PNL-10855
~~AD-902~~
EM-2010

Assessment of Unabated Facility Emission Potentials for Evaluating Airborne Radionuclide Monitoring Requirements at Pacific Northwest National Laboratory - 1995

M. Y. Ballinger
S. J. Jette
M. J. Sula

November 1995

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Richland, Washington 99352

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Summary

Assessments were performed to evaluate compliance with the airborne radionuclide emission monitoring requirements in the National Emission Standards for Hazardous Air Pollutants (NESHAP - U.S. Code of Federal Regulations, Title 40 Part 61, Subpart H). In these assessments, potential unabated offsite doses were evaluated for 31 emission locations at the Department of Energy's Pacific Northwest National Laboratory (DOE-Northwest) on the Hanford Site. Four of the buildings met State and Federal criteria for continuous sampling of airborne radionuclide emissions:

324 Building:	Waste Technology Engineering Laboratory
325 Building:	Applied Chemistry Laboratory
327 Building:	Post Irradiation Testing Laboratory
3720 Building:	Chemistry and Material Sciences Laboratory

The assessments were performed using building radionuclide inventory data obtained in 1995. Results of the assessments are summarized in Table S.1.

Table S.1. Radionuclide NESHAP Assessment Summary: DOE-Northwest Hanford Buildings

Building Evaluated	Continuous Emission Sampling Required	Building Evaluated	Continuous Emission Sampling Required
242-B/BL	No	329	No
2718-E	No	331/331-A	No
300-N	No	331-C	No
303-C	No	331-G	No
303-J	No	331-H	No
305-B	No	3708	No
306-W	No	3720	Yes
314	No	3730	No
318/318-Tr4	No	3745	No
318-Tr5	No	3745-B	No
320	No	3746-A	No
323	No	622-R	No
324	Yes	622-D	No
325	Yes	6652 (ALE)	No
326	No	747A	No
327	Yes		

Contents

Tables

1.0 Introduction

Requirements for sampling for airborne radionuclide emissions are contained in the following regulations and guides:

- U.S. Code of Federal Regulations (CFR), Title 40, Subpart H: National Emission Standards for Hazardous Air Pollutants (NESHAP)(1989)
- Washington Administrative Code (WAC) 246-247: Radiation Protection - Air Emissions (1994)
- U. S. Department of Energy, DOE 5400.1: General Environmental Protection Program (1990)
- U. S. Department of Energy, DOE/EH-0173T, Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (January 1991).

These documents require that continuous sampling be performed at emission points that have the potential to cause an offsite dose of 0.1 mrem/yr if routine emissions were not mitigated by engineered pollution control systems. In addition, DOE 5400.1 specifies that a written plan be prepared for each facility that uses, generates, releases, or manages signficant pollutants or hazardous materials. Thus, a Facility Effluent Monitoring Plan (FEMP) is prepared for facilities that require continuous sampling according to NESHAP.

In response to these requirements, the potential unmitigated offsite receptor dose from Battelle-operated facilities containing radioactive materials or sources is evaluated annually. These evaluations were performed initially in 1991 for the Department of Energy's Pacific Northwest National Laboratory[a] (DOE-Northwest) facilities on the Hanford Site. Based on the assessments, four buildings were identified as containing a sufficient inventory of radioactive material such that unmitigated emissions could potentially result in an annual offsite maximum receptor dose of 0.1 mrem. These buildings were the 324 Waste Technology Engineering Laboratory, the 325 Applied Chemistry Laboratory, the 327 Post Irradiation Testing Laboratory, and the 3720 Chemistry and Material Sciences Laboratory. In accordance with the NESHAP and the DOE regulatory guide, qualifying emission points from these buildings are sampled continuously. Also, in accordance with DOE 5400.1, FEMPs were prepared for these buildings.[b]

(a) Operated by Battelle under contract DE-AC06-76RLO 1830.

(b) PNL-MA-660. Facility Effluent Monitoring Plan for the 324 Facility. Facilities Management, Pacific Northwest Laboratory, Richland, Washington. November 1991.

PNL-MA-661. Facility Effluent Monitoring Plan for the 325 Facility. Facilities Management, Pacific Northwest Laboratory, Richland, Washington. November 1991.

PNL-MA-662. Facility Effluent Monitoring Plan for the 327 Facility. Facilities Management, Pacific Northwest Laboratory, Richland, Washington. November 1991.

PNL-MA-663. Facility Effluent Monitoring Plan for the 3720 Facility. Facilities Management, Pacific Northwest Laboratory, Richland, Washington. November 1991.

The original radionuclide assessments were updated in 1992, 1993, and 1994, and there were no changes in the facility emission NESHAP status. Results of the 1992-1993 assessment were documented by Sula and Jette (1994). This report documents the assessments of 31 DOE-Northwest facilities for 1995.

2.0 Assessment Methodology

Requirements for facility air emission sampling are promulgated by the Washington State Department of Health in Washington Administrative Code 246-247, "Regulation of Radioactive Air Emissions"; by the U.S. Environmental Protection Agency (EPA) in 40 CFR 61, "National Emissions Standards for Hazardous Air Pollutants," Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities"; and by the DOE in regulatory guide DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Monitoring and Environmental Surveillance." These regulations require that all emission units with the potential to emit radioactivity be evaluated and that the emission units be continuously sampled if there is the potential for unmitigated releases to cause a dose of 0.1 mrem per year to a maximum offsite receptor.

2.1 Projections of Annual Emission Quantities

Several methods for projecting potential unmitigated annual emission quantities are prescribed in the 1994 issuance of WAC 246-247:

- apply an annual release fraction to the radionuclide inventory in the facility
- multiply actual measured annual emissions by control system decontamination factors
- add actual measured annual emission quantities to actual measured quantities retained by control systems
- measure the annual discharge upstream from all control devices.

The inventory based assessment method[a] has been used by Battelle since the initial facility assessment in 1991. Whereas the inventory method yields an assessment based on the current building status (or even the future status if projected future inventory quantities are used in the assessment), the other prescribed methods yield an assessment based on past facility measurements. The inventory method may thus be more appropriate for use at research and development facilities where types and quantities of radionuclides may change from year to year and where historical sampling data may not be a reliable predictor of future emissions.

(a) This method is described in WAC 246-247-030 (21.a.) as follows. Multiply the annual possession quantity of each radionuclide by the release fraction for that radionuclide, depending on its physical state. Use the following release fractions: (i) 1 for gases, (ii) 10^{-3} for liquids or particulate solids, and (iii) 10^{-6} for solids. Determine the physical state for each radionuclide by considering its chemical form and the highest temperature to which it is subjected. Use a release fraction of 1 if the radionuclide is subjected to temperatures at or above its boiling point; use a release fraction of 10^{-3} if the radionuclide is subjected to temperatures at or above its melting point but below its boiling point. If the chemical form is not known, use a release fraction of 1 for any radionuclide that is heated to a temperature of one hundred degrees Celsius or more, boils at a temperature of one hundred degrees Celsius or less, or is intentionally dispersed into the environment.

At Battelle, radioactive source and material information is maintained using three separate inventory systems:

Nuclear Materials Inventory: This inventory includes the majority of tritium, uranium, and transuranics in PNL facilities. The inventory includes material in process as well as residual contamination from historical operations in the facility. The Nuclear Materials Inventory is categorized as "Type 3 inventory."

Composite Radioactive Materials Inventory. This inventory includes DOE and privately owned radionuclides used as calibration, testing, irradiation, or tracer sources. Most of the radionuclides in this inventory are in "sealed source" form. The Composite Radioactive Materials Inventory is categorized as "Type 2 inventory."

Facilities Management Radioactive Materials Inventory. This data base was developed specifically to account for all radioactive material not included in either the Type 2 or Type 3 inventories. This category consists primarily of fission product radionuclides, including radionuclides in process as well as residual contamination (e.g., in hot cells) from historical operations in the facility. The Facilities Management Radioactive Material Inventory is categorized as "Type 1 inventory."

In each of these inventories, radioactive materials are identified by type, physical form, and quantity. Quantities are expressed either in terms of activity (Ci) or mass (grams). Radioactive material types may be expressed as specific radionuclides or as standard mixtures of radionuclides. For example, mixed radionuclides may be expressed as natural uranium, depleted uranium, Hanford 6% (^{240}Pu) plutonium, etc., as shown in Table 1. In addition to the mixtures shown in the table, mixtures of fission products are assumed to consist of 50% ^{137}Cs and 50% ^{90}Sr. Individual radionuclides or mixtures of radionuclides in small quantities may also be reported as *alpha activity* or *beta activity* for simplification. These materials are assumed to be ^{241}Am (alpha) or ^{90}Sr (beta) for dose assessment purposes.

Radionuclides meeting any of the following criteria are excluded from the assessments:

- radionuclides present in commercially available building/construction materials
- radionuclides that can be purchased or possessed without a special radioactive materials license
- radionuclides <100 pCi/g alpha activity and <400 pCi/g beta activity.

Potential release fractions for radionuclides are based on the physical form of the radionuclide as shown in Table 2. Radionuclides present as sealed sources or in sealed, unvented Department of Transportation (DOT) shipping containers are assumed to be unavailable for release under normal circumstances.

Table 1. Common Radionuclide Mixtures

MATERIAL	ASSUMED RADIONUCLIDE	SPECIFIC ACTIVITY (Ci/g)
Depleted Uranium	^{238}U	3.64E-07
Natural Uranium	^{238}U	6.87E-07
U-enriched (<20% ^{235}U)	^{235}U	9.36E-06
U-enriched (<90% ^{235}U)	^{235}U	6.21E-05
Pu (6% ^{240}Pu)	^{239}Pu	8.00E-02
Pu (12% ^{240}Pu)	^{239}Pu	9.60E-02
Pu (24% ^{240}Pu)	^{239}Pu	3.48E-01

Table 2. Physical Forms and Potential Annual Release Fractions for Radionuclides

FORM	CODE	DESCRIPTION	POTENTIAL RELEASE FRACTION
Gas	G	Nuclide will exceed its boiling point when uncontained, except that nuclides in gaseous form in commercial gas cylinders that are not opened may be listed as L.	1
Liquid/Powder	L	Nuclide will exceed its melting point or be present in particulate form [Aerodynamic Mean Diameter (AMD) <100 microns] when uncontained, except liquid and powders in unopened containers may be listed as S.	10^{-3}
Solid	S	Nuclides not meeting conditions for the more dispersible classes.	10^{-6}
Contained	C	Sealed sources or material in sealed, DOT containers, except those meeting exempt criteria.	0
Exempt	E	Sealed sources engineered to pass the special form testing specified by the DOT in 40CFR173.469 or ANSI[a] N43.6, or sealed in Type B DOT shipping containers.	0

(a) American National Standards Institute.

2.2 Maximum Receptor Unit Dose Calculation

For the unit dose calculations, the maximum offsite receptor is defined as an individual whose residence location, work location, and lifestyle maximize the dose from airborne pathways. All potential environmental transport pathways associated with an airborne radionuclide release were included (i.e., air inhalation, air submersion, exposure to deposited radionuclides, uptake of vegetation grown in contaminated soil). In addition, site specific atmospheric dispersion and environmental transport and uptake parameters were used (see Appendix A).

Unit dose factors for the maximum offsite receptor were calculated for specific radionuclides using the EPA compliance code CAP88-PC (Parks 1992). The calculations were performed for a single source point in the 300 Area of the Hanford Site (Table 3) and a single source point in the 200 East Area of the Site (WHC 1991).

For Building 6652 (located in the Fitzner-Eberhardt Arid Land Ecology National Reserve), dose assessments were performed by applying a *location correction factor* to the 300 Area unit dose factor to correct for varying source-receptor distances and directions. The location correction factors was calculated by dividing the atmospheric dispersion values (Chi/Q) for 6652 by the atmospheric dispersion values for the 300 Area. CAP88-PC was used to calculate these dispersion values.

Appendix A describes how CAP88-PC was used to calculate the unit dose factors and Chi/Q dispersion factors.

2.3 Potential Emission Dose Assessment

Doses from projected radionuclide emissions were calculated by multiplying the quantity of each radionuclide present in the facility by its associated potential release fraction, the 300 Area unit dose factor, and the location correction factor. Doses from individual radionuclides were summed to derive the total potential annual emission dose for each facility.

A summary of the results of the assessment and the primary contributing radionuclides for facilities that require continuous monitoring is provided in Table 4.

Table 3. Unit Dose Factors for 300 Area Source Location

Nuclide	Dose (mrem/Ci)
H-3	4.23E-04
BE-7	4.57E-03
C-11	2.16E-04
C-14	5.06E-02
N-13	1.50E-04
O-15	3.86E-05
F-18	3.78E-04
NA-22	2.49E+00
NA-24	4.69E-03
P-32	5.76E-02
S-35	6.35E-03
CL-36	2.20E-01
AR-41	3.46E-04
K-40	3.32E+00
CA-41	2.07E-04
SC-46	2.72E-01
CR-51	2.29E-03
MN-54	3.50E-01
MN-56	9.13E-04
FE-55	7.02E-03
FE-59	1.18E-01
CO-57	6.18E-02
CO-58	1.22E-01
CO-60	5.11E+00
NI-59	8.27E-03
NI-63	1.05E-02
NI-65	3.66E-04
CU-64	3.45E-04
ZN-65	4.42E-01
ZN-69	2.77E-05
ZN-69M	9.16E-04
GA-67	1.69E-03
AS-76	3.13E-03
SE-75	9.10E-01
SE-79	1.70E+00
BR-82	6.46E-03
BR-83	2.80E-06
BR-84	4.73E-04
BR-85	3.72E-06
KR-83M	6.22E-08
KR-85	9.42E-07
KR-85M	4.38E-05
KR-87	2.27E-04
KR-88	6.08E-04
KR-89	1.22E-04
KR-90	3.32E-06
RB-86	7.38E-02
RB-87	2.69E-01
RB-88	1.72E-04
RB-89	4.23E-04
RB-90	1.26E-04
RB-90M	2.87E-04
SR-89	7.73E-02
SR-90	4.96E+00
SR-92	8.13E-04
Y-90	1.12E-02
Y-90M	2.70E-04
Y-91	9.96E-02
Y-91M	1.61E-04
Y-92	6.53E-04
Y-93	1.38E-03
ZR-93	3.30E-02
ZR-95	1.28E-01
NB-93M	2.87E-02
NB-94	1.62E+01
NB-95	6.57E-02
NB-95M	6.29E-03
NB-97	2.64E-04
NB-97M	9.74E-06
MO-93	5.72E-02
MO-99	5.18E-03
TC-97	1.37E-01
TC-99	6.33E-01
TC-99M	9.51E-05
TC-101	5.93E-05
RU-97	1.66E-03
RU-103	5.10E-02
RU-105	6.83E-04
RU-106	4.83E-01
RH-103M	3.50E-06
RH-105	9.59E-04
RH-105M	1.95E-07
RH-106	3.85E-07
PD-107	8.71E-03
PD-109	7.80E-04
AG-109M	2.21E-08
AG-110	2.66E-08
AG-110M	9.82E-01
AG-111	1.98E-02
CD-109	1.20E-01
CD-115	5.35E-03
CD-115M	1.47E-01
IN-113M	1.09E-04
IN-115	2.07E+00
IN-115M	1.60E-04
SN-113	4.70E-02
SN-123	1.05E-03
SN-125	5.86E-02
SN-126	1.20E+00
SB-124	2.24E-01
SB-125	6.32E-01
SB-126	9.32E-02
SB-126M	3.32E-04
SB-127	1.45E-02
TE-125M	3.56E-02
TE-127	2.01E-04
TE-127M	9.34E-02
TE-129	7.27E-05
TE-129M	8.81E-02
TE-131	1.36E-04
TE-131M	5.35E-03
TE-132	1.35E-02
TE-133	1.55E-04
TE-133M	6.41E-04
TE-134	2.27E-04
I-122	4.44E-05
I-123	1.40E-03
I-125	3.33E+00
I-129	5.79E+01
I-130	1.56E-02
I-131	1.75E+00
I-132	3.08E-03
I-133	1.27E-02
I-134	1.43E-03
I-135	5.61E-03
XE-122	1.88E-05
XE-123	1.67E-04
XE-125	6.92E-05
XE-127	7.27E-05
XE-131M	2.65E-06
XE-133	9.75E-06

Table 3. (continued)

Nuclide	Dose (mrem/Ci)
XE-133M	8.52E-06
XE-135	6.85E-05
XE-135M	7.58E-05
XE-137	1.39E-05
XE-138	2.14E-04
CS-134	2.18E+00
CS-134M	2.99E-05
CS-135	1.19E-01
CS-136	9.01E-02
CS-137	5.02E+00
CS-138	6.41E-04
CS-139	4.58E-05
BA-133	1.54E+00
BA-133M	8.80E-04
BA-137M	2.92E-05
BA-139	9.34E-05
BA-140	8.05E-02
BA-141	1.77E-04
BA-142	1.39E-04
LA-140	9.50E-03
LA-141	1.91E-05
LA-142	9.68E-04
CE-141	2.78E-02
CE-143	2.86E-03
CE-144	3.81E-01
PR-143	2.53E-02
PR-144	3.17E-05
PR-144M	1.28E-05
ND-147	2.24E-02
PM-147	2.84E-02
PM-148	3.01E-02
PM-148M	2.07E-01
PM-149	3.28E-03
PM-151	6.14E-04
SM-147	3.65E+01
SM-151	1.80E-02
SM-153	2.17E-03
EU-152	4.98E+00
EU-152M	2.36E-04
EU-154	4.06E+00
EU-155	1.71E-01
EU-156	7.59E-02
TB-160	1.64E-01
HO-166	2.14E-03
HO-166M	1.62E+01
TM-170	5.00E+00
HF-181	7.15E-02
W-181	9.69E-03
W-185	1.52E-02
W-187	1.14E-03
RE-187	6.57E-04
IR-192	1.41E-01
HG-203	4.51E-02
TL-207	1.39E-06
TL-208	2.25E-04
TL-209	9.07E-05
PB-209	4.53E-05
PB-210	6.41E+01
PB-211	3.65E-03
PB-212	7.78E-02
PB-214	3.92E-04
BI-207	1.00E-01
BI-210	1.02E-01
BI-211	7.59E-05
BI-212	1.41E-02
BI-213	5.31E-04
BI-214	4.55E-04
PO-210	2.12E+01
PO-218	5.19E-06
RN-219	4.81E-18
RN-220	6.94E-06
RN-222	4.40E-02
FR-221	6.42E-04
FR-223	9.24E-04
RA-223	6.75E+00
RA-224	2.09E+00
RA-225	4.84E+00
RA-226	1.75E+01
RA-228	8.09E+00
AC-225	3.20E+00
AC-227	3.38E+02
AC-228	3.97E-02
TH-227	5.65E+00
TH-228	1.19E+02
TH-229	3.34E+02
TH-230	1.21E+02
TH-231	5.60E-04
TH-232	1.98E+02
TH-234	1.02E-01
PA-231	2.73E+02
PA-233	3.58E-02
PA-234	1.71E-03
PA-234M	3.17E-07
U-232	2.51E+02
U-233	7.27E+01
U-234	7.19E+01
U-235	6.85E+01
U-236	6.80E+01
U-237	1.09E-02
U-238	6.40E+01
U-240	1.19E-03
NP-237	2.71E+02
NP-238	1.79E-02
NP-239	3.46E-03
NP-240	3.98E-04
NP-240M	4.38E-05
PU-236	4.55E+01
PU-238	1.85E+02
PU-239	2.00E+02
PU-240	2.00E+02
PU-241	3.26E+00
PU-242	1.90E+02
PU-243	1.18E-04
PU-244	1.89E+02
AM-241	2.94E+02
AM-242	2.87E-02
AM-242M	2.84E+02
AM-243	2.94E+02
CM-242	9.36E+00
CM-243	1.97E+02
CM-244	1.55E+02
CM-245	3.04E+02
CM-246	3.01E+02
CM-247	2.79E+02
CM-248	1.11E+03
CF-252	8.09E+01

Table 4. Emission System Potential Dose Assessment Summary

Emission System	Emission Type[a]	System Description	Emission Sampling Required	Nuclides Contributing >10% of Potential Dose	Comment
Systems Located in the Southeast Region (300 Area) of the Hanford Site					
300-N	Fugitive	Caisson	None		Sealed sources
303-C	Point	Materials Evaluation Lab	None		DOT containers
303-J	Point	Material Storage Building	Confirmatory		Sealed sources
305-B	Fugitive+Point	Chemical Waste Storage Unit	Confirmatory		
306-W	Point	Materials Development Lab	Confirmatory		
314	Fugitive+Point	Engineering Development Lab	Confirmatory		
318	Point	Radiological Sciences Lab	None		
318 Tr 5	Fugitive	Radiological Sciences Lab	Confirmatory		Depleted U slab
320	Point	Physical Sciences Lab	Confirmatory		
323	Point	Mechanical Properties Lab	Confirmatory		
324	Point	Waste Technology Engineering Lab	Continuous	^{137}Cs ^{90}Sr	
325	Point	Applied Chemistry Lab	Continuous	^{241}Am $^{238,239}Pu$	
326	Point	Materials Sciences Lab	Confirmatory		
327	Point	Post Irradiation Testing Lab	Continuous	^{238}Pu	
329	Point	Chemical Sciences Lab	Confirmatory		
331	Point	Life Sciences Lab	Confirmatory		
331-C	Point	Storage Warehouse	Confirmatory		
331-G	Point	Tissue Repository	Confirmatory		
331-H	Point	Wind Tunnel Facility	Confirmatory		
3708	Point	Radiation Measurements Lab	Confirmatory		
3720	Point	Chemistry and Material Sciences Lab	Continuous	^{241}Am ^{238}Pu	
3730	Point	Gamma Irradiation Facility	Confirmatory		
3745	Point	Radiological Calibrations and Standards Facility	Confirmatory		
3745-B	Fugitive	Radiological Physics Lab	Confirmatory		

Emission System	Emission Type[a]	System Description	Emission Sampling Required	Nuclides Contributing >10% of Potential Dose	Comment
3746-A	Point	Radiological Physics Lab	Confirmatory		
Systems Located in the Central Region (200 Areas) of the Hanford Site					
242-B/BL	Fugitive	De-activated Building. No powered exhaust.	Confirmatory		
2718-E	Fugitive	Storage Building	None		DOT containers
622-D	Fugitive	Storage Building	None		Sealed sources
622-R	Fugitive	Meteorological Lab	None		Sealed sources
Systems Located on the Fitzner-Eberhardt Ecology Reserve					
6652	Point	Ecology Lab	Confirmatory		
Systems Located in Richland					
747-A	Fugitive	In Vivo Counting Facility	Confirmatory		

[a] "Fugitive emissions" are radioactive air emissions which do not and could not reasonably pass through a stack, vent, or other functionally equivalent structure, and which are not feasible to directly measure and quantify (WAC 246-247).

"Point source" is a discrete, well-defined location from which radioactive air emissions originate, such as a stack, vent, or other functionally equivalent structure (WAC 246-247).

3.0 References

Parks, B. S. 1992. *User's Guide for CAP88-PC Version 1.0.* 402-B-92-001, U.S. Environmental Protection Agency, Office of Radiation Programs, Las Vegas Facility, Las Vegas, Nevada.

Sula, M. J. and S. J. Jette. 1994. *Pacific Northwest Laboratory Facilities Radionuclide Inventory Assessment CY 1992-1993.* PNL-10061. Pacific Northwest Laboratory, Richland, Washington.

Westinghouse Hanford Company. 1991. *Unit Dose Calculation Methods and Summary of Facility Effluent Monitoring Plan Determinations.* WHC-EP-0498. Westinghouse Hanford Company, Richland, Washington.

Appendix A

Unit Dose Factor Calculations—Emission Sampling Assessments

Appendix A

Unit Dose Factor Calculations—Emission Sampling Assessments

Unit dose factors were calculated for various radionuclides using the EPA compliance code CAP88-PC (Parks 1992). The unit dose factors are multiplied by the radionuclide inventory, the potential release fraction, and the facility location factor and summed over all radionuclides to yield the potential maximum receptor dose.

Unit dose factors were calculated assuming the point of release to be a 10-meter-high stack situated at the 331 Building and an offsite receptor 1000 meters east of the release point, as described in the attached application report. All environmental transport pathways potentially associated with an airborne radionuclide release were included in the calculation (i.e., air inhalation, air submersion, exposure to deposited radionuclides, uptake of vegetation grown in contaminated soil).

CAP88-PC was also used to calculate Chi/Q dispersion values for emission point locations outside the 300 Area. The ratio of the Chi/Q for the non-300 Area source to the 331 Building Chi/Q established the location modification factor used to correct the 331 unit dose factors for other source-receptor combinations. Since receptors in some of the non-300 Area locations do not consume foodstuffs grown at the receptor location, the use of the 331 Building unit dose factor (which includes foodstuff pathways) may grossly overestimate the dose.

The remainder of this appendix contains the documentation for the dose calculations showing that they have been approved by the Hanford Environmental Dose Overview Panel (HEDOP) (pages A.2-A.4), a description of the calculations performed (A.5-A.7), and results showing Chi/Q dispersion values (A.8) and unit doses (A.9-A.12).

Reference

Parks, B. S. 1992. *User's Guide for CAP88-PC Version 1.0.* 402-B-92-001. U.S. Environmental Protection Agency, Office of Radiation Programs, Las Vegas Facility, Las Vegas, Nevada.

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document reviewed (include title or description of calculation, document number, author, and date, as applicable):

CAP88-PC Dose Conversion Factors for 331 Building

Submitted by: Lissa Sawyer Date Submitted: 3/15/93

Scope of Review:

YES	NO*	N/A		
[x]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[ ]	[ ]	[x]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[x]	[ ]	[ ]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[x]	4.	Receptor locations were selected according to HEDOP recommendations.
[x]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[x]	[ ]	[ ]	6.	Hanford site data were used.
[x]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[x]	[ ]	[ ]	8.	The analysis is consistent with HEDOP recommendations.
[ ]		[x]	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
[x]	[ ]		10.	Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "NO" responses must be explained and use of nonstandard methods justified.

Kathy Rhoads K Rhoads 3/22/93
HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary):
Not Applicable

APPLICATION REPORT

1) Project title and number CAP88-PC DOSE CONVERSION FACTORS FOR 331 BUILDING M91738 3/11/93

2) Purpose of application package and relationship to other work:

This series of CAP88-PC runs was produced in order to report the 50-year maximally exposed individual (MI) committed effective dose equivalent (EDE) per Ci released for the 331 Building. These values will be used to demonstrate NESHAPs (National Emissions Standards for Hazardous Air Pollutants) compliance. The GENII computer code was run as a comparison with the CAP88-PC code for Hanford Dose Overview Panel review.

3) List original sources of input data, assumptions and derivations used to obtain it, and justification for its use, as appropriate. (If input information has been previously reviewed, reference the documentation of this review.)

One curie of each radionuclide was assumed to be released from the 331 Building 10 m stack. The maximum Chi/Q was chosen from runs performed for several 300 Area buildings to confirm the location of the MI (1000 m East of the 331 Building). Hanford parameters listed in McCormack et al (1984) were used in place of default CAP88-PC default parameters to better model the Hanford environment.

4) Minor changes made in the software that produced the application run (see section 4.1). N/A

5) Describe interrelationships and dependencies of each application run in the application package.

The EDEs for the CAP88-PC radionuclides were adjusted to represent the value with the contribution from progeny which were grown-in after the release from the facility. The adjustment factors were derived from GENII runs where only the parent is released, and the output includes the doses from the progeny. The adjustment factor was taken by dividing the dose from the parent by the total dose from the parent and progeny. The CAP88-PC value was then divided by the factor to represent the total dose. Where CAP88-PC calculated chains (i.e., Cs-137, Ba-140, Th-232 and U-238) the sum of the progeny were added to the parent, and no adjustment was made.

6) Summarize the overall output of the application package in relation of the purpose stated in item 2 above (including tables and graphs, as appropriate):

Parameter changes are listed in Table 1, maximum off-site chi/Q values for each building are listed with their location in Table 2, and Table 3 presents the 50-year EDE Conversion Factors as calculated by CAP88-PC. Table 4 includes the GENII results.

7) Submitted for ITR by:

[signature] 3/20/93

Preparer Date

8) Approved for reporting results to sponsor by:

[signature] 3/24/93

Preparer Date

APPLICATION RECORD LOG

1) Project title and number: CAP88-PC Dose Conversion Factors for 331 Building (M91738)

2) Application Record Log Number	3) Date and Time of Run	4) Software Name (title) and Version	5) computer type operating system compilers/libraries	6) Comments	7) Data input Identifier
Filename (a)	see below	CAP88-PC Ver 1.0	IBM/PS-2	see below	see below

FEMP1 331 H-ZN	03-06-93	1:56p
FEMP2 331 GA-ZR	03-06-93	1:58p
FEMP3 331 NB-IN	03-06-93	2:00p
FEMP4 331 SN-I	03-06-93	2:02p
FEMP5 331 XE-PR	03-06-93	2:05p
FEMP6 331 ND-W	03-06-93	2:06p
FEMP7 331 RE-FR	03-06-93	2:08p
FEMP8 331 RA-PA	03-06-93	2:10p
FEMP9 331 U-PU	03-06-93	2:12p
FEMP0 331 AM-CF	03-06-93	2:13p
9y chiQ 10m	12-15-92	3:42p
331 chiQ 10m 9y	02-16-93	5:15p
320 chiq10m 9y	02-16-93	5:19p
326 chiQ 10m 9y	02-16-93	5:17p
325 chiQ 10m 9y	02-16-93	5:18p
324 chiQ 10m 9y	02-16-93	5:18p
fempl 5y h-zn	03-03-93	12:44p
ESB CHIQ 10M 9Y	03-10-93	5:22p
ESB-R CHIQ 10M 9	03-10-93	5:23p

TITLE File	INH	ING	EXT	EDE (Intnl)	ORGAN D	UNIT	ORG	PTH	NUC	RUN DATE	TIME	SLP	ENVIRONMENTAL EXP PATH (near/ac/pop)	TIME (in/rel/com)
H-Y Femp 331 unit.:	5.4E-04	4.8E-03	1.7E-04	5.5E-03	1.4E-02	rem	Bon	Ing	SE79	03/09/93	15:36	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150
Zr-Te Femp 331 uni:	1.7E-03	2.0E-03	1.7E-04	3.9E-03	2.5E-02	rem	Kid	Ing	CD113M	03/09/93	15:20	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150
I-Ta Femp 331 unit:	4.2E-02	6.0E-03	2.0E-04	4.9E-02	7.2E-01	rem	Bon	Inh	SM147	03/09/93	15:25	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150
W-Cf Femp 331 unit:	7.5E+00	3.3E-01	1.7E-04	7.8E+00	1.1E+02	rem	Bon	Inh	TH229	03/09/93	15:33	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150
Progeny 1 331 unit:	6.5E-02	1.2E-03	8.6E-05	6.7E-02	5.4E-01	rem	Lun	Inh	U 238	03/10/93	14:08	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150
Progeny 2 Femp 331:	9.1E-03	4.0E-04	8.4E-06	9.5E-03	1.0E-01	rem	Bon	Inh	CM242	03/09/93	13:45	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150
Progeny 3 331 unit:	1.6E-01	2.2E-02	8.8E-06	1.8E-01	1.6E+00	rem	Bon	Inh	PU242	03/10/93	14:13	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150
Progeny 4 331 unit:	1.6E-01	1.5E-04	5.3E-10	1.6E-01	1.5E+00	rem	Bon	Inh	PU238	03/10/93	14:14	FFF	TTTTTTTTTTTTFFFFFFFFFFFFF	1 150

8) Prepared by: Signature [signature] Date 3/20/93

UNIT DOSE CALCULATIONS FOR PNL FACILITY EFFLUENT MONITORING PLANS

L. H. Sawyer

March 11, 1991

INTRODUCTION

Dose calculations for chronic unit (1 Ci) radionuclide releases were performed in support of efforts by Pacific Northwest Laboratories (PNL) to satisfy requirements of the U.S. Environmental Protection Agency (EPA) National Emmissions Standards for Hazardous Air Pollutants (NESHAPS) and Department of Energy's Facilities Effluent Monitoring Plan (DOE-FEMP) for PNL facilities in the 300 area of the Hanford site. Atmospheric releases from the 331 Building were modeled for 10 m stack releases. The CAP88-PC (Parks 1993) computer code package was used to model atmospheric releases using Hanford specific default parameters.

METHODS

Standard parameters for Hanford dose calculations (Table 1) were included in the calculations where possible (McCormack, et al 1984). Joint frequency meteorology data were collected from the 300 area weather stations and represent the nine-year average of wind data taken between 1983 and 1991. The calculations used the average annual rainfall and temperatures (i.e., 15.88 cm/y and 12 C, respectively). The location of the maximally exposed individual (MI) was based on the site boundary location having the greatest radionuclide air concentration under average atmospheric conditions. Distances to the site boundary were determined using the Threatened Areas Database (TADS). The maximum chi/q was determined by running tritium calculations for each of the PNL facility buildings and choosing that with the greatest value. The chi/Q values were also determined for selected buildings in the 3000 area.

CAP88-PC input:
Doses were calculated as 50-year committed effective dose equivalents for all internal deposition pathways using the EPA model specified in 40 CFR 61. Default solubility classes were used for all radionuclides in these preliminary calculations. These should be appropriate for most facilities evaluated, except where plutonium or uranium are released in soluble form and contribute substantially to the overall dose from a given facility. Default classes for uranium and plutonium assume these radionuclides are released as insoluble compounds; this will result in a lower overall dose than would be the case if they were released in more soluble form.

GENII Calculations:
The GENII code was also run for Handford Dose Overview Panel (HDOP) review and comparison to the CAP88-PC results. Where possible, the same parameters were entered into the GENII input codes. GENII output includes the dose from radionuclides which have been grown-in by the calculation code. The sum of the grown-in radionuclides were reported with the parent resulting in a total dose per parent Ci released. The percent of the dose contributed by the parent was calculated. This percent was divided into the CAP88-PC results to include the contribution to dose from the progeny.

RESULTS

The 331 building had the highest overall chi/Q value in the 1000 m East sector, as expected (Table 2). Results of the evaluation are presented in Tables 3 and 4, and represent the 50-year committed dose equivalent following a chronic annual release of 1 Ci of each radionuclide. CAP88-PC only calculates ingrowth of progeny radionuclide activities for 4 chains, Cs-137/Ba-137m, Ba-140/La140, Th-232, and U-238. CAP88-PC doses reported in Tables 3 and 4 are for the release of the parent nuclide only, except in the case where very short-lived daughters have been included in the parent dose as noted.

The total dose expected from emissions at a given facility can be obtained by multiplying the release quantity in Ci for each radionuclide by the corresponding unit dose factor in the tables, and summing the contributions for all nuclides in the effluent stream. Please note that doses calculated using the CAP88-PC code are reported in mrem to the maximum individual from an annual release, while those from GENII are reported in rem. Values in the tables have been left in the units reported by each code to avoid transcription errors.

REFERENCES

McCormack, W. D., J. V. Ramsdell, and B. A. Napier. 1984. Hanford Dose Overview Program: Standardized Methods and Data for Hanford Environmental Dose Calculations. PNL-3777, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

Park, B. S. 1992. User's Guide for CAP88-PC, Version 1.0. United States Environmental Protection Agency, Las Vegas, NV

U. S. Environmental Protection Agency. 1989. National Emission Standards for Hazardous Air Pollutants; Radionuclides; Final Rule and Notice of Reconsideration. 40 CFR Part 61, Federal Register 54 (240):51654-51715.

Table 1. Parameters Changed from CAP88-PC Default Values to Hanford Specific Values.

Parameter Description	Hanford Specific Value	CAP88-PC Default Value
Inhalation rate of man (cm^3/hr)	9.7E+05	9.176E+05
Fraction of radioactivity on vegetable & produce remaining after washing (-)	1.0	0.5
Ingestion rate of meat [beef and poultry] by MI (kg/yr)	98.	85
Ingestion rate of leafy vegetables by MI (kg/yr)	30.	18
Ingestion rate of milk by MI (L/yr)	270.	112
Ingestion rate of produce [fruit, roots and grains] by MI (kg/yr)	630.	176
Fraction year animals graze on pasture (-)	0.75	0.4
Fraction animals daily feed is pasture grass (-)	1.0	0.43
Removal rate constant - Physical loss by weathering (hr^{-1})	3.0E-3	2.9E-3
Effective surface density of soil, dry weight (Assumes 15 cm plow layer) (kg/m^2)	224.	215.
Fallout interception fraction - Pasture	0.25	0.57
Fallout interception fraction - Vegetable	0.25	0.20
Crop/leafy growing period (hr)	2160.	1440.
Stored feed holdup time (hr)	2400.	2160.
Leafy vegetable holdup time (hr)	24.	336.
Produce holdup time (hr)	120.	336.
Meat holdup time (d)	15.	20.
Milk productivity (kg/m^2)	1.5	0.28
Leafy/produce productivity (kg/m^2)	2.0	0.716
Long-term buildup in Soil (yr)	50	100.
Direction of the MI	13 (East)	Not specified
Distance to the MI (m)	1000	Not specified
Ground surface correction factor	1.0	0.5

Table 2. Chi/Q Values to Nearest Potential School, Residence or Office for Tritium Released From Various PNL Facility Buildings

Building	Maximum ^3H Chi/Q (s/m^3)	Distance* (m)	Direction
300 Area			
331	1.769E-6	1000	East
320	1.474E-6	1700	South
324	1.402E-6	1200	East
325	1.190E-6	2000	South
326	1.114E-6	2100	South
3000 Area Nearest School/Residential			
RTL	1.050E-6	1500	East
ESB	1.777E-6	1300	South Southeast
LSL II	9.425E-7	2100	South Southeast
PSL	8.842E-7	2200	South Southeast
3000 Area Nearest Office Building**			
RTL	1.444E-5	200	North
ESB	1.485E-5	200	South
LSL II	8.550E-6	200	West
PSL	8.817E-6	200	East
ALE Reserve			
6652H	7.851E-7	2400	South Southeast

* Distances determined by the Threatened Area Database System (TADS)

** Values included for information only. It is not appropriate to use MI dose factors for individuals located at office buildings. The MI dose factors assume year round occupancy and a backyard garden. Clearly these assumptions do not apply to Hanford Site buildings.

Table 3. CAP88-PC Unit Ci Release Dose Factors to the MI (1000 m East) 331 Building, 10 m Stack With Hanford Parameters, 9 Y Meteorologic Data (Page 1 of 2)

Nuclide	Dose Factor (mrem/y)	Nuclide	Dose Factor (mrem/y)	Nuclide	Dose Factor (mrem/y)
H-3	4.23E-04	RB-90	1.26E-04	SN-126	1.20E+00 (76)
BE-7	4.57E-03	RB-90M	2.87E-04	SB-124	2.24E-01
BE-10	*	SR-89	7.73E-02	SB-125	6.32E-01 (87)
C-11	2.16E-04	SR-90***	4.96E+00 (94)	SB-126	9.32E-02
C-14	5.06E-02	SR-91	1.03E-03	SB-126M	3.32E-04
C-15	**	SR-92	8.13E-04	SB-127	1.45E-02
N-13	1.50E-04	Y-90	1.12E-02	TE-125M	3.56E-02
O-15	3.86E-05	Y-90M	2.70E-04	TE-127	2.01E-04
F-18	3.78E-04	Y-91	9.96E-02	TE-127M	9.34E-02 (93)
NA-22	2.49E+00	Y-91M	1.61E-04	TE-129	7.27E-05
NA-24	4.69E-03	Y-92	6.53E-04	TE-129M	8.81E-02
P-32	5.76E-02	Y-93	1.38E-03	TE-131	1.36E-04
S-35	6.35E-03	ZR-93	3.30E-02	TE-131M	5.35E-03
AR-41	3.46E-04	ZR-95	1.28E-01 (76)	TE-132	1.35E-02
K-40	3.32E+00	NB-93M	2.87E-02	TE-133	1.55E-04
CA-41	2.07E-04	NB-94	1.62E+01	TE-133M	6.41E-04
SC-46	2.72E-01	NB-95	6.57E-02	TE-134	2.27E-04
CR-51	2.29E-03	NB-95M	6.29E-03 (75)	I-122	4.44E-05
MN-54	3.50E-01	NB-97	2.64E-04	I-123	1.40E-03
MN-56	9.13E-04	NB-97M	9.74E-06	I-125	3.33E+00
FE-55	7.02E-03	MO-93	5.72E-02	I-129	5.79E+01
FE-59	1.18E-01	MO-99	5.18E-03 ****	I-130	1.56E-02
CO-57	6.18E-02	TC-97	1.37E-01	I-131	1.75E+00
CO-58	1.22E-01	TC-99	6.33E-01	I-132	3.08E-03
CO-60	5.11E+00	TC-99M	9.51E-05	I-133	1.27E-02
NI-59	8.27E-03	TC-101	5.93E-05	I-134	1.43E-03
NI-63	1.05E-02	RU-97	1.66E-03	I-135	5.61E-03
NI-65	3.66E-04	RU-103	5.10E-02	XE-122	1.88E-05
CU-64	3.45E-04	RU-105	6.83E-04	XE-123	1.67E-04
ZN-65	4.42E-01	RU-106	4.83E-01	XE-125	6.92E-05
ZN-69	2.77E-05	RH-103M	3.50E-06	XE-127	7.27E-05
ZN-69M	9.16E-04	RH-105	9.59E-04	XE-131M	2.65E-06
GA-67	1.69E-03	RH-105M	1.95E-07	XE-133	9.75E-06
AS-76	3.13E-03	RH-106	3.85E-07	XE-133M	8.52E-06
SE-79	*	PD-107	8.71E-03	XE-135	6.85E-05
BR-82	6.46E-03	PD-109	7.80E-04	XE-135M	7.58E-05
BR-83	2.80E-06	AG-109M	2.21E-08	XE-137	1.39E-05
BR-84	4.73E-04	AG-110	2.66E-08	XE-138	2.14E-04
BR-85	3.72E-06	AG-110M	9.82E-01	CS-134	2.18E+00
KR-83M	6.22E-08	AG-111	1.98E-02	CS-134M	2.99E-05
KR-85	9.42E-07	CD-113	*	CS-135	1.19E-01
KR-85M	4.38E-05	CD-113M	*	CS-136	9.01E-02
KR-87	2.27E-04	CD-115	5.35E-03	CS-137	5.02E+00 ****
KR-88	6.08E-04	CD-115M	1.47E-01	CS-138	6.41E-04
KR-89	1.22E-04	IN-113M	1.09E-04	CS-139	4.58E-05
KR-90	3.32E-06	IN-115	2.07E+00	BA-133	1.54E+00
RB-86	7.38E-02	IN-115M	1.60E-04	BA-133M	8.80E-04
RB-87	2.69E-01	SN-113	4.70E-02 (87)	BA-137M	2.92E-05
RB-88	1.72E-04	SN-123	1.05E-03	BA-139	9.34E-05
RB-89	4.23E-04	SN-125	5.86E-02	BA-140	8.05E-02 ****

Table 3. CAP88-PC Unit Ci Release Dose Factors to the MI (1000 m East) 331 Building, 10 m Stack With Hanford Parameters, 9 Y Meteorologic Data (Page 2 of 2)

Nuclide	Dose Factor (mrem/y)	Nuclide	Dose Factor (mrem/y)	Nuclide	Dose Factor (mrem/y)
BA-141	1.77E-04	PB-214	3.92E-04	U-237	1.09E-02
BA-142	1.39E-04	BI-210	1.02E-01	U-238	6.40E+01 ****
LA-140	9.50E-03	BI-211	7.59E-05	U-240	1.19E-03
LA-141	1.91E-05	BI-212	1.41E-02	NP-237	2.71E+02
LA-142	9.68E-04	BI-213	5.31E-04	NP-238	1.79E-02
CE-141	2.78E-02	BI-214	4.55E-04	NP-239	3.46E-03
CE-143	2.86E-03	PO-210	2.12E+01	NP-240	3.98E-04
CE-144	3.81E-01	PO-212	**	NP-240M	4.38E-05
PR-143	2.53E-02	PO-213	**	PU-236	4.55E+01
PR-144	3.17E-05	PO-214	**	PU-238	1.85E+02
PR-144M	1.28E-05 (58)	PO-215	**	PU-239	2.00E+02
ND-147	2.24E-02	PO-216	**	PU-240	2.00E+02
PM-147	2.84E-02	PO-218	5.19E-06	PU-241	3.26E+00
PM-148	3.01E-02	AT-217	**	PU-242	1.90E+02
PM-148M	2.07E-01 (97)	RN-219	4.81E-18	PU-243	1.18E-04
PM-149	3.28E-03	RN-220	6.94E-06	PU-244	1.89E+02
PM-151	6.14E-04	RN-222	*	AM-241	2.94E+02
SM-147	3.65E+01	FR-221	6.42E-04	AM-242	2.87E-02 (97)
SM-151	1.80E-02	FR-223	9.24E-04	AM-242M	2.84E+02
SM-153	2.17E-03	RA-223	6.75E+00	AM-243	2.94E+02
EU-152	4.98E+00	RA-224	2.09E+00	CM-242	9.36E+00
EU-152M	2.36E-04	RA-225	4.84E+00	CM-243	1.97E+02
EU-154	4.06E+00	RA-226	1.75E+01	CM-244	1.55E+02
EU-155	1.71E-01	RA-228	8.09E+00	CM-245	3.04E+02
EU-156	7.59E-02	AC-225	3.20E+00	CM-246	3.01E+02
GD-152	*	AC-227	3.38E+02	CM-247	2.79E+02
TB-160	1.64E-01	AC-228	3.97E-02	CM-248	1.11E+03
HO-166	2.14E-03	TH-227	5.65E+00	CF-252	8.09E+01
HO-166M	1.62E+01	TH-228	1.19E+02		
HF-181	7.15E-02	TH-229	3.34E+02		
W-181	9.69E-03	TH-230	1.21E+02		
W-185	1.52E-02	TH-231	5.60E-04		
W-187	1.14E-03	TH-232	1.98E+02 ****		
RE-187	6.57E-04	TH-234	1.02E-01		
IR-192	1.41E-01	PA-231	2.73E+02		
HG-203	4.51E-02	PA-233	3.58E-02		
TL-207	1.39E-06	PA-234	1.71E-03		
TL-208	2.25E-04	PA-234M	3.17E-07		
TL-209	9.07E-05	U-232	2.51E+02		
PB-209	4.53E-05	U-233	7.27E+01		
PB-210	6.41E+01 ****	U-234	7.19E+01		
PB-211	3.65E-03	U-235	6.85E+01		
PB-212	7.78E-02	U-236	6.80E+01		

* Dose factors not included in CAP88-PC.
** Nuclide half-life too short to produce a dose.
*** Value adjusted to include dose from grown-in progeny. CAP88-PC value divided by percent contribution from the parent derived from GENII.
**** Includes dose from short-lived progeny.

Table 4. GENII Unit Ci Release Effective Dose Equivalent Factors to the MI (1000 m East) from 331 Building, Chronic Release, 9 Y Meteorlogic Data. Values in Parenthesis Indicate the Parent's Contribution to the Total Chain Decay Dose Reported.

Nuclide	Dose Factor (rem/y)	
H 3	5.2E-07	
BE 7	3.0E-07	
BE 10	2.1E-04	
C 14	1.1E-04	
N 13	3.3E-07	
F 18	5.5E-07	
NA 22	4.6E-04	
NA 24	3.0E-06	
SI 31	1.2E-07	
P 32	4.6E-05	
P 33	6.3E-06	
S 35	1.1E-05	
CL 36	2.2E-04	
K 40	2.4E-04	
AR 39	1.0E-10	
AR 41	4.9E-07	
CA 41	1.2E-05	
CA 45	2.6E-05	
SC 46	4.9E-05	
CR 51	5.5E-07	
MN 54	2.7E-05	
MN 56	9.5E-07	
FE 55	4.7E-06	
FE 59	2.9E-05	
CO 57	1.0E-05	
CO 58	2.2E-05	
CO 60	2.4E-04	
NI 59	1.3E-06	
NI 63	3.5E-06	
NI 65	3.7E-07	
CU 64	2.1E-07	
ZN 65	3.1E-04	
ZN 69M	7.8E-07	
ZN 69	2.8E-08	
GA 72	2.5E-06	
AS 76	2.6E-06	
SE 75	9.1E-04	
SE 79	1.7E-03	
BR 82	1.7E-05	
BR 83	5.7E-08	
KR 83M	1.2E-10	
BR 84	7.9E-07	
KR 85M	5.4E-08	
KR 85	1.1E-09	
KR 87	3.8E-07	

Nuclide	Dose Factor (rem/y)	
SR 87M	1.5E-07	
RB 87	4.7E-05	
KR 88	8.5E-07	
RB 88	3.6E-07	
KR 89	2.9E-07	
RB 89	8.5E-07	
SR 89	2.9E-05	
KR 90	1.4E-09	
RB 90M	7.0E-07	
RB 90	3.2E-07	
SR 90	8.9E-04	(94)
Y 90	6.8E-06	
RB 86	4.1E-05	
SR 85	9.8E-06	
SR 91	8.1E-07	
Y 91M	2.9E-07	
Y 91	4.8E-05	
SR 92	9.5E-07	
Y 92	5.8E-07	
Y 93	1.3E-06	
MO 93	0.0E+00	
ZR 93	4.2E-15	
NB 93M	7.2E-18	
MO 93	7.2E-06	
ZR 93	5.0E-05	
NB 93M	1.8E-05	
ZR 95	2.9E-05	(76)
NB 95M	2.8E-06	(75)
NB 95	1.1E-05	
ZR 97	2.4E-06	
NB 97M	3.0E-07	
NB 97	3.8E-07	
NB 94	2.7E-04	
MO 99	2.2E-06	
TC 99M	9.7E-08	
TC 99	8.9E-05	
TC 101	1.4E-07	
RU 103	1.3E-05	(100)
PD 103	2.9E-06	
RH 103M	2.8E-09	
RU 105	6.4E-07	
RH 105	1.0E-06	
RU 106	3.5E-04	
PD 107	7.9E-06	
PD 109	8.3E-07	

Nuclide	Dose Factor (rem/y)	
AG 110M	5.2E-04	
AG 111	2.5E-05	
CD 109	1.2E-04	
CD 113M	1.7E-03	
CD 115M	8.1E-05	
CD 115	3.1E-06	
IN 115M	2.4E-07	
IN 111	7.8E-07	
IN 114M	6.0E-05	
SN 113	2.1E-05	(87)
IN 113M	1.2E-07	
SN 117M	6.6E-06	
SN 119M	9.8E-06	
SN 121M	1.9E-05	(79)
SN 121	3.4E-07	
SN 123	5.1E-05	
SN 125	2.2E-05	
SB 125	3.1E-05	(87)
TE 125M	1.7E-05	
SN 126	2.1E-04	(76)
SB 126M	5.9E-07	(100)
SB 126	2.4E-05	
SB 122	5.0E-06	
SB 124	5.1E-05	
SB 127	6.6E-06	
TE 127M	5.6E-05	(93)
TE 127	1.8E-07	
TE 129M	4.1E-05	(100)
TE 129	6.7E-08	(100)
TE 123M	3.6E-05	
TE 131M	4.6E-06	
TE 131	2.2E-07	
I 131	2.1E-05	
XE 131M	3.3E-12	
TE 132	7.5E-06	
I 132	9.7E-07	
TE 133M	1.1E-06	
TE 133	3.8E-07	
I 133	1.8E-07	
XE 133M	4.9E-12	
XE 133	1.0E-10	
I 129	2.2E-02	
I 131	1.3E-03	
XE 131M	3.5E-09	
I 132	1.4E-06	

Table 4. GENII Unit Ci Release Effective Dose Equivalent Factors to the MI (1000 m East) from 331 Building, Chronic Release, 9 Y Meteorlogic Data. Values in Parenthesis Indicate the Parent's Contribution to the Total Chain Decay Dose Reported.

Page 2 of 2

Nuclide	Dose Factor (rem/y)	
I 133	2.1E-05	
XE 133M	1.3E-08	
XE 133	2.1E-08	
TE 134	4.1E-07	
I 134	1.3E-06	
I 125	2.3E-03	
CS 134M	3.4E-08	
CS 134	7.9E-04	
I 130	6.0E-06	
I 135	2.0E-06	
XE 135M	1.8E-07	
XE 135	1.5E-07	
CS 135	8.1E-05	
XE 137	4.5E-08	
CS 137	5.8E-04	
XE 138	4.2E-07	
CS 138	1.1E-06	
CS 139	1.0E-07	
BA 139	1.1E-07	
BA 140	2.6E-05	(50)
LA 140	3.9E-06	
CS 136	3.6E-05	
BA 141	3.5E-07	
LA 141	3.6E-07	
CE 141	1.0E-05	
BA 142	3.0E-07	
LA 142	1.4E-06	
CE 143	2.3E-06	
PR 143	1.0E-05	
CE 144	2.7E-04	(100)
PR 144M	1.4E-08	(58)
PR 144	3.6E-08	
PR 142	1.8E-06	
ND 147	8.0E-06	
PM 147	2.6E-05	
SM 147	4.2E-02	
PM 148M	3.9E-05	(97)
PM 148	1.2E-05	
PM 149	2.2E-06	
PM 151	1.3E-06	
SM 151	1.8E-05	
SM 153	1.4E-06	
EU 152M	6.1E-07	
EU 152	1.7E-04	
EU 154	2.2E-04	
EU 155	2.9E-05	
EU 156	2.2E-05	
GD 153	1.7E-05	
GD 159	4.4E-07	
TB 160	3.8E-05	
TB 161	3.8E-06	
DY 165	8.4E-08	
HO 166M	4.8E-04	
HO 166	2.0E-06	
ER 169	2.5E-06	
ER 171	4.8E-07	
TA 182	5.4E-05	
W 181	2.3E-06	
W 185	9.1E-06	
W 187	6.9E-07	
RE 187	8.6E-08	
OS 185	5.8E-06	
OS 191	1.4E-06	
IR 192	3.6E-05	
HG 203	6.3E-05	
TH 230	1.4E-01	
RA 226	7.9E-03	
RN 222	4.4E-05	
PB 210	2.6E-02	
BI 210	1.4E-04	
PO 210	1.3E-02	
PU 236	7.4E-02	
U 232	3.6E-01	
TH 232	6.5E-01	
RA 228	5.2E-03	
AC 228	1.0E-04	
TH 228	1.9E-01	
RA 224	2.2E-03	
PB 212	3.2E-04	
BI 212	5.9E-05	
U 234	7.3E-02	
U 236	6.9E-02	
U 235	6.8E-02	
TH 231	5.0E-06	
PA 231	5.2E-01	
AC 227	7.6E-01	
TH 227	9.1E-03	
FR 223	4.2E-06	
RA 223	5.3E-03	
PU 237	2.1E-06	
U 237	4.3E-06	
NP 237	3.7E-01	
PA 233	2.5E-05	
U 233	7.4E-02	
TH 229	9.6E-01	
RA 225	4.9E-03	
AC 225	4.9E-03	
U 238	6.5E-02	(100)
TH 234	4.1E-05	(100)
PA 234	1.3E-06	
AM 242M	2.4E-01	
AM 242	3.2E-05	(97)
CM 242	9.4E-03	(100)
PU 242	1.6E-01	
NP 238	2.5E-05	
PU 238	1.6E-01	
CM 244	1.4E-01	
PU 244	1.6E-01	
U 240	2.5E-05	
PU 240	1.7E-01	
CM 245	2.6E-01	
PU 241	2.7E-03	
AM 241	2.5E-01	
CM 246	2.7E-01	
CM 247	2.4E-01	
CM 243	1.8E-01	
PU 243	1.6E-06	
AM 243	2.5E-01	
NP 239	1.6E-05	
PU 239	1.7E-01	
CM 248	9.5E-01	
CF 252	7.9E-02	

Distribution

No. of
Copies

Offsite

12 DOE/Office of Scientific
and Technical Information

Onsite

2 **DOE Richland Operations Office**

M. A. Barnard, L4-40
H. M. Rodriquez, A5-15

1 **Westinghouse Hanford Company**

W. E. Davis, H6-20

No. of
Copies

29 **Pacific Northwest National Laboratory**

M. Y. Ballinger, P7-68 (10)
J. J. Evanoff, K9-44
S. J. Jette, P7-68 (5)
S. L. Jones, P7-57
H. E. Kjarmo, K2-22
P. L. Novak, K7-62
G. A. Simiele, P7-79
M. S. Sula, SEQUIM
R. K. Woodruff, P7-68
J. Y. Young, K4-16
Publishing Coordination
Technical Report Files (5)