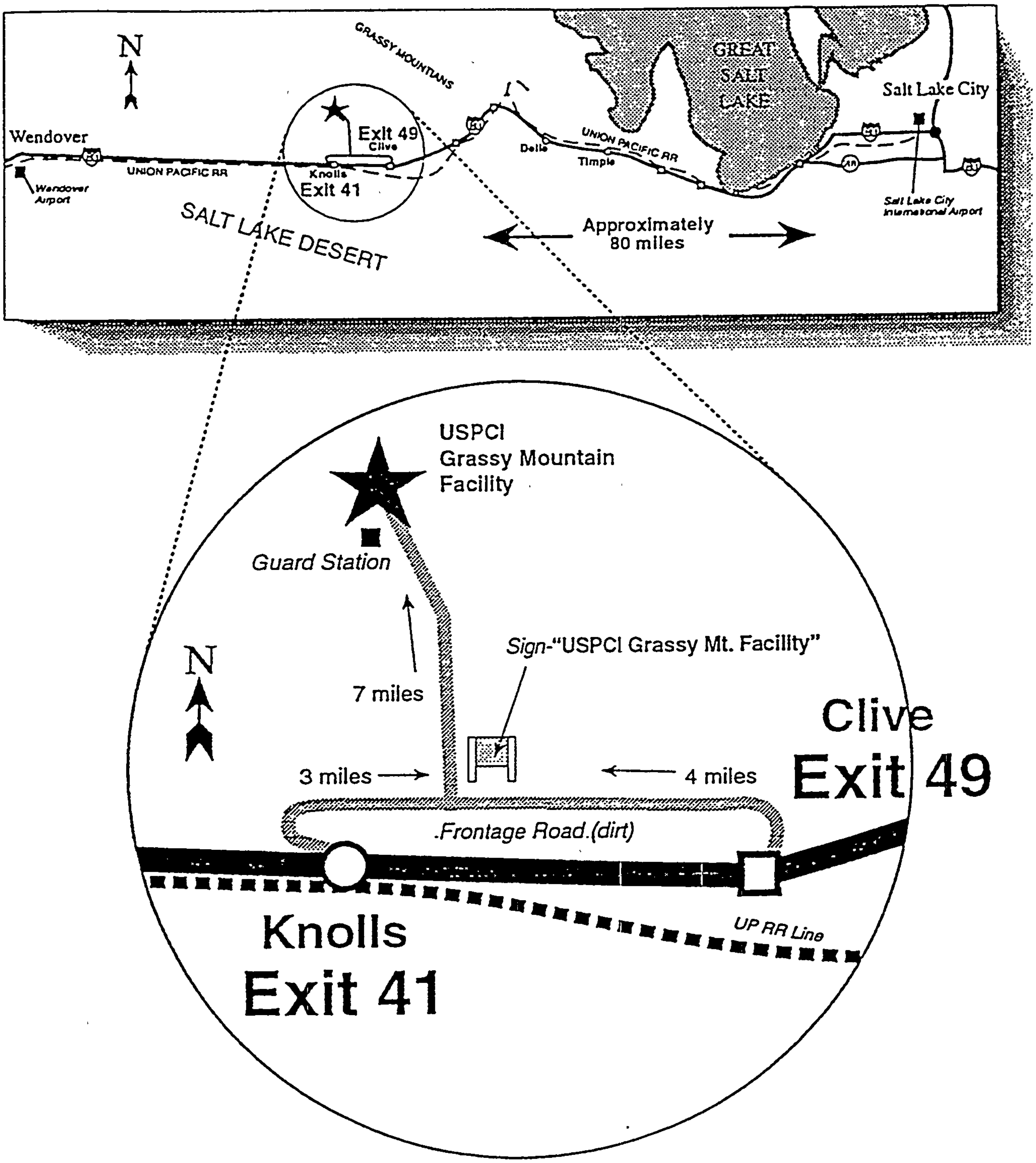

Fig. 2.1. Facility Location.

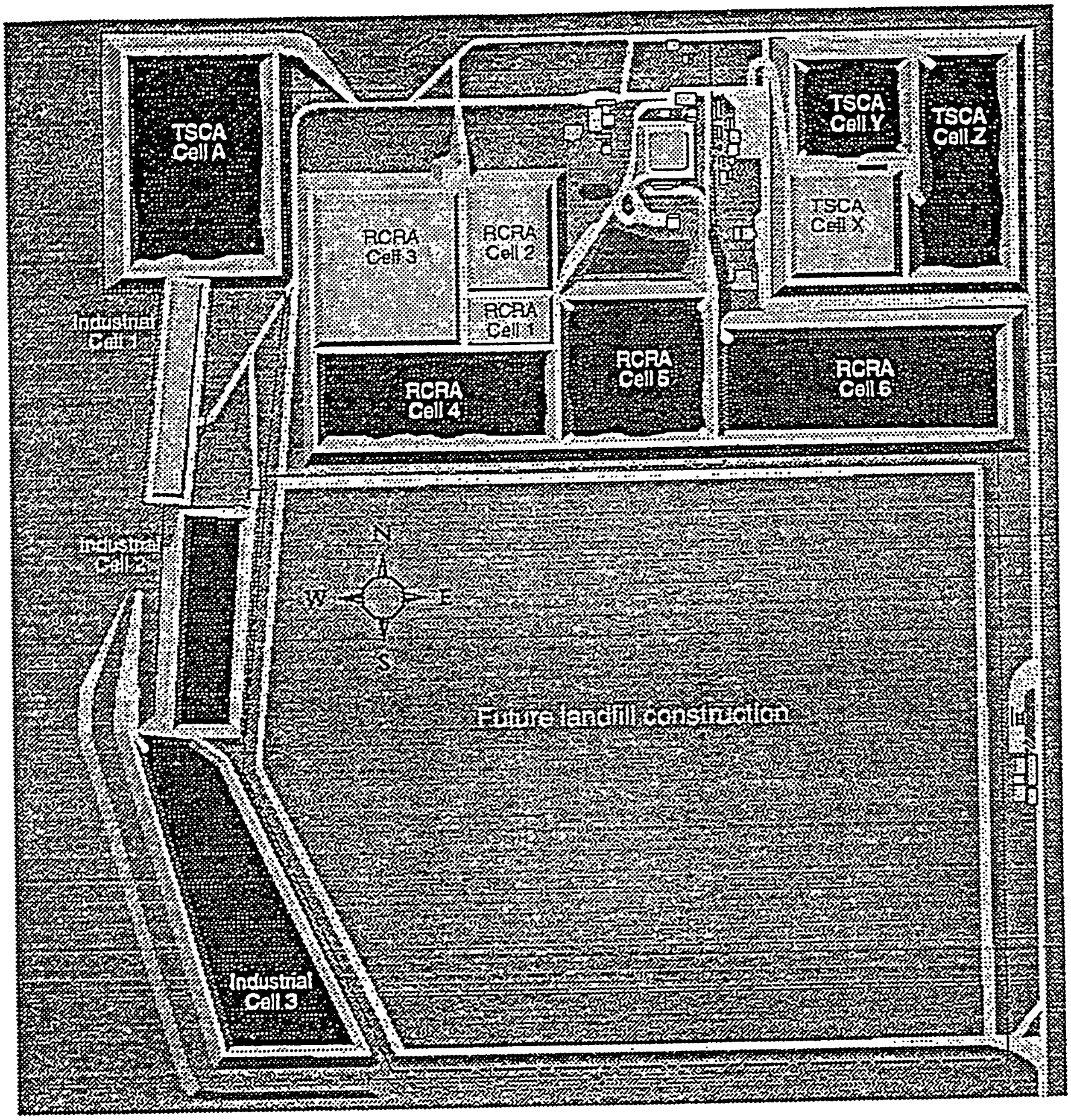

Fig. 2.2. USPCI Facility Plan.

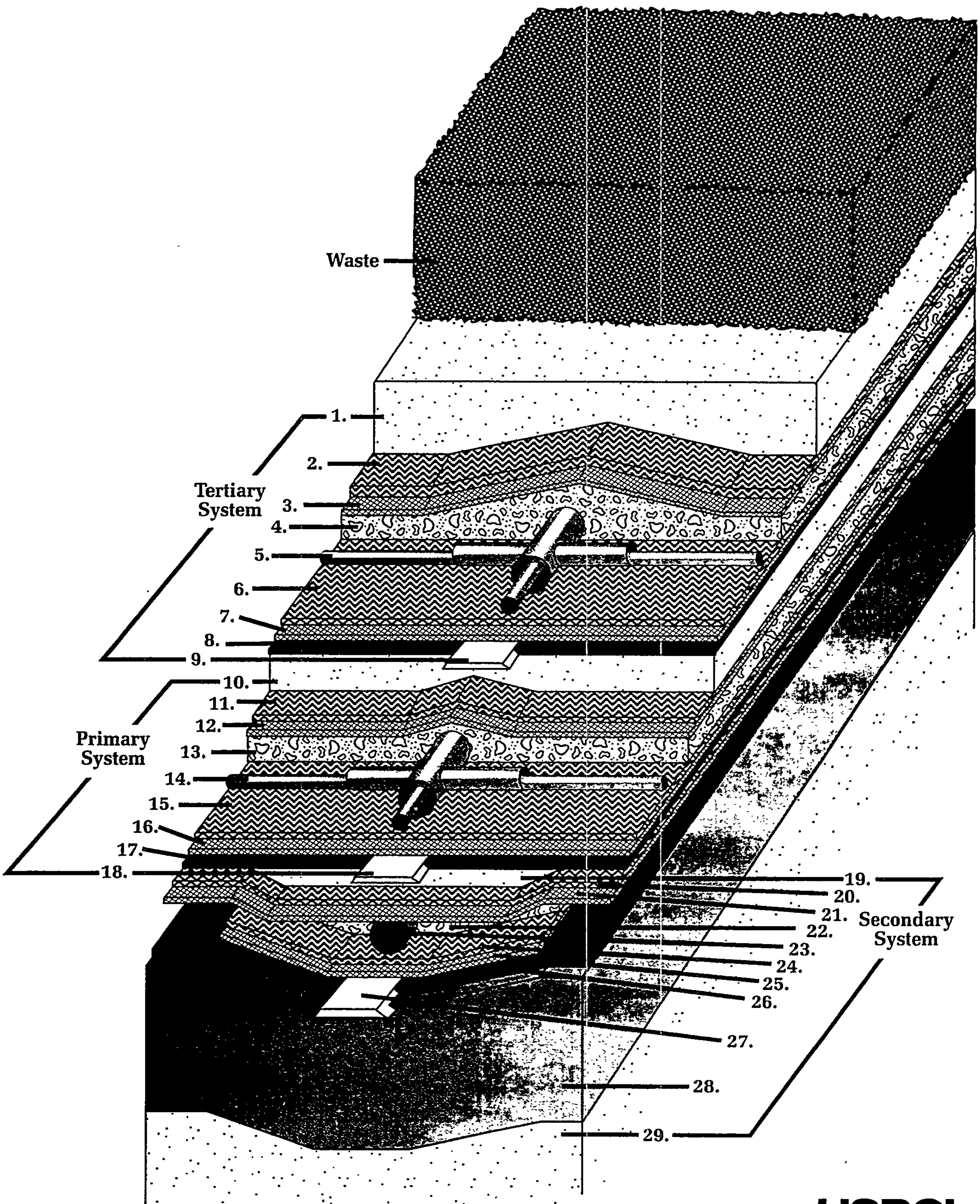

Fig. 2.3. USPCI Liner and Leachate Collection System.

USPCI Liner and Leachate Collection System
Continued

COMPONENT	FUNCTION
Tertiary System	
1. Protective soil cover	Protects liner from physical damage
2. Non-woven geotextile filter fabric	Protects drainage net from clogging
3. High Density Polyethylene (HDPE) drainage net	Leachate collection
4. Rounded 3/4" washed rock	Leachate collection
5. Sump & piping system	Leachate collection
6. Non-woven geotextile filter fabric	Protects drainage net from clogging
7. High Density Polyethylene (HDPE) drainage net	Leachate collection
8. 80 mil HDPE liner	Impermeable barrier/synthetic liner
9. HDPE sump plates	Supports sump & piping system/protects liner
Primary System	
10. Protective soil cover	Protects liner from physical damage
11. Non-woven geotextile filter fabric	Protects drainage net from clogging
12. High Density Polyethylene (HDPE) drainage net	Leachate collection/leak detection
13. Rounded 3/4" washed rock	Leachate collection/leak detection
14. Sump & piping system	Leachate collection/leak detection
15. Non-woven geotextile filter fabric	Protects drainage net from clogging
16. High Density Polyethylene (HDPE) drainage net	Leachate collection
17. 60 mil HDPE liner	Impermeable barrier/synthetic liner
18. HDPE sump plates	Supports sump & piping system/protects liner
Secondary System	
19. Protective soil cover	Bedding for primary sump plate
20. Non-woven geotextile filter fabric	Protects drainage net from clogging
21. High Density Polyethylene (HDPE) drainage net	Leachate collection/leak detection
22. Rounded 3/4" washed rock	Leachate collection/leak detection
23. Sump & piping system	Leachate collection/leak detection
24. Non-woven geotextile filter fabric	Protects drainage net from clogging
25. High Density Polyethylene (HDPE) drainage net	Leachate collection/leak detection
26. 60 mil HDPE liner	Impermeable barrier/synthetic liner
27. HDPE sump plates	Supports sump & piping system/protects liner
28. Compacted clay liner	Low permeability barrier
29. Compacted soil base	Foundation/dikes

Note: The sump consists of rounded aggregate wrapped in non-woven geotextile filter fabric and a second layer of High-Density Polyethylene (HDPE) beneath the aggregate which acts as a protective rub sheet.

Fig. 2.3. (cont).

The facility employs approximately 121 employees on site; approximately 38 are operational workers. At the landfill itself, there are five workers who might be present during waste handling and one supervisor who would be present approximately 20% of the time.

2.2 Waste Operations

Operations at the USPCI facility involved in handling the Pinellas waste include waste sampling, waste stabilization, and waste burial. Each is described below. If approved by the State of Utah, the transfer of Pinellas sludge to USPCI is expected to be conducted in October, 1995. The sludge would be transported in 5 vacuum boxes, each containing approximately 11.5 m^3 (15 yd^3) of sludge. The vacuum boxes have a capacity of 15 m^3 (20 yd^3), leaving 3.8 m^3 (5 yd^3) of headspace. The vacuum boxes are equipped with 61-cm (24-in.) fill hatches and 10-cm (4-in.) flange drains.

2.2.1 Sampling

A technician would take one representative sample [approximately 470 ml (1 pint) or less] of Pinellas sludge from each of the 5 vacuum boxes. Sampling would be performed through the top fill hatches while the technician is standing on a platform immediately above the vacuum box. The worker would take a probable maximum of 15 minutes to sample any individual truck. Sampling would be conducted during the daytime at ambient temperatures, outside of any walls.

Samplers generally do not come into direct contact with the waste; samplers wear coated tyvek coveralls, hard hats, safety glasses with side shields, steel-toed boots, and latex gloves. They also wear cartridge-type full-face respirators while actually sampling from the truck, if any liquids are present; otherwise, a half-face respirator is used with safety glasses. The cartridges are combined particulate matter/organic vapor cartridges that also control acid gases, pesticides, mists and fumes, and radioactive particles. The cartridges used with the respirators do not filter tritium, therefore, no credit is given to the use of respirators in the dose analysis. Generally there are two samplers on duty at any given time, but each sampler obtains samples from a given truck independently.

Sampling consists of a series of relatively quick physical tests (e.g., color, appearance, pH, reactivity to acid, etc.) to verify that the material exhibits the same gross physical characteristics that are described in the profile. All analyses are performed at the Grassy Mountain Laboratory, which is certified by the State of Utah. Analyses are performed in a lab room with controlled ventilation; testing which might evolve fumes is performed under a hood that exhausts directly to the outside air. Samples are bulked together for disposal, based on waste type or codes.

2.2.2 Stabilization

After a waste shipment is cleared from sampling, it is scheduled into stabilization. At the stabilization unit, the waste is drained into one of three open-topped, double-walled steel tanks. The tanks measure 6.1 m x 6.1 m (20 ft x 20 ft) and have a working depth of 1.8 m (6 ft) (an approximate capacity of 67 m^3, or 18,000 gallons). The sludge from two vacuum boxes are likely to be combined into the stabilization tank. Stabilizing agents (e.g., cement kiln dust, lime kiln dust, and portland cement) are added to bind the metals and free water. The waste and reagents are then mixed with a trackhoe bucket, which then transfers the mixture (now completely free of liquids) into end-dump trucks for transport to the landfill cell. As a result of adding the reagents, the volume of material ultimately placed in the cell is roughly 2.5 times that of the incoming waste. Before being removed from the tanks, the waste is sampled and tested to verify that no free liquids are present. For this analysis, the tritium is assumed to behave as normal hydrogen in the water molecule, and bind into the water/reagent matrix.

The entire time to stabilize a batch of waste varies, but each batch of this material should be stabilized and off-loaded into the disposal cell within 30 minutes. All stabilization is performed out-of-doors, at ambient temperatures. The reagents used react with water in a generally exothermic reaction, which may generate some water vapor.

All personnel on the stabilization unit will wear the same personal protective equipment as that described for the samplers, with the exceptions that they will also wear chemical resistant rubber boots and work gloves over the latex gloves and half-face respirators.

2.2.3 Burial

At the landfill cell, trucks dump the stabilized waste into a pile. The pile is pushed by a bulldozer into the final disposal area being used that day. All stabilized materials, once they are actually disposed of, are of a soil- or rock-like consistency. Less than 15 minutes generally is required to transport a batch of stabilized waste from the stabilization unit to the landfill cell. Although placement of the waste in the cell takes only minutes, workers are present in the cell and would be in the vicinity of the waste for approximately eight to nine hours of a ten-hour shift. Workers at the cells wear the same personal protective equipment as those at the stabilization unit.

The volume of the Pinellas waste that would be disposed of in either landfill cell is only a small fraction of the capacity of the cells. The volume of the Pinellas waste is determined from the volume of the incoming sludge. Five vacuum boxes, each containing approximately 11.5 m^3 of sludge (Sect. 2.2), equals a total sludge volume of Pinellas waste of about 57.5 m^3. With the addition of solidification materials during stabilization, the volume of the waste is increased by 2.5 times that of the incoming waste (Sect. 2.2.2). Therefore, the total volume of the waste is approximately 143 m^3. The Pinellas waste would only constitute about 0.05% of the total volume capacity of either RCRA Cell 4 or 5 (i.e., 286,000 m^3 and 273,000 m^3, respectively) (Sect. 2.1). When the waste is placed in the landfill, the expected surface area dimensions of the waste are 6.7 m (22 ft) x 3.7 m (12 ft) = 25.5 m^2 (264 ft^2) [L. Griffith, USPCI, Inc., personal communication with M. L. Socolof, Oak Ridge National Laboratory (ORNL), September 19, 1995]. The resulting depth of the waste placed in the landfill, based on a volume of 143 m^3, is 5.8 m.

There is no routine daily cover placed on the landfill cell, but when needed, water is sprayed on the cell surface to control dust. If there is a specific need, a cover can be applied over a given load or loads, using either clean soils from the surrounding area, or other heavier waste materials. Once a cell is completely full, it is covered by a minimum of the following: 0.6 m (2 ft) of recompacted clay, an 80-mil High Density Polyethylene Membrane Liner, a porous drainage net, 0.6 m (2 ft) of compacted soil and at least 10 cm (4 in.) of gravel/riprap (a total of approximately 1.3 m or 4.3 ft). Up to 3 m (10 ft) of additional waste could also be placed over the Pinellas waste, before the cap is added. While the waste is sometimes covered the same day, the average time before the waste is covered is two weeks (L. Griffith, USPCI, Inc., personal communication with M. L. Socolof, ORNL, September 19, 1995).

3. DOSE ANALYSIS

Tritium has a radiological half-life of 12.3 years and is a naturally occurring isotope of hydrogen produced by the interaction of cosmic ray protons and neutrons with nitrogen and oxygen atoms. Tritium is also a fission product of nuclear reactors as a result of neutron interaction with coolant additives and other reactor components. Tritium decays to helium-3 by emitting a low-energy beta particle (E_{max} = 0.0186 MeV), precluding tritium from posing an external radiation hazard. However, tritium can pose an internal radiological hazard from inhalation, absorption, or ingestion. Tritium has essentially the same chemical behavior as stable isotopes of hydrogen (i.e., H-1 and H-2). This analysis assumes tritium acts as normal hydrogen in the water molecule. The following sections present the dose analyses for worker and public exposures to tritium in the Pinellas F006 sludge. All doses presented are effective dose equivalents[1]. The following dose analysis is based on a representative composite sample of the Pinellas F006 sludge that has a tritium concentration equal to 28.3 (±1.4) pCi/g and that consists of 91% unbound water (i.e., water that may transport out of the sludge matrix freely). Many assumptions are made throughout this analysis. Those that are referred to as conservative would result in a dose that is either a reasonable upper bound estimate or is higher than expected.

3.1 Worker Exposure Scenarios

The radioactive tritium contained in the DOE waste could be released to the atmosphere during (1) sampling and inspection of the waste, (2) stabilizing the waste, and (3) disposing of the waste in the landfill. For the first two operations, the internal dose from inhalation and skin absorption of tritiated water vapor (water vapor where one or both of the hydrogen atoms are replaced by tritium) is calculated assuming the sludge water evaporates into the worker's breathing zone. The models used simulate evaporation from a water spill, and therefore, the tritium activity concentration, by directly estimating the concentrations of water vapor in air (M.H. Chew & Associates, Inc. 1994). The calculation of the dose to the burial worker is conducted using the computer code RESRAD, Version 5.60 (Yu et al. 1993), which estimates the doses over time from residual radioactivity in the landfilled waste. RESRAD uses a model that estimates evapotranspiration of tritium-laden water, while accounting for leaching and radioactive decay (described in Sect. 3.1.3). RESRAD was chosen over the water spill model because (1) the free water in the sludge is removed during the stabilization process, (2) the

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[1]The effective dose equivalent is the weighted sum of the organ-specific doses given in millirem (mrem); 1 mrem equals 0.01 milliSievert (mSv).

waste is landfilled and therefore affected by other natural phenomena (e.g., leaching), and (3) the exposure period extends beyond an acute exposure time.

Annual doses resulting from the sampling and stabilization scenarios are calculated using Eq. 3-1. Note that waste sampling and waste stabilization dose scenarios are from short-term exposure scenarios that occur within one year. Therefore, the total dose from each scenario is represented as an annual dose. This is done so that the doses can be compared to annual background levels and annual regulatory limits. Since acute radiation poisoning is of no concern at the dose levels in this analysis, these "acute" exposure scenario doses will be compared to low-level chronic limits. The waste burial and public exposure scenarios are from longer-term exposures that are also presented as annual doses.

$$H = C_a \times IR_a \times T \times N \times DCF \qquad \text{(Eq. 3-1)}$$

where,

H = annual dose (rem/y),

C_a = activity concentration of tritium in the air (Ci/m^3),

IR_a = inhalation rate of air (worker, light exercise: 4.2×10^{-4} m^3/s) (ICRP 1994),

T = exposure time of each operation (s),

N = number of operations (5 y^{-1}), and

DCF = inhalation/percutaneous dose conversion factor for tritium (96 rem/Ci) (EPA 1988; ICRP 1979).

The values of C_a and T will vary for each occupational activity. Descriptions and calculations of the scenario-specific components are presented in Sects. 3.1.1 and 3.1.2. The inhalation rate of a worker during light exercise of 4.2×10^{-4} m^3/s (ICRP 1994) is used in the occupational exposure scenarios. The number of operations, which would occur during one year, is 5. The dose conversion factor (DCF) for tritium in the U. S. Environmental Protection Agency's (EPA's) Federal Guidance Report No. 11 (EPA 1988) is 1.73×10^{-11} Sv/Bq (64 rem/Ci). This DCF does not include the dose contribution from absorption of tritiated water vapor through the skin, which amounts to about 50% of the inhalation dose (ICRP 1979). Therefore, the EPA DCF is increased by 50% to equal 96 rem/Ci in this analysis.

3.1.1 Sampling

This section uses a water evaporation model to estimate the internal dose to workers from inhalation and absorption of the tritium released to the atmosphere during inspection and sampling of the vacuum boxes containing contaminated sludge. The atmospheric concentration (C_a) in Eq. 3-1 is calculated from the initial concentration of tritium in the vacuum box, the release of tritium out of the vacuum box into the atmosphere, and the dilution of tritium in the atmosphere once released. Due to evaporation, tritiated water vapor fills the vacuum box headspace. First the water vapor concentration in the vacuum box headspace ($C_{wv,hs}$) is calculated assuming evaporation from a water spill (M. H. Chew & Associates 1994):

$$C_{wv,hs} = \left(\frac{MW}{V_0}\right)\left(\frac{P_{vap}}{P_0}\right)\left(\frac{T_0}{T_{vap}}\right) \quad \text{(Eq. 3-2)}$$

where,

$C_{wv,hs}$ = concentration of water vapor in the vacuum box headspace (g/m^3),
MW = molecular weight of water (18 g/mol),
V_0 = volume of 1 mole of gas at standard conditions (0.0224 m^3/mol),
P_{vap} = saturation water vapor pressure at 25°C (24 mm Hg),
P_0 = standard pressure (760 mm Hg),
T_0 = standard temperature (273 K), and
T_{vap} = vapor temperature (K) (25°C = 298 K).

This analysis conservatively assumes that all the water vapor in the headspace comes from the waste and that all the tritium is in the sludge water. The calculation requires the saturation water vapor pressure as input into the equation, which depends on temperature (i.e., the higher the temperature, the greater the vapor pressure of water). This analysis assumes the water-vapor pressure is 24 mm Hg, corresponding to water at 25°C (78°F). This temperature is a conservative estimate for average temperatures in October in Tooele. The average daily temperature in Tooele in October is 11°C (52°F) (NRC 1993). Since operations are expected to occur during the daytime, the temperatures would be higher than this daily average. However, the normal daily maximum in Salt Lake City in October is 19°C (66°F) (DOC 1995), which is below the 25°C assumed in this analysis. This analysis is conservative since the higher the temperature, the greater evaporation and thus a greater air concentration of tritium.

Substituting the above values into Eq. 3-2, the water vapor concentration ($C_{wv,hs}$) is 23 g/m^3. The concentration of tritium in the vacuum box headspace depends on the amount of tritium in the sludge water and the amount of water vapor in the headspace. Assuming that tritium acts as water vapor, the initial concentration in the headspace is calculated as:

$$C_{hs}^{\,0} = \left(\frac{A}{f_{wat}}\right) C_{wv,hs} \qquad \text{(Eq. 3-3)}$$

where,

$C_{hs}^{\,0}$ = initial activity concentration of tritium in the vacuum box headspace (before hatch is opened for sampling) (Ci/m^3),
A = activity of tritium in sludge (2.83 x 10^{-11} Ci/g),
f_{wat} = fraction of water in the sludge (0.91) (dimensionless), and
$C_{wv,hs}$ = mass concentration of water vapor in the vacuum box headspace (g/m^3) (Eq. 3-2).

Initial sampling of the sludge revealed an average tritium activity (A) of 2.83 x 10^{-11} Ci/g and the fraction of water in the sludge (f_{wat}) of 0.91. Substituting these values and the $C_{wv,hs}$ value from Eq. 3-2 into Eq. 3-3 yields a $C_{hs}^{\,0}$ of 7.2 x 10^{-10} Ci/m^3. This equation assumes that the tritium is only in the water. Worker exposure occurs when the vacuum box is opened and tritium is released and diluted in the ambient air. The tritium exposure concentration in the air depends on the time-dependent tritium activity in the headspace and the dilution of the headspace volume once exposed to the atmosphere. The time-dependent tritium activity concentration in the headspace [$C_{hs}(t)$] due to leakage can then be obtained by integrating the following mass balance equation (M.H. Chew & Associates 1994):

$$\frac{dC_{hs}(t)}{dt} = -\frac{F\,C_{hs}^{\,0}}{V_{hs}} \qquad \text{(Eq. 3-4)}$$

which yields,

$$C_{hs}(t) = C_{hs}^{\,0} \exp\left(\frac{-F\,t}{V_{hs}}\right) \qquad \text{(Eq. 3-5)}$$

where,

$C_{hs}(t)$ = tritium activity concentration in the headspace as a function of time (Ci/m^3),
C_{hs}^0 = initial tritium activity concentration in the vacuum box headspace (Ci/m^3),
F = leakage rate (0.058 m^3/s), and
V_{hs} = volume of the vacuum box headspace (3.8 m^3).

The leakage rate is scaled from a leakage rate for a 1.9-m^2 door in calm weather conditions of 0.38 m^3/s (Strock and Koral 1965 in M.H. Chew & Associates 1994). The leakage rate for a 0.61-m (2-ft) circular hatch is 0.058 m^3/s. This would correspond to an exit velocity of 0.20 m/s (calculated by dividing the leakage rate by the area of the hatch opening).

The vapor concentration outside the vacuum box is diluted by the air outside the box. The dilution of the headspace volume, when exposed to the atmosphere, is calculated as follows:

$$DIL = \frac{(V_a + V_w)}{V_a} \qquad \text{(Eq. 3-6)}$$

where,

$V_a = v \times 1 \text{ sec} \times \pi(L/2)^2$,
$V_w = v \times 1 \text{ sec} \times u \times 1 \text{ sec} \times L$,

and

DIL = dilution factor (dimensionless),
V_a = volume of air that leaks through the opening in 1 s (m^3),
V_w = dilution volume of air outside the opening due to wind dispersion in 1 s (m^3),
v = exit velocity of tritiated air from vacuum box (0.20 m/s),
u = wind speed (conservatively assume calm conditions: 0.5 m/s), and
L = diameter of vacuum box opening [0.61 m (2 ft)].

In calculating V_w , a vertical mixing depth of the one-second travel distance of contaminated air moving at the exit velocity (0.20 m) is assumed (i.e., the product of $v \times 1$ sec). This is the distance above the opening within which the tritiated water vapor is assumed to be mixed into the outside air passing over the opening. For times beyond 1 second, the velocity of the outside air would have moved the tritiated vapor beyond the breathing zone of the sampling worker. This is a conservative assumption since the individual taking the sample is not likely to get closer than 0.6 m (2 ft) from the opening.

A calm wind speed (u) of 0.5 m/s is used. This is a conservative assumption since the wind speed would likely be higher [the annual average wind speed in Salt Lake City, Utah is approximately 4 m/s (DOC 1995)] and because wind speed and concentration are inversely related (i.e., the lower the wind speed, the lower the dilution and consequently, the higher the concentration of tritium in the air). Using the given values of v, u, and L in Eq. 3-6, the values of V_a and V_w equal 0.058 m^3 and 0.060 m^3, respectively. Subsequently, the dilution factor is 2.0.

The concentration of tritium in the air is the concentration in the headspace divided by the dilution factor.

$$C_a = \frac{C_{hs}(t)}{DIL} \qquad \text{(Eq. 3-7)}$$

where,

C_a = activity concentration of tritium in the air (Ci/m^3),

$C_{hs}(t)$ = time-dependent activity concentration of tritium in the vacuum box headspace (Ci/m^3), and

DIL = dilution factor from surrounding outside air (2.0; Eq. 3-6).

The concentration in the outside air is then calculated by combining Eqs. 3-5 and 3-7,

$$C_a = \frac{C_{hs}^{\,0} \exp\left(\frac{-F\,t}{V_{hs}}\right)}{DIL}. \qquad \text{(Eq. 3-8)}$$

This concentration is then used to calculate the dose to the sampler. Since the concentration in the air is a function of time, the dose is integrated over the sampling exposure time. This is shown below as the definite integral of Eq. 3-1 from time zero to time T.

$$H = \int_0^T C_a(t) \times IR_a \times N \times DCF\, dt \qquad \text{(Eq. 3-9)}$$

where,

H = annual dose (rem/y),

T = exposure time of each operation (900 s),

$C_a(t)$ = activity concentration of tritium in the air as a function of time (Ci/m^3),
IR_a = inhalation rate of air (worker, light exercise: 4.2 x 10^{-4} m^3/s) (ICRP 1994),
N = number of operations (5 y^{-1}), and
DCF = inhalation/percutaneous dose conversion factor for tritium (96 rem/Ci) (EPA 1988; ICRP 1979).

The definite integral from time zero to time T is expressed as

$$H = \left(\frac{C_{hs}^{0}}{DIL}\right)\left(\frac{V_{hs}}{F}\right)\left[1 - \exp\left(\frac{-F\,T}{V_{hs}}\right)\right] IR_a \times N \times DCF. \qquad \text{(Eq. 3-10)}$$

The sampling exposure scenario assumes one worker conducts all 5 sampling operations (N=5) and each operation takes 15 minutes (900-s) exposure time. Substituting in each term given above into Eq. 3-10, and converting rem to mrem, the annual dose to one worker from sampling all the Pinellas waste is 1.2 x 10^{-5} mrem/y.

3.1.2 Stabilization

The Pinellas sludge will be placed into the open stabilization tank for treatment. Two loads of sludge likely would be stabilized together, however, for this analysis, each of the five loads are assumed to be stabilized separately. During stabilization, tritium may be released to the atmosphere as a result of evaporation of the water content in the sludge. The potential exposure would be from tritiated water vapor above the tank. The concentration of tritiated water vapor in the air above the tank (C_a) is calculated by estimating the concentration of water vapor above the tank, for which the source term is the evaporation of water from the tank and the removal term is advection in the wind and ambient air. The mass balance equation for the concentration of water vapor above the tank, representing the time-dependent concentration in relation to the source term and the removal term is as follows:

$$\frac{dC_{wv}}{dt} = \frac{A_t\,Q}{V} - \frac{u\,A_s\,C_{wv}}{V} \qquad \text{(Eq. 3-11)}$$

where,

C_{wv} = mass concentration of water vapor in a volume of air above the stabilization tank (g/m^3),

A_t = surface area of the top of the stabilization tank (m^2) (6.1 m x 6.1 m = 37 m^2),
Q = water evaporation rate per unit area ($g/s\text{-}m^2$),
V = volume of waste in stabilization tank (m^3),
u = wind speed (assume calm winds, 0.5 m/s), and
A_s = cross sectional area of a side of mixing volume above the mixing stabilization tank (m^2) (6.1 m x 0.77 m = 4.7 m^2).

Assuming steady state conditions, the time-dependent term in Eq. 3-11 is set equal to zero. This results in the following simplified equation:

$$C_{wv} = \frac{A_t Q}{u A_s}. \qquad \text{(Eq. 3-12)}$$

This analysis assumes a certain mixing volume above the stabilization tank, the dimensions of which are used to calculate the top and cross-sectional surface areas. The mixing volume is assumed to be equivalent to the volume of the waste in the tank. Therefore, using the dimensions of the stabilization tank (6.1 m x 6.1 m x 1.8 m), the surface area of the top of the tank (A_t) equals 6.1 m x 6.1 m, or 37 m^2. The height of the mixing zone above the tank is assumed to be the same as the depth of the grouted waste in the tank. The depth of the sludge is calculated from the original volume of one load of sludge (approximately 11 m^3), which is increased by a factor of 2.5 by the addition of stabilization agents. The cross-sectional area (A_s) is then calculated with the height and width of the waste (6.1 m x 0.77 m = 4.7 m^2). A calm wind speed (u) of 0.5 m/s is used. The evaporation rate is conservatively estimated below based on a water spill (EPA 1987), which uses the ideal gas law and wind speed.

$$Q = \frac{MW\ K\ P_{vap}}{R\ T_{vap}} \qquad \text{(Eq. 3-13)}$$

where,

$$K = 0.25\ u^{0.78} \qquad \text{(Eq. 3-14)}$$

and

Q = water evaporation rate per unit area ($g/s\text{-}cm^2$),

MW = molecular weight of water (18 g/mol),
K = gas phase mass transfer coefficient (cm/s),
P_{vap} = saturation vapor pressure (24 mm Hg at 25°C),
R = gas constant 62,358 mm Hg-cm^3/mol-K,
T_{vap} = vapor temperature (K) (25°C=298 K), and
u = wind speed (0.5 m/s).

Substituting the values given above into Eq. 3-13, the water evaporation rate per unit area (Q) is 3.4 x 10^{-6} g/s-cm^2. To substitute Q into Eq. 3-12, the value must be converted to 0.034 g/s-cm^2 so that the units are consistent. Substituting Q into Eq. 3-12 yields a water vapor concentration above the stabilization tank (C_{wv}) of 0.54 g/m^3. Substituting that water vapor concentration value into the right hand side of Eq. 3-3 yields a tritium concentration in the air above the tank (C_a) for the stabilization scenario.

$$C_a = \left(\frac{A}{f_{wat}}\right) C_{wv} \qquad \text{(Eq. 3-15)}$$

where,

C_a = activity concentration of tritium in a volume of air above the stabilization tank (Ci/m^3),
A = activity of tritium in sludge (2.83 x 10^{-11} Ci/g),
f_{wat} = fraction of water in the sludge (0.91) (dimensionless), and
C_{wv} = mass concentration of water vapor in a volume of air above the stabilization tank (g/m^3).

The concentration of tritium in the air, to which a worker is exposed, is calculated to be 1.7 x 10^{-11} Ci/m^3. This concentration is then substituted into Eq. 3-1 to calculate the dose. The exposure time is conservatively assumed to be 30 min (1800 s) per vacuum box of sludge, which is the time for stabilization activities and transfer to the disposal cell. The same worker also is assumed to conduct all five stabilization operations (N=5). The calculated dose from Eq. 3-1 for stabilization operations, after being converted from rem to mrem, is 6.0 x 10^{-6} mrem/y.

3.1.3 Burial

The RESRAD code (Yu et al. 1993) is used to calculate the inhalation dose to a landfill worker. The maximum potential exposure is estimated assuming tritium is released to the atmosphere from the grouted sludge. RESRAD uses a tritium model based on specific activity. The model is based on the fact that tritium has essentially the same chemical behavior as stable isotopes of hydrogen (i.e., H-1, H-2). Therefore, tritium occurs in the environment in concentrations that are proportional to the ratio of tritium to stable hydrogen in the environment (Yu et al. 1993). Furthermore, the circulation of tritium in the environment generally is expected to closely follow that of water. The RESRAD model assumes tritium acts as water and calculates the amount of tritium in the environment as water vapor from evaporation. The model also accounts for evapotranspiration, leaching, runoff, erosion, and radioactive decay.

To calculate the evaporation of tritium from the waste into the air, the dimensions of the waste are needed. These are assumed to be 6.7 m x 3.7 m x 5.8 m in the RCRA landfill cell (Sect. 2.2.3). Tritium is assumed to be released to the atmosphere from the grouted waste form. The worker is assumed to be exposed to the waste form before it is covered in the RCRA cell. The waste form dimensions are used to determine the concentration in the soil, which is then used to calculate a concentration in the air. RESRAD calculates an air concentration by accounting for the humidity in the air, the density of the waste and soil cover, the hydraulic conductivity of the waste, the erosion rate of the cover soil and the waste, the porosity of the waste, the precipitation rate, the irrigation rate, and evapotranspiration and runoff characteristics. All parameter values are presented in Appendix A, Sect. A.1.

The mean annual absolute humidity for Utah and surrounding states is 4.7 g/m^3 (Yu et al. 1993, p. 310). The density of the waste is assumed to be about 1.2 g/cm^3, and the hydraulic conductivity of the waste is assumed to be 10 m/y. These values are the same as those of similar Pinellas waste that underwent similar treatment that was sent to South Carolina for disposal in 1992 (M.H. Chew & Associates 1994). The erosion rate of the contaminated zone (RESRAD default value of 0.001 m/y) is used and is insensitive to the calculated dose and, therefore, a more precise value is not needed for this analysis.

The porosity, precipitation rate, irrigation rate, evapotranspiration coefficient, and runoff coefficient are used to calculate the infiltration of water through the contaminated zone to estimate leaching. The effective porosity of the contaminated zone, on average, is estimated to be 0.3 (L. Griffith, USPCI, Inc., personal communication with M. L. Socolof, ORNL, September 7, 1995). The annual rainfall is approximately 0.13 m. Although there is no irrigation in the area, the landfill cells are sometimes sprayed with water for dust suppression purposes. The introduction of irrigation or dust suppression water would increase leaching and thus decrease the atmospheric release of tritium from the waste. Therefore, assuming no "irrigation" term is conservative. The runoff coefficient assumes the land is flat, with open sandy loam and cultivated lands (as opposed to woodlands) (Yu et al. 1993, p. 199). The evapotranspiration coefficient, which can vary between 0 and 1, conservatively is assumed to be at the upper bound of 1.0.

A worker conservatively is assumed to be exposed to atmospheric releases from the waste nine hours a day for 250 work days in a year (8.1×10^6 s/y). The inhalation rate used assumes conditions of light exercise (4.2×10^{-4} m^3/s) (ICRP 1994). The internal dose conversion factor of 96 rem/Ci for inhalation and absorption is also used (EPA 1988; ICRP 1979). The resulting annual dose is 9.8×10^{-4} mrem. Appendix A lists the specific input parameters used by the RESRAD code to calculate the burial worker dose and presents the RESRAD output.

3.2 Potential Public Doses

The most likely radiation dose to the public from the disposal of Pinellas waste at the USPCI facility is based on atmospheric emission of tritium. Exposure via groundwater and surface water is not included because the assumption that USPCI releases lead to exposures through these pathways is not reasonable. The groundwater consists of a shallow salty-brine aquifer. Groundwater flow is slow [e.g., two test results of hydraulic conductivity are 5×10^{-4} and 1.9×10^{-4} cm/s (9.93×10^{-4} and 3.78×10^{-5} ft/min)] and the deeper zone of the aquifer has an upward gradient. The groundwater quality is poor (e.g., high average total dissolved solids level ranging from 88,000 to 100,000 ppm; high chloride level of about 44,000 ppm) (L. Griffith, USPCI, Inc., personal communication with M. L. Socolof, ORNL, September 7 and 19, 1995). The groundwater and surface waters in the area of the USPCI site do not have beneficial uses (e.g., potable water, fishing). The nearest pubic drinking water source is a groundwater source in the town of Gransville, approximately 97 km (60 mi) east-southeast of the site. Surface water is essentially absent from the area. Surface water quality data are generally unavailable for Tooele County, which is a reflection of the lack of water and population centers. The only water quality station is in Big Spring near Timpie [about 32 km (20 mi) east of the site]. The spring feeds a waterfowl management area and has no other uses. The water is very hard and very high in dissolved solids, primarily sodium chloride. Moderate concentrations of arsenic, nickel, copper, and silver are also present (NRC 1993).

No food crops are grown or cattle grazed in this desert region. The only grazing that may occur is during the spring in the Grayback Mountains [never occurring closer than 8 km

(5 mi) to the landfill]. Therefore, the greatest potential for public exposure is through direct inhalation. The public dose is calculated using RESRAD (Yu et al. 1993), which assumes a hypothetical maximally exposed individual, located directly above the covered waste, is inhaling tritium released to the atmosphere.

Most of the same site-specific parameters used for the burial worker assessment are used to calculate the public dose. However, for the public exposure scenario, the waste is assumed to be covered and the maximally exposed member of the public is assumed to spend 100% of his time breathing contaminated air released from the landfill. This analysis conservatively assumes exposure begins immediately after the waste is put in place and covered. This assumption ignores (1) the required 30-year institutional control period stipulated in the facility's RCRA permit and (2) the fact that the facility will likely operate for an additional 30 to 50 years. Regarding the landfill cover, the RESRAD code uses a reference cover depth of 0.3 m, above which no tritium escapes through this distance and into the atmosphere. Therefore, the minimum anticipated depth of the cover material at USPCI of 1.3 m (see Sect. 2.2.3) is not used in the analysis. If this cover depth were used, RESRAD would calculate a dose of zero since more time is needed for the cover to erode away than for the tritium to radioactively decay to a negligible dose.

The inhalation rate for the public is assumed to be 8400 m^3/y, which is a weighted sum of a human's resting and light exercise inhalation rates (ICRP 1994). The dose conversion factor is assumed to be 96 rem/Ci, accounting for inhalation and absorption (EPA 1988, ICRP 1979). The annual dose represented over time is shown in Fig. 3.1. The maximum public dose of 1.2×10^{-5} mrem/y occurs after about 14 years. The dose initially increases with time as the cover is eroding. However, after approximately 14 years, the dose begins to decrease with time due to the radioactive decay of tritium and other source-reducing factors (e.g., leaching). Note that this analysis assumes a thinner cap than would be placed on the waste at USPCI. If the dose were modeled with the appropriate cap depth, there also would be virtually no exposure. Appendix A lists the specific input parameters used by the RESRAD code to calculate the public doses and also presents the output.

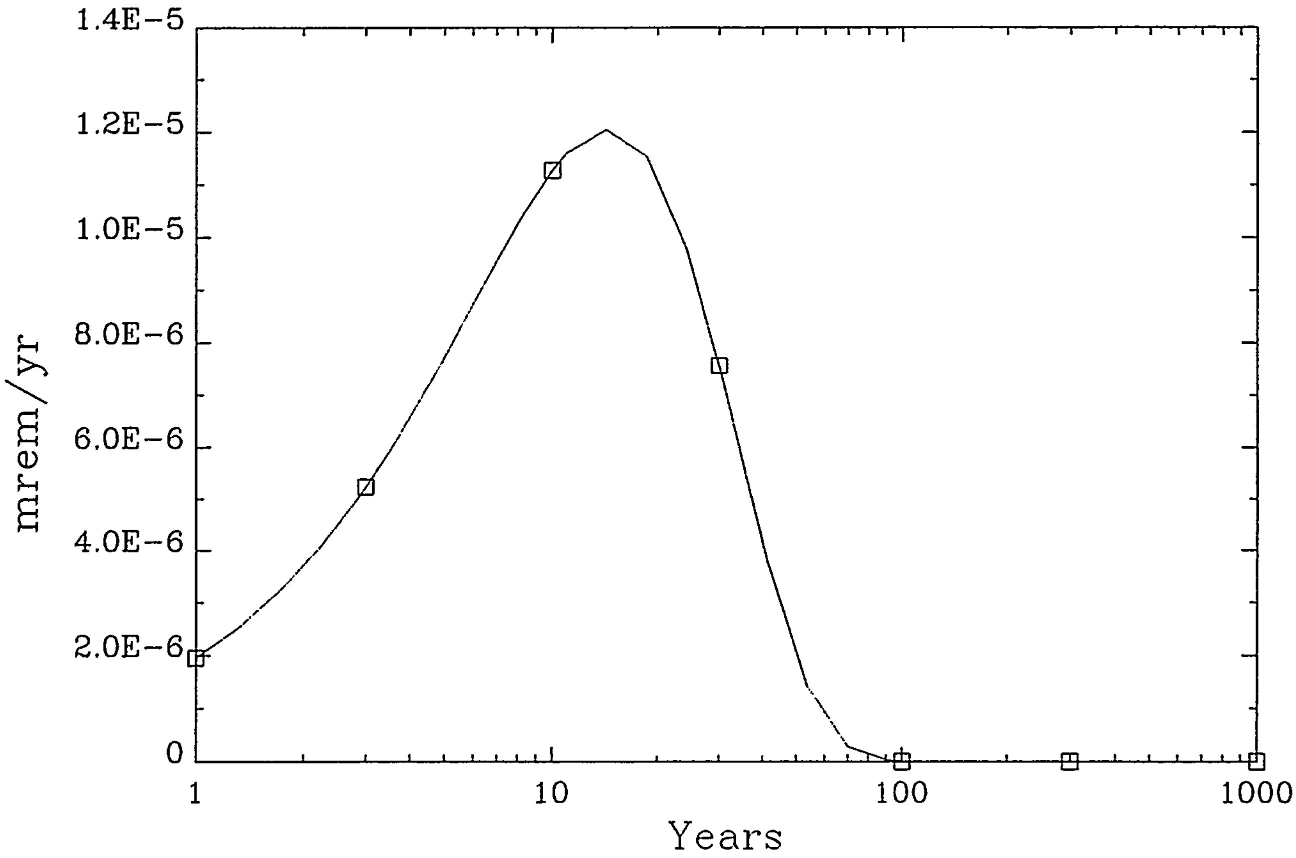

Fig. 3.1. Public Dose from Inhalation of Tritium.

4. DISCUSSION OF RESULTS

4.1 Summary of Results

The results of this upper-bound dose assessment reveal extremely low annual doses (Table 4.1). The conservative assumptions made throughout the analyses lead to overestimates of dose. The following are some of the major conservative assumptions:

- For the worker exposure scenarios, the dose conversion factor used assumes 50% of the inhaled dose is absorbed through the skin. However, the use of personal protective equipment would reduce the surface area of exposed skin and thus the amount of tritium absorbed through the skin.

- For stabilization activities, one load of waste was assumed to be stabilized at a time, instead of two loads being mixed and stabilized together.

- For the burial worker exposure scenario, no additional waste or cover is assumed to be placed on top of the Pinellas waste for a year and the worker is assumed to spend nine hours of every working day for a year above the RCRA cell that would contain the Pinellas waste.

- For the burial worker and the public exposure scenarios, the evapotranspiration coefficient is assumed to be the maximum of 1.0. By reducing the coefficient to 0.5, the doses calculated by the RESRAD code would only be reduced by a factor of about six.

- For the public exposure scenario, a member of the public is assumed to stand above the buried waste 100% of the time inhaling water vapor contaminated with tritium. This ignores institutional controls, which are required by the RCRA permit for 30 years. Furthermore, the facility is likely to continue to operate for 30 to 50 more years before closure. Therefore, public access would not occur until 60 to 80 years after the waste was placed in the landfill. The dose assessment also ignores the designation of the West Desert Hazardous Industry Area, which precludes residential housing in this area and may restrict access.

- For the public exposure scenario, the assumption of a 0.3 m cover results in higher doses than expected since the cover would be at least 1.3 m (4.3 ft) thick.

4.2 Comparison to Background and Regulatory Limits

The doses calculated in this analysis are compared to background levels and existing regulatory limits. The average background dose from all sources of radiation to a U.S.

Table 4.1 Summary of radiological doses

Exposure scenario	Dose (mrem/y)[a]	Fraction of natural background[b]	Fraction of regulatory limit[c]
Waste sampling	4.7×10^{-6}	1.6×10^{-8}	9.4×10^{-10}
Waste stabilization	6.0×10^{-6}	2.0×10^{-8}	1.2×10^{-9}
Waste burial	9.8×10^{-4}	3.3×10^{-6}	2.0×10^{-7}
Public exposure[d]	1.2×10^{-5}	4.0×10^{-8}	1.2×10^{-6}

[a] Waste sampling and waste stabilization are from short-term exposure scenarios that occur within one year. Because the doses are so low, no acute radiation effects are anticipated. Therefore, the most reasonable comparison is to annual background and annual occupational dose levels. The waste burial and public exposure scenarios are from longer-term exposures that are also compared to annual background and annual occupational doses.

[b] Annual average individual natural background level is 300 mrem.

[c] Occupational limit = 5000 mrem/y; public limit = 10 mrem/y.

[d] Peak annual exposure occurs about 14 years after placement of waste.

individual is about 360 mrem/y. The contribution of natural sources is about 300 mrem/y (NCRP 1987). The Nuclear Regulatory Commission (NRC) and DOE annual occupational dose limits are both 5,000 mrem (NRC 1995, DOE 1989). The NRC dose limit for protection of the public from all sources and all pathways combined is 100 mrem/y (NRC 1995). The Clean Air Act National Emissions Standards for Hazardous Air Pollutants (NESHAPs) require the public dose from all exposure pathways due to air emissions be below 10 mrem/y. Since air emissions are the only releases applicable to waste operations at the USPCI facility in Tooele, Utah, the more restrictive NESHAP is used for comparison to the public dose.

The worker doses from sampling, stabilization, and waste burial, and the public dose from inhalation of tritium are presented in Table 4.1. All the predicted doses are far below the natural background levels and the applicable regulatory limits. The percents of the natural background and of the regulatory limits for each scenario are also presented in Table 4.1. The worker doses from waste operations are 310 thousand to 64 million times less than radiation doses from natural sources and 5.1 million to 1.1 billion times less than the regulatory limit. The total public dose is 25 million times less than natural background and 830 thousand times less than the NESHAP limit. Therefore, despite the conservative assumptions about the potentially maximally exposed individuals, the doses are well below the regulatory limits, as well as being only a very small fraction of the average U.S. background levels.

4.3 Health Effects

The health effect associated with low-dose exposures to radiation is cancer. The risk of excess cancer fatalities has been quantified based on atomic bomb exposure data in which large doses of radiation were received. To determine cancer risks at low doses, a common assumption is that exposure to a carcinogen and the development of cancer follow a linear, no-threshold dose-response relationship. The International Commission on Radiological Protection (ICRP) used the atomic bomb exposure data to estimate excess cancer risks per unit dose due to chronic, low dose exposures. These conversion factors for workers and the public are 4×10^{-4} and 5×10^{-4} excess risk/rem, respectively. Despite the linear, no-threshold assumption, the ICRP cautions against using the cancer risk conversion factors for such low doses as those presented in this analysis. Therefore, although this assessment does not specifically quantify the cancer risk, the risk would be far below 1×10^{-7} or any risk level of concern. As discussed in Sect. 3.2, the public dose is virtually zero, emphasizing the point that there is no cancer risk of concern.

5. REFERENCES

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APPENDIX A

RESRAD VERSION 5.60 INPUT PARAMETERS AND DOSE SUMMARY

A.1 BURIAL WORKER SCENARIO

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	2.450E+01	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	5.800E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	3.000E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): H-3	2.834E+01	0.000E+00	---	S1(1)
R012	Concentration in groundwater (pCi/L): H-3	not used	0.000E+00	---	W1(1)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.150E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	3.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Humidity in air (g/cm**3)	4.700E+00	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	9.990E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.300E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	Zero shows Simpson's rule.	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for H-3				
R016	Contaminated zone (cm**3/g)	0.000E+00	0.000E+00	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	0.000E+00	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	0.000E+00	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.390E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R017	Inhalation rate (m**3/yr)	1.314E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Exposure duration	1.000E+00	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	not used	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	0.000E+00	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.600E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	not used	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	not used	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	not used	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	not used	1.000E+00	---	STOR_T(2)
STOR	Milk	not used	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	not used	2.000E+01	---	STOR_T(4)
STOR	Fish	not used	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	not used	7.000E+00	---	STOR_T(6)
STOR	Well water	not used	1.000E+00	---	STOR_T(7)
STOR	Surface water	not used	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	not used	4.500E+01	---	STOR_T(9)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	not used	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	suppressed
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	suppressed
9 -- radon	suppressed

Contaminated Zone Dimensions	
Area:	24.50 square meters
Thickness:	5.80 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
H-3	2.834E+01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	9.756E-04	8.024E-04	5.427E-04	1.379E-04	2.715E-06	2.493E-12	0.000E+00	0.000E+00
M(t):	3.252E-05	2.675E-05	1.809E-05	4.597E-06	9.052E-08	8.309E-14	0.000E+00	0.000E+00

Maximum TDOSE(t): 9.756E-04 mrem/yr at t = 0.000E+00 years

A.2 PUBLIC DOSE SCENARIO

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	2.450E+01	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	5.800E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	3.000E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): H-3	2.834E+01	0.000E+00	---	S1(1)
R012	Concentration in groundwater (pCi/L): H-3	not used	0.000E+00	---	W1(1)
R013	Cover depth (m)	3.000E-01	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.150E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	3.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Humidity in air (g/cm**3)	4.700E+00	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	9.990E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.300E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	Zero shows Simpson's rule.	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for H-3				
R016	Contaminated zone (cm**3/g)	0.000E+00	0.000E+00	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	0.000E+00	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	0.000E+00	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.390E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	not used	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	0.000E+00	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	1.000E+00	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	not used	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	not used	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	not used	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	not used	1.000E+00	---	STOR_T(2)
STOR	Milk	not used	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	not used	2.000E+01	---	STOR_T(4)
STOR	Fish	not used	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	not used	7.000E+00	---	STOR_T(6)
STOR	Well water	not used	1.000E+00	---	STOR_T(7)
STOR	Surface water	not used	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	not used	4.500E+01	---	STOR_T(9)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	not used	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	suppressed
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	suppressed
9 -- radon	suppressed

Contaminated Zone Dimensions	
Area:	24.50 square meters
Thickness:	5.80 meters
Cover Depth:	0.30 meters

Initial Soil Concentrations, pCi/g	
H-3	2.834E+01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	0.000E+00	1.960E-06	5.235E-06	1.128E-05	7.564E-06	7.186E-09	0.000E+00	0.000E+00
M(t):	0.000E+00	6.535E-08	1.745E-07	3.759E-07	2.521E-07	2.395E-10	0.000E+00	0.000E+00

Maximum TDOSE(t): 1.206E-05 mrem/yr at t = 14.34 þ 0.01 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 14.34 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
H-3	0.000E+00	0.0000	1.206E-05	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	1.206E-05	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 14.34 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
H-3	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.206E-05	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.206E-05	1.0000

*Sum of all water independent and dependent pathways.

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