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TECHNICAL MEMORANDUM RADIOLOGICAL ASSESSMENT FOR RESIDUAL ACTIVITY GUIDELINES ALAMEDA POINT INSTALLATION RESTORATION SITES 5 AND 10

ALAMEDA POINT
(FORMER NAVAL AIR STATION ALAMEDA)
ALAMEDA, CALIFORNIA

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Technical Memorandum
Radiological Assessment for Residual Activity Guidelines
Alameda Point
Installation Restoration Sites 5 and 10
Alameda, California

1. Introduction and Purpose

The purpose, technical background, and information concerning initial characterization of Installation Restoration (IR) Sites 5 and 10 at Alameda Point is presented. The site background and concise operational history for the sites are also presented in this section.

1.1 Purpose

An Action Memorandum for a removal action for radiological contamination has been approved (TtEMI 1998b) by the Department of Toxic Substances Control (DTSC) for these sites. The approved Action Memorandum for this removal action establishes a residual radioactivity criterion for pipes below grade at a radiation dose of 25 millirem per year, with a further reduction to 15 millirem per year (TtEMI 1988b) in order to achieve the as low as reasonably achievable (ALARA) criteria.

The purpose of this technical memorandum is to support the dose criterion contained in the Action Memorandum, by developing a residual activity criterion that can be directly measured. This will be accomplished by demonstrating, based on the directly measurable criterion, that radiation doses to the defined population group will not exceed 15 millirem per year. The directly measurable residual radioactivity criterion selected were based on the point source equivalent measurement methodology. This methodology relies on quantification of gamma emission of radium progeny to quantify the radium present. The residual radioactivity criterion that will be used at Sites 5 and 10 are an average point source equivalent of 20 nanocuries of radium-226 averaged over a 10 meter section of pipe, with individual point measurements less than 60 nanocuries of radium-226. This technical memorandum supports the residual radioactivity criteria, and shows that resulting radiation doses will be substantially below the dose criterion, and also result in a health risk estimate within the acceptable health risk range.

1.2 Site Background

Alameda Point (formerly Naval Air Station[NAS] Alameda) lies at the geographic center of San Francisco Bay, occupying the western third of Alameda Island. Alameda Point occupies 2,842 acres: 1,734 acres is land, and 1,108 acres consists of water and an airspace easement. Most of the land at Alameda Point was created by filling existing tidelands, marshlands, and sloughs. NAS Alameda was closed in April 1997 under the Base Realignment and Closure program.

Radioactive contamination and buried radioactive materials have been identified at several locations at Alameda Point, including drain lines at Sites 5 and 10 (PRC 1996a).

1.3 Concise Operational History

The following sections describe the operational history at Sites 5 and 10 locations as it relates to radiological concerns. The use of radioactive materials at Alameda Point began in the 1940s in Building 5 (IR Site 5), where radioluminescent aircraft instrument dials were refurbished with radium-226. The Building 5 radium operations ended in the late 1950s to early 1960s (exact date unknown). Similar radiological refurbishing operations were conducted in Building 400 (IR Site 10) from the 1950s up to the closing of the base.

Several areas are known or suspected of being contaminated with radioactive material. The radioactive contaminant of concern for these sites is radium-226. Radium-226 is a component of radioluminescent paint, which was commonly used, stored, and disposed of at Alameda Point. These paints are a combination of phosphorescent compounds and chemically separated radium. This paint was used to enhance night visibility of indicator needles, knobs, gun sites, markings on gauges, and on markers that lined the edges of ships (deck markers). Instrument shops that used radium-226 caused contamination of equipment, building surfaces and drainlines.

1.4 Initial Characterization

To characterize radiological contamination at Alameda Point, a series of radiological surveys were conducted. Radioactive contamination was detected in piping, equipment, and building surfaces of both Buildings 5 and 400 as well as drain lines, storm sewers, manholes, and entrained sediments associated with those buildings (PRC 1996a). Based on the results of the radiological surveys, it was recommended that further investigations and removal actions be

considered for IR Site 5 (Building 5), IR Site 10 (Building 400), and storm sewer line F and related manholes (associated with Buildings 5 and 400).

IR Sites 5 and 10 contain lines confirmed to be contaminated and lines suspected of being contaminated with radium-226. The lines running within Buildings 5 (Site 5) and 400 (Site 10) are constructed of cast iron (or steel) pipe and concrete (larger diameter sewer lines). Some of these lines have been identified for remedial action in the Final Radiological Removal Action Technical Work Document/Removal Action Plan (TtEMI 1998a). Other lines will be identified as the work progresses. Conditions at these sites pose a potential exposure of building occupants, demolition workers, or sewer repair personnel to ionizing radiation from radium-226 and progeny (including lead-210).

2. Technical Approach

The Navy determined that use of a radiation dose assessment methodology was more appropriate than a risk based assessment[1] for determining the extent of the removal action for any remaining buried and small diameter pipes at Sites 5 and 10. Refer to Section 2.4 for the basis for this determination. An approximate estimate of the cumulative risk using Environmental Protection Agency (EPA) radiological risk estimation factors (EPA 1995, EPA 1998a) is also presented in Section 5 of this document in order to permit the estimated doses to be compared from a health risk perspective.

2.1 Criterion for Removal Action

In accordance with the Action Memorandum for this removal action (TtEMI 1988b), two criteria must be established, first a residual radioactivity criterion to determine where pipeline contamination may require excavation and removal of pipes, and second a detection limit criterion for surveying suspect piping to assure that the methods of surveying are sufficiently sensitive to allow detection of contaminated areas. This technical memorandum supports selection of an average point source equivalent criterion of 20 nanocuries as corresponding to less than 15 millirem per year to an average member of the critical population group. This document also supports the use of a 15 nanocurie (as a point source) detection limit criterion for

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1 The baseline risk assessment methodology guidance documents provided by EPA do not describe a method for assessing the situation at Alameda Point, therefore, in accordance with EPA guidance (EPA 1991), a site-specific approach was prepared under the direction of a health physicist.

any final surveys that will be conducted after removal of impacted pipe sections and for checking associated lateral piping. The 15 nanocurie detection limit proposed herein is significantly less than the 100 nanocurie detection limit originally approved for the project by the DTSC.

2.2 Conceptual Model Selection

In order to establish a relationship between the permissible annual dose limit of 15 millirem and a directly measurable numerical criterion within the pipelines at the site, a conceptual model of the site must be described. The conceptual model for this site consists of a series of pipe sections ranging from 4-inch diameter to 42-inch diameter. The sections are either below the building floor slab or below paved runways or taxiways. All pipe sections are at least 5-feet below grade, with some more than 10 feet in depth. Normal maintenance workers would not access these pipe sections. Heavy construction equipment would be required to access these pipe sections. Future work on these pipe sections would be for removal or replacement actions associated with major redevelopment of the site.

The conceptual model is discussed in more detail in Section 3 below.

2.3 Exposure Scenario Selection

Following the conceptual model, specific exposure scenarios must be described. The exposure scenarios consider the potential use of the building. Potential uses of an industrial building can be classified into two major categories: building occupancy and building remediation. Building occupancy scenarios include residential use and commercial office or industrial workers. Building remediation scenarios include decontamination worker, building renovation worker, and demolition worker. Exposure in the building occupancy scenarios are usually rather long-term chronic exposures, whereas exposure in building remediation scenarios are usually short-term exposures. The principal differences between these scenarios are the exposure duration, the amount and rate of contaminants released into air, and the pathways involved. For the buried pipeline sections, described in the conceptual model, only the building renovation worker scenario is analyzed for the following reasons:

- Residual activity levels are so low that exposure rates in occupied buildings are not distinguishable from background.

- Pipes are buried 5 feet or more beneath a reinforced concrete slab, therefore only a major construction project or demolition of the buildings could expose these pipes for direct access.

NRC (NRC 1992) also analyzed what scenarios might be appropriate and concluded that renovation and demolition can be represented by the same conceptual model. This analysis has selected and included substantially the same scenarios utilized in the NRC generic model.

The total radiation dose calculated is the sum of the contributions from the identified scenarios (NRC 1992).

2.4 Use of a Dose Based Assessment

The basis for formulating a residual activity criterion in terms of an annual dose limit is contained in two federal documents. First the National Contingency Plan (NCP) at 40 CFR Part 300 (EPA 1990) favors use of applicable and relevant or appropriate requirements (ARAR) over risk-based assessments where they can be applied[2]. Second, the Nuclear Regulatory Commission (NRC) has promulgated a dose based ARAR (NRC 1997) suitable to the specific circumstances at Alameda Point[3]. Inasmuch as the ARAR has been promulgated by the NRC, the Navy is using NRC interpretive guidelines to the extent feasible for developing removal action numerical goals. The new NRC guidelines and criteria do not rely on NRC Regulatory Guide 1.86 (NRC 1974) which was the previous Federal basis for residual activity criteria.

2.5 Computer Code Selection

The Navy considered two codes, the NRC's recently released generic code (NRC 1998c), "Decontamination and Decommissioning" (DandD) and the Department of Energy's RESRAD-BUILD (ANL 1994). The DandD code is available[4] but complete documentation is not yet available. DandD incorporates the scenarios, models, mathematical formulations, assumptions, and justifications of parameter selections documented in NUREG/CR-5512, Volume 1. This

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2 10 CFR 20.1402 addresses multiple pathways and multiple radioactive contaminants, thus it is the preferred type of ARAR contemplated by 40 CFR 300, et. seq. See Section 300.400 (e)(2)(A)(2),

3 See 10 CFR Part 20.1402 and the Action Memorandum at page 21.

4 This code is available from the Internet.

generic modeling approach defines radiation exposure scenarios to address residual radioactive contamination inside buildings, in soils, and in groundwater.

The Navy has determined that DandD is not a suitable code for modeling the unique site conditions at Site 5, Alameda Point, because; it is a screening level model; has limited flexibility to vary input parameters; and cannot model specific source configurations. Consistent with NRC guidelines, the Navy is using a site-specific modeling approach for Alameda Point. This approach is acceptable to the NRC as described in NUREG 1549 (NRC 1988a) and Regulatory Guide DG-4006 (NRC 1988b). Regulatory Position 2 (Section 2.10.4) of DG-4006 addresses embedded piping and suggests that a necessary approach may be to consider in dose assessment, renovation of the building that would disturb the piping, and that the survey should be consistent with the dose modeling assumptions (NRC 1998).

Under the auspices of the U.S. Department of Energy, Argonne National Lab (ANL 1994) developed a computer code for evaluation of residual radioactive material. RESRAD-BUILD can be used to derive residual radioactive material guidelines in buildings. This code can be used to develop guidelines for residual radioactivity for a wide variety of source configurations, building geometries, and intake pathways and has sufficient flexibility for modeling the unique site conditions at Alameda Point. The Navy believes that RESRAD-BUILD is an appropriate methodology to develop residual radioactivity guidelines for the pipelines at Alameda Point. RESRAD-BUILD (ANL, Version 2.20, June 1997) was used in this evaluation.

2.6 Detector Sensitivity

For purposes of measurement and calibration, all pipe surveys were designed around the assumption that the activity was concentrated at a point. Thus, detection sensitivity requirements could be specified to the removal action and survey contractor. For the initial pipeline characterization, a sensitivity was required such that a point source of 100 nanocuries could be detected by a scan or at the maximum distance from a fixed point reading if using regularly spaced measurements. The survey contractor was required to demonstrate that this activity could be detected on a scan or on a series of equally spaced fixed point readings. The regulatory agencies approved this approach for the characterization of Sites 5 and 10.

2.7 Validation Measurements

A measurement study recently performed by New World Technology (NWT 1998) using actual material from Site 5 showed that within a 12-inch pipe, an average activity of approximately[5] 2,200 dpm/100 cm^2 (100 nCi/m^2) responded as would a 2-inch sodium iodide (NaI) detector exposed to a 50 nCi point source of radium-226. This result shows that the measurement technique is compatible with the dose modeling approach and that NaI detectors can be used to estimate surface activity within pipe.

RESRAD-BUILD was also used to estimate the detector response for a detector centered between two adjacent contaminated surfaces[6], each 0.5 m^2 area, with the detector positioned 0.5 cm above the surface. Using RESRAD-BUILD, a dose rate of 3 microrem per hour was estimated. This corresponds to a nominal[7] detector response of 2700 cpm for a 2-inch NaI detector. Depending on the exact calibration factor, this equates to approximately a 40-60 nanocurie point source. This example shows that the external dose model used by RESRAD-BUILD produces results similar to those obtained by direct measurement.

3. RESRAD-BUILD Model

Based on the conceptual model for major building renovation and demolition, several exposure pathways are combined to estimate potential exposure to the average member of the critical population group of demolition workers. The parameter selection, exposure pathways and hot spot criteria are discussed in the following subsections.

3.1 Parameter Selection

Using the conceptual model and exposure scenarios described, parameters are developed and applied to a computer code that calculates radiation doses from residual radioactivity. Where

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5 This average activity was determined by a series of beta-gamma surface activity measurements inside a 12 inch diameter pipe. Beta-gamma surrogate measurements are more appropriate for rough surfaces. The Final Status Radiation Survey And Field Sampling Workplan (TtEMI 1998c) Section 6.6.4 (page 27) describes the method of characterization for drain lines.

6 In order to model a pipe, a dose rate was calculated for a square half-space with the detector centered along one edge of the 0.5 m^2 area; the dose rate was doubled to represent a 1 m^2 area with an aspect ratio of 2.

7 The detector manufacturer (Ludlum Instruments) states that the response is 900 cpm per microrad per hour.

exposure parameters from NRC (NUREG/CR-5512 [NRC 1992], NUREG 1549 [NRC 1998a] or supporting documentation) are available, they are noted[8]. Otherwise conservative assumptions which tend to overestimate the annual dose are made and described. Refer to Table 1 for a comparison of the NRC default parameters to the RESRAD default parameters and the parameter values used. All parametric values used with RESRAD-BUILD are described in this report, in either the text, accompanying tables, or in the attached computer printouts. In order for the dose model and survey methodology to be consistent, residual activity is modeled both as a point source and a distributed area source. The area source is an approximate representation of the activity contained within the point source and must be used with some RESRAD-BUILD scenarios.

The exposure scenario includes three exposure pathways with dose components for each pathway. These pathways are described in detail in the following sections.

Complete RESRAD-BUILD results for an initial evaluation without consideration of erosion, decay time factors, or other time-dependent factors are provided in the appendices. Integrated doses over the first 30 years (the period over which risk is estimated) would be lower if these factors were included the risk estimate, however, they are not included in the assessment in order to simplify the modeling effort.

Tables 2 and 3 summarize the parameters used in the included RESRAD-BUILD runs. The scenario codes (A1, F, and so forth) correspond to input file names used by the program. These input file names appear on the printouts provided as attachments. These input files can be made available for use by regulatory agency staff.

3.2 EXPOSURE PATHWAYS

Table 4 identifies the pathways RESRAD-BUILD can consider and which were applied to this model.

The first three pathways would result in external exposures, and the others would result in internal exposure due to internal contamination of the exposed individual. RESRAD-BUILD allows the user to vary any of the input parameters and to select the time of exposure, duration of exposure, source configuration, and the pathways to be considered.

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[8] The default parameter values established in NUREG/CR-5512 have been established by NRC as sufficiently conservative for a screening level assessment.

3.3 General Assumptions to All Analyses in RESRAD-BUILD Runs

The factors described in this section are common to all RESRAD-BUILD runs.

- Dose factors for radium-226 and progeny and lead-210 and progeny are used for all calculations. Any radium-226 sources are thus evaluated as if they are in equilibrium concentration with progeny; therefore, ingrowth and decay of progeny need not be considered further. Only the evaluation at time zero needs to be considered because it represents the maximum dose condition.

- All evaluation times for RESRAD-BUILD runs are for the time zero result.

- The calculation basis presented in data printout is an areal concentration of 4×10^4 pCi/m^2 (40 nCi/m^2) of radium-226 and the same areal concentration of lead-210. Since 2,200 dpm/100 cm^2 equates to 1 nCi/100 cm^2 or 100 nCi/m^2, the calculation basis is then 880 dpm/100 cm^2. The results of dose tabulation correspond to a surface contamination areal concentration of 880 dpm/100 cm^2.

- An average annual dose is calculated on the basis of a 30-year work life at Alameda Point and one project every 5 years involving exposure as described for this scenario. This corresponds to 90 days of exposure to the conditions described in the scenario in the years 1, 6, 11, 16, 21, and 26 following completion of the work.

- The average annual dose is converted to risk using the EPA age- and gender-weighted conversion factor for cancer morbidity (incidence) for external exposure. For ingestion and inhalation, factors were taken from Federal Guidance Report No. 13 (EPA 1998a) and converted from intake quantities to dose in accordance with EPA recommended methods (EPA 1998b).

3.4 Hot Spot Criteria

Based on the doses calculated for the average activity, small hot spots will not substantially affect the external pathway radiation dose estimate, as external exposure only accounts for less than 5 percent of the total dose. The inhalation and ingestion pathways are based on average concentrations; therefore, provided the average activity within a 10-meter section meets the average criteria, presence of hot spots will not have an impact on the conclusions of the dose assessment.

3.5 Detailed Exposure Pathway Descriptions

The direct, ingestion, and inhalation pathways and specific parametric values used are described in the following subsections.

3.5.1 Direct Exposure Pathway

The scenario for direct exposure is based on a worker in contact with a 12 inch diameter pipe that is contaminated internally with a 20 nCi point source of radium. A dose is calculated for a 0.375 inch (Schedule 40) pipe wall[9]. The worker is at a distance of 0.5 meter for 90 days per year (for 8 hours per day[h/d]) and at 1.0 meters (8 h/d) for 90 days per year. If the building were demolished, a large excavation necessary for a high-rise construction would be an unlikely event, due to proximity of the water table (the present buildings do not have basements). If these pipes were to be removed, a narrow trench would be excavated and the pipes would be lifted from above with heavy equipment[10], so exposure time to individual workers would be limited. The 90 day estimate would be sufficient for a worker who had to remove up to 270 pipe sections (3 per day) containing the reference quantity of activity. A 10-meter line source of pipe containing 20 nCi/m of radium-226 results in a more conservative dose estimate than for a point source, therefore this source was also included in the external exposure estimate, for a 8 hour per day exposure duration at 1 meter distance.

Attachment 1 presents the results of a RESRAD-BUILD run (Scenario A1) for the 0.5-meter source-to- receptor distance shielded source. Attachment 2 presents the results of a RESRAD-BUILD run (Scenario A2) for the 1.0-meter source-to- receptor distance shielded source. Attachment 3 presents the results of a RESRAD-BUILD run (Scenario F) for the 10-meter source-to-receptor distance to a shielded line source.

3.5.2 Ingestion Pathway

The scenario for ingestion considers a construction worker who handles contaminated pipe or residual soil activity during a future construction activity then ingests contaminated material after handling the pipe. Secondary ingestion is also considered in examining the inhalation

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9 Concrete is the material used in the shielding calculation. This results in a conservative estimate for ferrous metal or concrete pipe.

10 Modern construction equipment could grapple and lift pipe sections from a deep excavation without the need for person entry. NRC (NRC 1992) notes that demolition may be remote, involving heavy wrecking equipment.

pathway. The ingestion pathway appears to be the limiting (or critical) pathway based on scenarios analyzed. The worker is assumed to ingest loose sediment or sludge material contaminated to a concentration of 10 picocuries per gram (which is 2 times the numerical cleanup goal for soil) at soil ingestion rate of 50 milligrams per day (0.5 picocuries ingested per day). For this scenario, the workers source of exposure could be from handling pipe, entering the excavation, or otherwise coming into contact with the pipe. The exposure duration for this scenario is 90 working days per year (45 picocuries total ingestion). Material contaminated at this level would have been identified and removed by the present removal action. Attachment 4 presents the results of a RESRAD-BUILD run (Scenario C) for the ingestion pathway.

3.5.3 Inhalation Pathway

The scenario for the inhalation pathway simulates a worker entering a contaminated sewer pipe (hypothetically large enough for entry) or excavation pit with limited air re-circulation. This activity concentration is 40 nCi of radium-226 per square meter with a source size of 10 square meters. For purposes of this model, the entire source is released in 730 days (2 years). Dust concentrations are calculated within the code, but are not otherwise available. A value of 0.2 is used in the model for the removable fraction of radioactive material. Secondary ingestion of dust is modeled at a rate of 1×10^{-4} per m^2 per hour of the fraction released to air. Additionally, direct ingestion of radium-226 at a rate of 1×10^{-5} per hour is included. This scenario considers the worker entering the sewer every working day for two hours per day for 90 days per year. Attachment 5 presents the results of a RESRAD-BUILD run (Scenario D) for the inhalation pathway.

In order to estimate the total quantity of intake by the inhalation pathway, inhalation exposure was also evaluated using a dust mass loading approach. A source of soil at 5 pCi per gram was assumed to contribute 60 percent of the airborne dust the worker inhales. The dust loading is established at a high value of 0.005 grams of dust per cubic meter of air. The worker inhales air at a rate of 18 cubic meters per day. The same exposure duration is used as above. The quantity of radium-226 inhaled is 3.4 pCi per year. This result give the same annual inhalation dose calculated using RESRAD-BUILD as the above scenario. This inhalation quantity value is then used in the risk estimate.

4. SUMMARY OF DOSES

The doses calculated are presented by pathway and by component if more than one dose component makes up the pathway. Refer to Table 5 for a summary of the estimated radiation doses by pathway. The calculated dose for the construction or demolition scenario is 1.81 millirem per year for an average construction worker involved in demolition of Building 5 and excavation of associated buried pipelines and laterals.

These scenarios are considered to be representative of the average member of the critical population group[11] that may be exposed in the future. The most restrictive condition of the scenarios discussed are also considered consistent with the reasonable maximum exposure[12] case required by EPA for risk assessment.

5. Health Risk Estimate

The estimated lifetime health risk expressed as a lifetime excess total cancer risk (risk) is presented in this section.

The risk is estimated by two methods used by EPA. The first method (uses a commonly applied oversimplification of the prescribed process [EPA 1991, 1994, 1995, 1988b], converts dose directly to a risk estimate. The second method, which is more precise, considers the pathway (ingestion, inhalation, or external), and applies a risk conversion factor to each estimated quantity of intake or exposure. Based on factors that the EPA[13] provides, the risk conversion factor is a risk of 2.3×10^{-5} per millirem per year over a 30-year exposure period. Using that factor and the average dose of 0.30 millirem per year equates to a lifetime risk of 6.9×10^{-6}. A more precise estimate can be obtained by using the total lifetime excess cancer risk slope factors that are given by EPA (EPA 1995) for radium-226 and lead-210 including the effects of the progeny. The pertinent data is reproduced in the Table 6.

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11 Critical population group (CPG) is a term used in NRC regulated activities such as release for unrestricted use.

12 Reasonable maximum exposure (RME) is a term used in EPA CERCLA response actions for baseline human health risk assessments

13 Converted from the EPA risk factor is 7.6×10^{-7} risk per millirem per year for total cancer incidence over all organs and genders [EPA 402-R-96-016]

The slope factors are 1.3×10^{-9} total cancers per picocurie ingested and 6.6×10^{-9} total cancers per picocurie inhaled for the entire radium-226 decay series. Using these factors, the conceptual model and scenarios described, and the approximate activity ingested using the over 30 years, equates to an excess lifetime cancer incidence risk of 3.1×10^{-6} for any individual from internal and external sources. The acceptable risk range for industrial workers is generally accepted as below 1×10^{-4}.

TABLE 1

EVALUATION OF SELECTED PARAMETRIC VALUES

Parameter	NRC DandD Default	RESRAD Default	Value Selected This Study	Notes
Dust Loading	0.001 g/m^3	na	0.005 g/m^3	RESRAD and DandD use different approaches to model air concentrations.
Inhalation Rate	1.2 m^3/h	18 m^3/d	18 m^3/d	
Secondary Ingestion	10^{-4}/h	10^{-4}/h	10^{-5}/h	Ingestion is also directly included at 0.05 g/d.
Soil Ingestion	0.01g/h	0 g/h	0.05 g/d	EPA (EPA 1991) recommends 0.05 g/d for industrial settings.
Resuspension	0.0000005 /s	0.0000005 /s	0.000001 /s	
Renovation Period	90 d	na	90 d	
Removable Fraction	na	0.5	0.2	DandD uses the dust loading model
Building Height	na	2.5 m	2 m	DandD uses the dust loading model
Source Area	na	36 m^2	10 m^2	DandD uses the dust loading model
Air Exchange Rate	na	0.8 /h	0.8 /h	DandD uses the dust loading model
Inhalation Dose Conversion Ra-226	0.00858 mrem/pCi	0.0086 mrem/pCi	0.0086	NRC values are from FGR-11 (EPA 1988)
Ingestion Dose Conversion[14] Pb-210	0.0053 mrem/pCi	0.00727 mrem/pCi	0.00727	The factor 0.00536 is the stochastic limit value. The RESRAD default factor was used in all calculations.

Notes:

pCi	picoCurie	h	hour
m	meter	y	year
g	gram	s	second
m^2	square meter		

[14] The values in FGR-11 are in units of Sievert (Sv) per Becquerel (Bq). The units are converted using the factor is (3700 mrem/pCi) per (Sv/Bq). FGR-11 provides data which is used to derive a non-stochastic dose conversion factor (DCF) and a stochastic DCF. The non-stochastic factor is appropriate for radiation workers for protection of the bone from non-stochastic effects with a dose limit of 50 rem. DandD and RESRAD both use a stochastic DCF value.

TABLE 2

PARAMETRIC INPUT VALUES FOR RESRAD-BUILD

Parametric Values for Ingestion and Inhalation Scenarios

Scenario	Source Concentration	Source Area	Ingestion Fraction/Hour	Direct Ingestion (m^2/h)	Resuspension Rate (s^{-1})	Deposition Velocity (m/s)	Exposure Duration (d)	Exposure Frequency (h/d)	Total Hours
C	10 pCi/g	na	0.00625 g/h	na	na	na	90	8	720
D	40,000 pCi/m^2	10 m^2	0.00001	0.0001	0.000001	0.01	90	2	180

Parametric Values for External Exposure Scenarios

Scenario	Source Concentration	Source Area	Geometry	Source to Receptor Distance (m)	Exposure Frequency (h/d)	Exposure Duration (d)	Total Hours
A1	20 nCi	na	point	0.5	8	90	720
A2	20 nCi	na	point	1	8	90	720
F	40 nCi/m	na	line	1	8	90	720

Notes:

pCi	picoCurie
m	meter
g	gram
m^2	square meter
s	second
h	hour
y	year
na	not applicable to the scenario

TABLE 3

SUMMARY OF PATHWAYS MODELED AND FACTORS USED FOR RISK ESTIMATION

Scenario	Geometry	Concentration	Pathway	Component	Annual Intake (pCi)	Annual Dose (millirem)
A1	point	20 nCi	External	External	na	0.037
A2	point	20 nCi	External	External	na	0.0092
F	line	20 nCi/m	External	External	na	0.051
C	volume	10 pCi/g	Ingestion	Ingestion	45	0.387
D	area	40 nCi/m^2	Inhalation	Deposition	na	0.038
D	area	40 nCi/m^2	Inhalation	Inhalation	3.4	0.033
D	area	40 nCi/m^2	Inhalation	Ingestion	145	1.25
Totals			**All**	**All**		**1.81**

Notes: pCi picoCurie
m meter
g gram
m^2 square meter
s second
h hour
y year

TABLE 4

SUMMARY PATHWAY ANALYSIS

Pathway	Included in Scenario	Discussion
External exposure to penetrating radiation emitted directly from the sources.	Direct exposure included	Point and line sources are included in estimating direct exposure.
External exposure to penetrating radiation emitted from radioactive particulate deposited onto the floors of the compartments.	As deposition	Any deposition would be small and diluted in an outdoor construction scenario. Included in inhalation scenario as deposition fraction
External exposure to penetrating radiation due to submersion to airborne radioactive particulate.	no	Insignificant for outdoor scenario
Inhalation of airborne radioactive particulate.	yes	There are no closed rooms during construction scenario. A calculation is included to illustrate the impact of entering a pipeline or limited ventilation excavation. Deposition, inhalation and ingestion are included in this scenario.
Inhalation of aerosol indoor radon decay products.	No	Outdoor scenario precludes radon buildup
Inadvertent ingestion of radioactive material contained in removable material directly from the source	yes	This is handled by converting the 0.5 pci per day to an ingestion rate for RESRAD-BUILD input. Ingestion is also included in the inhalation model.
Inadvertent ingestion of airborne radioactive particulate deposited onto the surface of the building.	No	Ingestion is estimated at 0.5 pci/d and included above

Table 5

SUMMARY OF CALCULATED DOSES AND RISKS

Pathway	Component	Calculated Dose Component (millirem)	Average Dose (millirem)	Average Lifetime Risk ($\times 10^{-6}$)	Notes
External Point	Distance 0.5 meter	0.037	0.006	0.138	Point source
External Point	Distance 1 meter	0.0092	0.0015	0.03	Point source
External Line	Distance 1 meter	0.05	0.008	0.184	Line source
Ingestion	45 pCi ingestion	0.387	0.06	0.42	Direct soil ingestion
Inhalation	deposition	0.038	0.006	0.004	External dose from settled material
Inhalation	inhalation	0.033	0.005	0.89	Direct inhalation
Inhalation	ingestion	1.25	0.20	1.36	Ingestion via settled material
All	**All**	**1.81**	**0.30**	**3.04**	

Notes:

Average lifetime risk is calculated from the average of the annual intakes listed in Table 3.

Risk is total (mortality and morbidity) excess lifetime cancer risk.

Lifetime Excess Cancer Risk Slope Factors
(reproduced from EPA (EPA 1995)

Table 4: Radionuclide Carcinogenicity -- Slope Factors[a] November 1995
(In Units of Picocuries[b])

Element (Atomic Number)	Isotope[c]	CASRN[d]	Radioactive Half-life[e]		ICRP Lung Class[f]	GI Absorption Factor (f_1)[g]	Slope Factor Lifetime Excess Total Cancer Risk Per Unit Intake or Exposure: Ingestion (Risk/pCi)	Inhalation (Risk/pCi)	External Exposure (Risk/yr per pCi/g soil)
Lead (82)	Pb-203	014687-25-3	5.20E+01	H	D	2.00E-01	1.03E-12	3.10E-13	6.40E-07
	Pb-209	014119-30-3	3.25E+00	H	D	2.00E-01	2.09E-13	6.85E-14	0
	Pb-210	014255-04-0	2.23E+01	Y	D	2.00E-01	6.75E-10	1.67E-09	1.12E-10
	Pb-210+D	014255-04-0(+D)	2.23E+01	Y	D	2.00E-01	1.01E-09	3.86E-09	1.45E-10
	Pb-211	015616-77-0	3.61E+01	M	D	2.00E-01	3.38E-13	1.03E-11	1.85E-07
	Pb-212	015092-94-1	1.06E+01	H	D	2.00E-01	1.80E-11	3.85E-11	3.00E-07
	Pb-214	015067-28-4	2.68E+01	M	D	2.00E-01	2.94E-13	6.23E-12	7.09E-07
Radium (88)	Ra-223	015623-45-7	1.14E+01	D	W	2.00E-01	2.34E-10	3.60E-09	2.44E-07
	Ra-224	013233-32-4	3.62E+00	D	W	2.00E-01	1.49E-10	2.25E-09	2.48E-08
	Ra-225	013981-53-8	1.48E+01	D	W	2.00E-01	1.57E-10	2.38E-09	1.71E-09
	Ra-226	013982-63-3	1.60E+03	Y	W	2.00E-01	2.95E-10	2.72E-09	1.31E-08
	Ra-226+D	013982-63-3(+D)	1.60E+03	Y	W	2.00E-01	2.98E-10	2.75E-09	6.74E-08
	Ra-228	015262-20-1	5.75E+00	Y	W	2.00E-01	2.46E-10	9.61E-10	0

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Attachment 1

Scenario 1

Dose Rate From Residual Activity In A Steel Pipe Located Near The Worker Contaminated With A 20 pCi Point Source Of Radium-226

(Run RADIUMA1)

RESRAD-BUILD Output

CENTER 1995 AGENCY HEADER HERE
OI FORM REPORT
ALL HANDLERS

DATABASE DIR: c:\brs95 SOURCE FILE: OFFSITE

EPA ID NO. HIT000603514 NAME UNITEK ENVIRONMENTAL SERVICES, INC.

SITE #	A. OFF-SITE ID	B. OFF-SITE NAME
4		LUIGI FIGUEROA

C. HANDLER TYPE
X GENERATOR
TRANSPORTER
TSDR

D. STREET 1 92-438 FARRINGTON HWY.
STREET 2
CITY EWA BEACH
STATE HI ZIP 96707-

COMMENTS: OI PAGE: 161
2959-0

Title : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.I

RESRAD-BUILD Table of Contents

DATABASE DIR: c:\brs95 SOURCE FILE: OFFSITE

EPA ID NO. HIT000603514 NAME UNITEK ENVIRONMENTAL SERVICES, INC.

SITE #	A. OFF-SITE ID	B. OFF-SITE NAME
2		LINDSEY'S KAPAHULU SHELL

C. HANDLER TYPE
X GENERATOR
TRANSPORTER
TSDR

D. STREET 1 755 KAPAHULU AVENUE
STREET 2
CITY HONOLULU
STATE HI ZIP 96816-

COMMENTS: OI PAGE: 160
6430-0

Title : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.I

RESRAD-BUILD Input Parameters

Number of Sources : 1
Number of Receptors: 1
Total Time : 9.000000E+01 days
Fraction Inside : 3.330000E-01

Receptor Information

Receptor	Room	x [m]	y [m]	z [m]	FracTime	Inhalation [m3/day]	Ingestion(Dust) [m2/hr]
1	1	0.000	0.000	0.500	1.000	1.80E+01	1.00E-04

Receptor-Source Shielding Relationship

Receptor	Source	Density [g/cm3]	Thickness [cm]	Material
1	1	2.40E+00	9.52E-01	Concrete

CENTER 1995 AGENCY HEADER HERE
OI FORM REPORT
ALL HANDLERS

DATABASE DIR: c:\brs95 SOURCE FILE: OFFSITE

EPA ID NO. HIT000603514 NAME UNITEK ENVIRONMENTAL SERVICES, INC.

SITE #	A. OFF-SITE ID	B. OFF-SITE NAME
2		LEX BRODIE'S TIRE COMPANY - HILO

C. HANDLER TYPE
X GENERATOR
TRANSPORTER
TSDR

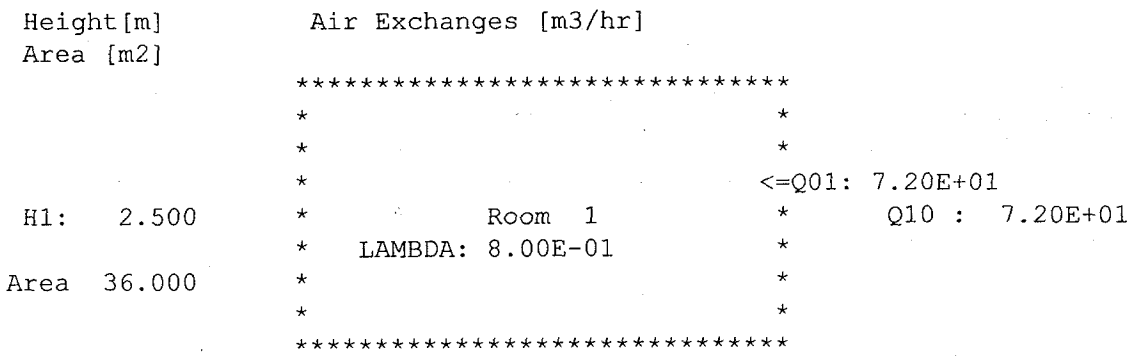
D. STREET 1 170D WIWOOLE STREET
STREET 2
CITY HILO
STATE HI ZIP 96720-

COMMENTS: OI PAGE: 159
5157-0

Title : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.I

Building Information

Building Air Exchange Rate: 8.00E-01 1/hr



Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

DATABASE DIR: c:\brs95 SOURCE FILE: OFFSITE

EPA ID NO. HIT000603514 NAME UNITEK ENVIRONMENTAL SERVICES, INC.

SITE # 5

A. OFF-SITE ID

B. OFF-SITE NAME
LAUPAHOEHOE TRANSPORT. - KONA

C. HANDLER TYPE
X GENERATOR
TRANSPORTER
TSDR

D. STREET 1 74-5610 ALAPA STREET
STREET 2
CITY KAILUA-KONA
STATE HI ZIP 96740-

COMMENTS:
6371-10

OI PAGE: 157

Title : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.I

Source Information

Source: 1
Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]
Geometry:: Type: Point
Pathway ::
Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 0.000E+00
Removable fraction: 0.000E+00
Time to Remove: 1.000E+04 [day]

Radon Release Fraction: 0.000E+00

Contamination::

Nuclide	Concentration	Dose Conversion Factors				
		Ingestion	Inhalation	External (Surface)	External (Volume)	Submersion
	[pCi]	[mrem/pCi]	[mrem/pCi]	[mrem/yr/ (pCi/m2)]	[mrem/yr/ (pCi/m3)]	[mrem/yr/ (pCi/m3)]
A-226	2.000E+04	1.330E-03	8.600E-03	1.940E-04	7.000E-06	1.040E-02
PB-210	2.000E+04	7.270E-03	2.320E-02	4.140E-07	3.820E-09	1.430E-05

DATABASE DIR: c:\brs95 SOURCE FILE: OFFSITE

EPA ID NO. HIT000603514 NAME UNITEK ENVIRONMENTAL SERVICES, INC.

SITE # 5

A. OFF-SITE ID

B. OFF-SITE NAME
LARRY'S FOREIGN AUTO

C. HANDLER TYPE
X GENERATOR
TRANSPORTER
TSDR

D. STREET 1 440 D ULUMAU
STREET 2
CITY HAIKU
STATE HI ZIP 96708-

COMMENTS:
6385-0

OI PAGE: 156

Title : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.IEvaluation Time: 0.000000 years

Assessment for Time: 1
Time =0.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]
Geometry:: Type: Point
Pathway ::

Direct Ingestion Rate:	0.000E+00 [1/hr]
Fraction released to air:	0.000E+00
Removable fraction:	0.000E+00
Time to Remove:	1.000E+04 [day]

Contamination::

Nuclide	Concentration [pCi]
RA-226	2.000E+04
PB-210	2.000E+04

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OI FORM REPORT
ALL HANDLERS

DATABASE DIR: c:\brs95 SOURCE FILE: OFFSITE

EPA ID NO. HIT000603514 NAME UNITEK ENVIRONMENTAL SERVICES, INC.

SITE #	A. OFF-SITE ID	B. OFF-SITE NAME
3		LAHAINALUNA HIGH AUTO SHOP

C. HANDLER TYPE
X GENERATOR
TRANSPORTER
TSDR

D. STREET 1 980 LAHAINALUNA RD.
STREET 2
CITY LAHAINA
STATE HI ZIP 96761-

COMMENTS:
6394-0

OI PAGE: 155

Title : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.IEvaluation Time: 0.000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

	Source 1	Total
Receptor 1	3.7E-02	3.7E-02
Total	3.7E-02	3.7E-02

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OI FORM REPORT
ALL HANDLERS

DATABASE DIR: c:\brs95 SOURCE FILE: OFFSITE

EPA ID NO. HIT000603514 NAME UNITEK ENVIRONMENTAL SERVICES, INC.

SITE # 3

A. OFF-SITE ID

B. OFF-SITE NAME
KUULEI UNION SERVICE

C. HANDLER TYPE
X GENERATOR
TRANSPORTER
TSDR

D. STREET 1 330 KUULEI RD
STREET 2
CITY KAILUA
STATE HI ZIP 96734-

COMMENTS:
6360-0

OI PAGE: 154

Title : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.IEvaluation Time: 0.000000 years

Pathway Detail of Doses

[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	3.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	3.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

☒ External	☐ Deposition	☐ Immersion	☐ Inhalation	☐ Radon	☐ Ingestion

Only the pathway checked was included in the calculation.

itle : point source for radium 20 nci
Input File : C:\WINBLD\RADIUMA1.IEvaluation Time: 0.000000 years

Nuclide Detail of Doses

[mrem]

ource: 1

Nuclide	Receptor 1	Total
RA-226		
RA-226	3.69E-02	3.69E-02
PB-210		
PB-210	3.30E-05	3.30E-05

Attachment 2

Scenario A2

Dose Rate From Residual Activity In A Steel Pipe Located Near The Worker Contaminated With A 20 pCi Point Source Of Radium-226

(Run RADIUMA2)

RESRAD-BUILD Output

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.I

RESRAD-BUILD Table of Contents

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.I

RESRAD-BUILD Input Parameters

Number of Sources : 1
Number of Receptors: 1
Total Time : 9.000000E+01 days
Fraction Inside : 3.330000E-01

Receptor Information

Receptor	Room	x [m]	y [m]	z [m]	FracTime	Inhalation [m3/day]	Ingestion(Dust) [m2/hr]
1	1	0.000	0.000	1.000	1.000	1.80E+01	1.00E-04

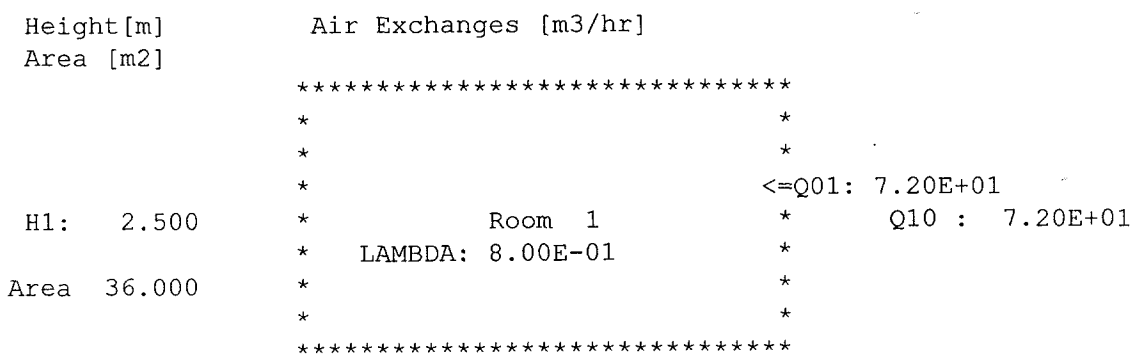
Receptor-Source Shielding Relationship

Receptor	Source	Density [g/cm3]	Thickness [cm]	Material
1	1	2.40E+00	9.52E-01	Concrete

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.I

Building Information

Building Air Exchange Rate: 8.00E-01 1/hr



Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.I

Source Information

Source: 1
Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]
Geometry:: Type: Point
Pathway ::
Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 0.000E+00
Removable fraction: 0.000E+00
Time to Remove: 1.000E+04 [day]

Radon Release Fraction: 0.000E+00

Contamination::

Nuclide	Concentration	Dose Conversion Factors				
		Ingestion	Inhalation	External (Surface)	External (Volume)	Submersion
	[pCi]	[mrem/pCi]	[mrem/pCi]	[mrem/yr/ (pCi/m2)]	[mrem/yr/ (pCi/m3)]	[mrem/yr/ (pCi/m3)]
A-226	2.000E+04	1.330E-03	8.600E-03	1.940E-04	7.000E-06	1.040E-02
PB-210	2.000E+04	7.270E-03	2.320E-02	4.140E-07	3.820E-09	1.430E-05

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.IEvaluation Time: 0.000000 years

Assessment for Time: 1
Time =0.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]
Geometry:: Type: Point
Pathway ::
Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 0.000E+00
Removable fraction: 0.000E+00
Time to Remove: 1.000E+04 [day]

Contamination::

Nuclide	Concentration [pCi]
RA-226	2.000E+04
PB-210	2.000E+04

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.IEvaluation Time: 0.000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

	Source 1	Total
Receptor 1	9.2E-03	9.2E-03
Total	9.2E-03	9.2E-03

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.IEvaluation Time: 0.000000 years

Pathway Detail of Doses

[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	9.24E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	9.24E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

☒ External	☐ Deposition	☐ Immersion	☐ Inhalation	☐ Radon	☐ Ingestion

Only the pathway checked was included in the calculation.

Title : point source for radium 20 nci @ 1m
Input File : C:\WINBLD\RADIUMA2.IEvaluation Time: 0.000000 years

Nuclide Detail of Doses

[mrem]

ource: 1

Nuclide	Receptor 1	Total
RA-226		
RA-226	9.23E-03	9.23E-03
PB-210		
PB-210	8.18E-06	8.18E-06

Attachment 3

Scenario F

Dose Rate From Residual Activity In A Steel Pipe Located Near The Worker Contaminated With A 20 pCi per meter Line Source Of Radium-226

(Run RADIUMF)

RESRAD-BUILD Output

Title : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.IN

RESRAD-BUILD Table of Contents

Title : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.IN

RESRAD-BUILD Input Parameters

Number of Sources : 1
Number of Receptors: 1
Total Time : 9.000000E+01 days
Fraction Inside : 3.330000E-01

Receptor Information

Receptor	Room	x [m]	y [m]	z [m]	FracTime	Inhalation [m3/day]	Ingestion(Dust) [m2/hr]
1	1	0.000	0.000	1.000	1.000	1.80E+01	0.00E+00

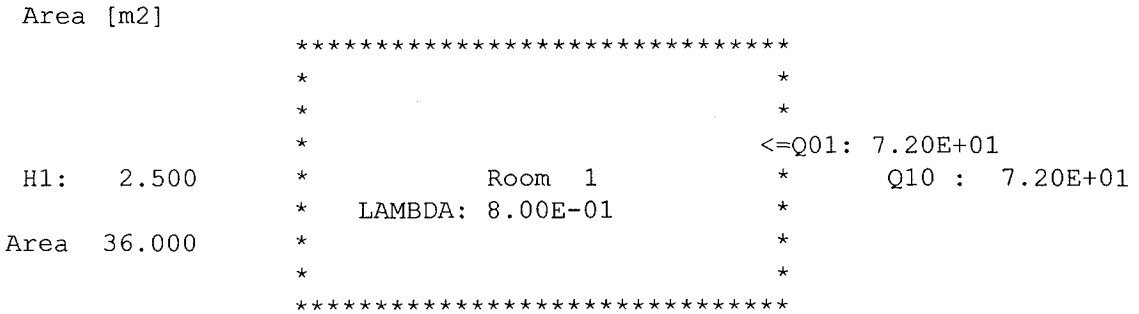
Receptor-Source Shielding Relationship

Receptor	Source	Density [g/cm3]	Thickness [cm]	Material
1	1	2.40E+00	3.75E-01	Concrete

Title : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.IN

Building Information

Building Air Exchange Rate: 8.00E-01 1/hr



Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.IN

Source Information

Source: 1
Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]
Geometry:: Type: Line Length:1.00E+01 [m] Direction: x
Pathway ::
Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 0.000E+00
Removable fraction: 0.000E+00
Time to Remove: 1.000E+04 [day]

Radon Release Fraction: 0.000E+00

Contamination::

Nuclide	Concentration	Dose Conversion Factors				
		Ingestion	Inhalation	External (Surface)	External (Volume)	Submersion
	[pCi/m]	[mrem/pCi]	[mrem/pCi]	[mrem/yr/ (pCi/m2)]	[mrem/yr/ (pCi/m3)]	[mrem/yr/ (pCi/m3)]
A-226	4.000E+04	1.330E-03	8.600E-03	1.940E-04	7.000E-06	1.040E-02
PB-210	4.000E+04	7.270E-03	2.320E-02	4.140E-07	3.820E-09	1.430E-05

Title : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.INEvaluation Time: 0.000000 years

Assessment for Time: 1
Time =0.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]
Geometry:: Type: Line Length:1.00E+01 [m] Direction: x
Pathway ::

Direct Ingestion Rate:	0.000E+00 [1/hr]
Fraction released to air:	0.000E+00
Removable fraction:	0.000E+00
Time to Remove:	1.000E+04 [day]

Contamination::

Nuclide	Concentration [pCi/m]
RA-226	4.000E+04
PB-210	4.000E+04

Title : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.INEvaluation Time: 0.000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

	Source 1	Total
Receptor 1	5.1E-02	5.1E-02
Total	5.1E-02	5.1E-02

itle : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.INEvaluation Time: 0.000000 years

Pathway Detail of Doses

[mrem]

ource: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	5.06E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	5.06E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

☒ External	☐ Deposition	☐ Immersion	☐ Inhalation	☐ Radon	☐ Ingestion

Only the pathway checked was included in the calculation.

itle : line source for radium 40 nci/m 8 h/d @
Input File : C:\WINBLD\RADIUMF.INEvaluation Time: 0.000000 years

Nuclide Detail of Doses

[mrem]

ource: 1

Nuclide	Receptor 1	Total
RA-226		
RA-226	5.05E-02	5.05E-02
PB-210		
PB-210	6.60E-05	6.60E-05

Attachment 4

Scenario C

A Construction Worker Who Handles Contaminated Pipe Or Residual Soil Activity During A Future Construction Activity And Ingests Contaminated Material From Handling The Pipe

(Run RADIUMC

RESRAD-BUILD Output

Title : ingestion case soil conc @ 10p/g for 90
Input File : C:\WINBLD\RADIUMC.IN

RESRAD-BUILD Table of Contents

itle : ingestion case soil conc @ 10p/g for 90
Input File : C:\WINBLD\RADIUMC.IN

RESRAD-BUILD Input Parameters

Number of Sources : 1
Number of Receptors: 1
Total Time : 9.000000E+01 days
Fraction Inside : 3.330000E-01

Receptor Information

eceptor	Room	x [m]	y [m]	z [m]	FracTime	Inhalation [m3/day]	Ingestion(Dust) [m2/hr]
1	1	0.000	0.000	10.000	1.000	1.80E+01	0.00E+00

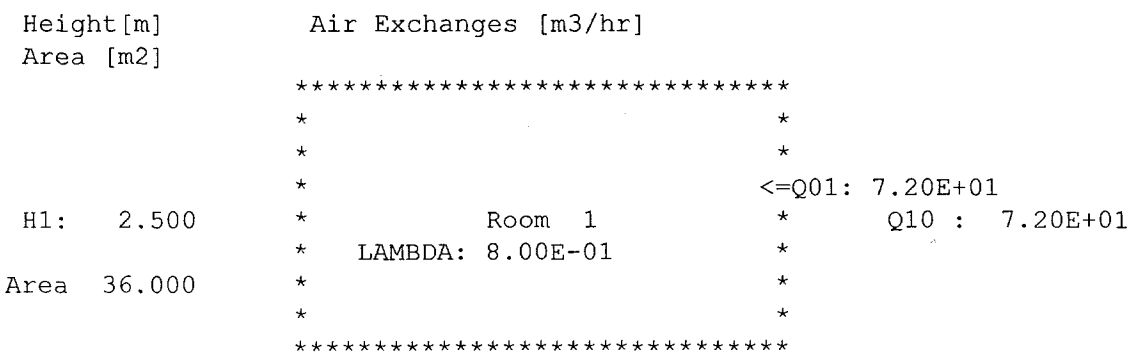
Receptor-Source Shielding Relationship

Receptor	Source	Density [g/cm3]	Thickness [cm]	Material
1	1	2.40E+00	0.00E+00	Concrete

Title : ingestion case soil conc @ 10p/g for 90
Input File : C:\WINBLD\RADIUMC.IN

Building Information

Building Air Exchange Rate: 8.00E-01 1/hr



Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : ingestion case soil conc @ 10p/g for 90
Input File : C:\WINBLD\RADIUMC.IN

Source Information

Source: 1
Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]
Geometry:: Type: Volume Area:1.00E+01 [m2] Direction: z
Pathway ::
Direct Ingestion Rate: 6.250E-03 [gm/hr]
Fraction released to air: 0.000E+00

Containment :: Number of Regions: 1 Contaminated Region: 1

Region	: 1
Thickness [cm]	:1.50E+01
Density [g/cm3]	:2.40E+00
Material	:Concrete
Erosion Rate [cm/day]	:2.40E-08
Porosity	:1.00E-01
Eff. Diffusion [m2/s]	:2.00E-05
Emanation Fractions (1)	:2.00E-01
(2)	:2.00E-01

Contamination::

Nuclide	Concentration	Dose Conversion Factors				
		Ingestion	Inhalation	External (Surface)	External (Volume)	Submersion
	[pCi/g]	[mrem/pCi]	[mrem/pCi]	[mrem/yr/ (pCi/m2)]	[mrem/yr/ (pCi/m3)]	[mrem/yr/ (pCi/m3)]
RA-226	1.000E+01	1.330E-03	8.600E-03	1.940E-04	7.000E-06	1.040E-02
PB-210	1.000E+01	7.270E-03	2.320E-02	4.140E-07	3.820E-09	1.430E-05

Title : ingestion case soil conc @ 10p/g for 90
Input File : C:\WINBLD\RADIUMC.INEvaluation Time: 0.000000 years

Assessment for Time: 1
Time =0.00E+00 yr

Source Information

Source: 1
Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]
Geometry:: Type: Volume Area:1.00E+01 [m2] Direction: z
Pathway ::
Direct Ingestion Rate :6.250E-03 [gm/hr]
Fraction released to air: 0.000E+00

Containment :: Number of Regions: 1 Contaminated Region: 1
Region : 1
Thickness [cm] :1.50E+01
Fraction Contaminated :1.00E+00
Density [g/cm3] :2.40E+00

Contamination::

Nuclide	Concentration [pCi/g]
RA-226	1.000E+01
PB-210	1.000E+01

Title : ingestion case soil conc @ 10p/g for 90
Input File : C:\WINBLD\RADIUMC.INEvaluation Time: 0.000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

	Source 1	Total
Receptor 1	1.5E+00	1.5E+00
Total	1.5E+00	1.5E+00

Title : ingestion case soil conc @ 10p/g for 90
Input File : C:\WINBLD\RADIUMC.INEvaluation Time: 0.000000 years

Pathway Detail of Doses

[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	1.08E-01	0.00E+00	0.00E+00	0.00E+00	1.03E+00	3.87E-01
Total	1.08E-01	0.00E+00	0.00E+00	0.00E+00	1.03E+00	3.87E-01

☐	☐	☐	☐	☐	☒
External	Deposition	Immersion	Inhalation	Radon	Ingestion

Only the pathway checked was included in the calculation.

Nuclide Detail of Doses

[mrem]

Source: 1

Nuclide	Receptor 1	Total
RA-226		
RA-226	1.20E+00	1.20E+00
PB-210		
PB-210	3.27E-01	3.27E-01

Attachment 5

Scenario D

Inhalation

A Construction Worker Who Enters a Pit and Inhales Soil Activity and Ingests Soil Activity from Resuspension During A Future Construction Activity

(Run RADIUMD

RESRAD-BUILD Output

Title : inhalation radium 40,000 pci/m2
Input File : C:\WINBLD\RADIUMD.IN

RESRAD-BUILD Table of Contents

Title : inhalation radium 40,000 pci/m2
nput File : C:\WINBLD\RADIUMD.IN

RESRAD-BUILD Input Parameters

Number of Sources : 1
Number of Receptors: 1
Total Time : 9.000000E+01 days
Fraction Inside : 3.330000E-01

Receptor Information

Receptor	Room	x [m]	y [m]	z [m]	FracTime	Inhalation [m3/day]	Ingestion(Dust) [m2/hr]
1	1	0.000	0.000	0.500	0.250	1.80E+01	1.00E-04

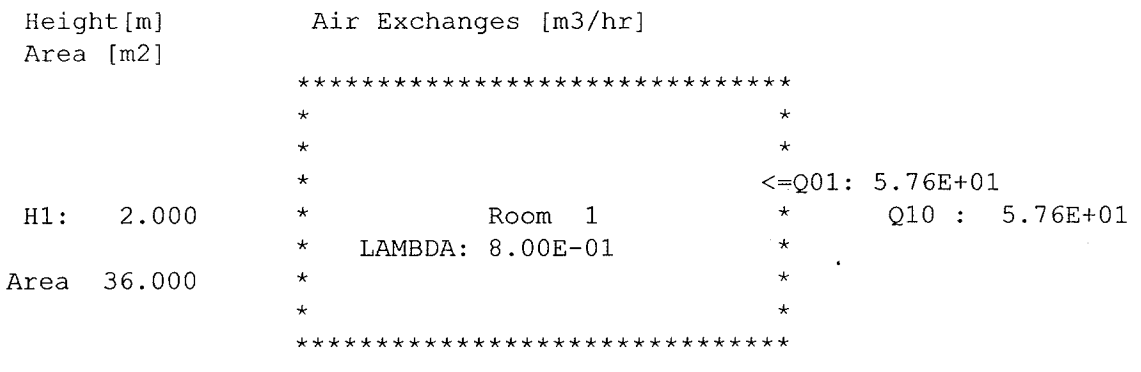
Receptor-Source Shielding Relationship

Receptor	Source	Density [g/cm3]	Thickness [cm]	Material
1	1	2.40E+00	0.00E+00	Concrete

Title : inhalation radium 40,000 pci/m2
nput File : C:\WINBLD\RADIUMD.IN

Building Information

Building Air Exchange Rate: 8.00E-01 1/hr



Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 1.00E-06 [1/s]

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]
Geometry:: Type: Area Area:1.00E+01 [m2] Direction: z
Pathway ::
Direct Ingestion Rate: 1.000E-05 [1/hr]
Fraction released to air: 1.000E-01
Removable fraction: 2.000E-01
Time to Remove: 7.200E+02 [day]

Radon Release Fraction: 0.000E+00

Contamination::

Nuclide	Concentration	Dose Conversion Factors				
		Ingestion	Inhalation	External (Surface)	External (Volume)	Submersion
	[pCi/m2]	[mrem/pCi]	[mrem/pCi]	[mrem/yr/ (pCi/m2)]	[mrem/yr/ (pCi/m3)]	[mrem/yr/ (pCi/m3)]
RA-226	4.000E+04	1.330E-03	8.600E-03	1.940E-04	7.000E-06	1.040E-02
PB-210	4.000E+04	7.270E-03	2.320E-02	4.140E-07	3.820E-09	1.430E-05

Title : inhalation radium 40,000 pci/m2
Input File : C:\WINBLD\RADIUMD.INEvaluation Time: 0.000000 years

Assessment for Time: 1
Time =0.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]
Geometry:: Type: Area Area:1.00E+01 [m2] Direction: z
Pathway ::
Direct Ingestion Rate: 1.000E-05 [1/hr]
Fraction released to air: 1.000E-01
Removable fraction: 2.000E-01
Time to Remove: 7.200E+02 [day]

Contamination::

Nuclide	Concentration [pCi/m2]
RA-226	4.000E+04
PB-210	4.000E+04

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

	Source 1	Total
Receptor 1	1.3E+00	1.3E+00
Total	1.3E+00	1.3E+00

Title : inhalation radium 40,000 pci/m2
Input File : C:\WINBLD\RADIUMD.INEvaluation Time: 0.000000 years

Pathway Detail of Doses

[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	3.87E-02	7.25E-05	1.72E-06	3.39E-02	2.25E-08	1.25E+00
Total	3.87E-02	7.25E-05	1.72E-06	3.39E-02	2.25E-08	1.25E+00

☐	☒	☐	☒	☐	☒
External	Deposition	Immersion	Inhalation	Radon	Ingestion

Only the pathway checked was included in the calculation.

Title : inhalation radium 40,000 pci/m2
Input File : C:\WINBLD\RADIUMD.INEvaluation Time: 0.000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

Nuclide	Receptor 1	Total
RA-226		
RA-226	2.41E-01	2.41E-01
PB-210		
PB-210	1.08E+00	1.08E+00