DOSE ASSESSMENT OF SEVERAL POTENTIAL SCENARIOS OF SHIELDALLOY METALLURGICAL CORPORATION'S TRANSFER OF BAGHOUSE DUST CONTAINING 0.05 PERCENT URANIUM AND THORIUM BY WEIGHT TO NON-NRC LICENSEES

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DOSE ASSESSMENT OF SEVERAL POTENTIAL SCENARIOS OF SHIELDALLOY METALLURGICAL CORPORATION'S TRANSFER OF BAGHOUSE DUST CONTAINING 0.05 PERCENT URANIUM AND THORIUM BY WEIGHT TO NON-NRC LICENSEES

Introduction

In a letter, dated June 24, 1996, Shieldalloy Metallurgical Corporation (SMC) in Newfield, New Jersey requested to transfer baghouse dust to a facility not holding a U.S. Nuclear Regulatory Commission (NRC) license (Ref. 1). The letter included a report entitled, "Technical Basis for the Use of Baghouse Dust as an Additive in Concrete Production." SMC's report evaluated five scenarios to estimate the potential radiological exposure rates from transferring the baghouse dust to a non-NRC licensee. NRC staff concludes that although the scenarios are reasonable, they are not conservative enough.

NRC staff performed four in-depth dose assessments of the scenarios likely to result in the highest dose. The purpose of these assessments is to release the baghouse dust for unrestricted use. The selected scenarios are a cement worker scenario, a road accident scenario, a resident farmer at abandoned cement manufacturer scenario, and a resident farmer on one truckload of baghouse dust scenario. The dose assessments were performed using the U.S. Department of Energy's (DOE's) computer code RESRAD, Version 5.62 (Ref. 2).

Background

SMC produces metal alloys derived from ores which may contain by weight more than 0.05 percent of uranium and thorium. During the production of the alloys, dust is generated, which rises and is collected under a large hood connected to baghouses by ducts (Ref. 1) SMC intends to transfer its entire stock of baghouse dust to a cement manufacturer that proposed to use the dust as raw material in the cement mixture. The licensee said that the cement manufacturer's estimate for consuming SMC's entire quantity of baghouse dust is less than one year (Ref. 1), but more likely, about four months (Ref. 3) Since the baghouse dust would remain at SMC until needed by the cement manufacturer, the materials would not be stockpiled at the cement plant.

Approximately 8 percent of the feed material that goes into the production process enters the dust collection system (Ref. 1). The radiological concern of the baghouse dust is the slight increase in concentration of source materials from the ore. According to the licensee, the volume of baghouse dust stored on-site, as of 1992, is approximately 20,000 cubic meters, and approximately 3.64×10^5 kilograms are produced annually (~800 m^3 from 1993 to 1997) (Ref. 1). Thus, 20,000 m^3 or 1,000 truckloads was used in this analysis (Ref. 3).

Direct exposure is the dominant pathway for this material due to thorium daughters. Inhalation is the other important pathway. Through a sampling effort to quantify the radiological constituents in the stockpile of baghouse dust on-site, SMC determined that the dust contains about 0.03 percent by weight source material and that the variation in the source material content is minimal (Ref. 1). NRC staff used the source material concentrations of 0.05 percent by weight, in accordance with 10 CFR 40.13, in this analysis.

Table 1 shows the concentrations of the source materials for 0.03 percent and 0.05 percent by weight.

Table 1: Concentrations of Source Materials Used in Analysis

Radionuclide	0.03% (pCi/g)	0.05% (pCi/g)
Th-232	28.7	46.5
U-238	13.8	22.4

The RESRAD code was used to calculate the total dose from all pathways as a result of U-238, Th-232, and their daughters. Where possible, the values provided in the NRC Policy and Guidance Directive 8-08 (PG-8-08) were used as input values (Ref. 4). For parameters that were not included in PG-8-08, the RESRAD default values were used.

PG-8-08 Worker Scenario default values are based on a worker at an NRC-licensed site and do not account for potential dilution of the contaminated soil. PG-8-08 Resident Farmer Scenario default values are based on a farmer that moves onto the site, builds a home, and raises crops and livestock for consumption on the contaminated material. The RESRAD default values are based on an example site in the eastern U.S.; therefore, it was assumed that these default values were valid for modeling a site in southern New Jersey.

The radionuclide concentrations in the baghouse dust are reduced significantly once the dust is mixed with other materials to make cement and concrete (Ref. 1). Thus, NRC staff has decided to use scenarios that result in exposure from unmixed and undiluted baghouse dust, unless otherwise stated, because this material would most likely result in the highest dose. The following four sections are descriptions of the assumptions and analyses used for four very conservative exposure scenarios.

Cement Worker Scenario

Workers at the cement plant would be the group of individuals most likely to receive an exposure from the baghouse dust that is transferred from SMC to a cement manufacturing firm. The cement worker scenario provides a conservative analysis of the dose to the maximally exposed worker. This scenario is the most probable of the four presented in this analysis.

The cement worker scenario assumes a cement plant worker, who works in the vicinity of the baghouse dust, stands on top of an accumulation of one-week's worth of baghouse dust (20 truckloads) for 8 hours per day, 5 days per week, 50 weeks per year. During the one-year period that SMC's entire stock is transferred, it was assumed that the baghouse dust is being used by the cement manufacturer at the same rate as new shipments arrive at the cement plant so that there is never an accumulation of more than 20 truckloads at the plant at any given time.

Pathways through which the cement worker could receive a radiological dose are direct radiation and inhalation. RESRAD's external ground radiation

pathway assumes that the radiation field is at a distance of one meter above the ground surface and the source is approximated by a cylindrical contaminated zone of a defined radius and depth. RESRAD's inhalation pathway takes into consideration the resuspension factor and dilution of the baghouse dust resulting from the transfer of the dust from SMC to the cement plant.

The dose assessment was performed by using the specific criteria for this scenario, the default values from the Worker Scenario of PG-8-08 (Ref. 4), and RESRAD default (Ref. 2) values. The resulting dose to the worker, who is in continuous contact with the baghouse dust at work, is 183 mrem/yr, as depicted in Scenario A1 of Table C.1 in Appendix C. Figure D.1 in Appendix D shows the dose to a cement worker as a function of time.

This cement worker scenario results in a dose above the 25 mrem/yr limit of the Decommissioning Rule. However, the probability of the occurrence of a dose of 183 mrem/yr is very small and more realistic approaches result in doses that are much smaller. NRC staff performed additional RESRAD assessments with more realistic assumptions than in the cement worker scenario.

The cement industry would most likely have some type of institutional control over the storage area of the baghouse dust before the material is used so that a worker could not be in very close proximity to the baghouse dust and could not be near the baghouse dust for more than a small fraction of the hours at work. A cement worker who spends 1 hour per day, 5 days per week, 50 weeks per year in the vicinity of the baghouse dust is more realistic than the one in which he is in the vicinity of the dust during his entire working hours. Also, the cement manufacturer does not intend to stockpile any baghouse dust at its plant. Thus, the accumulation of the baghouse dust for cement production would be less than a one-week supply.

In the cement worker scenario with more realistic assumptions, the worker is in the vicinity of an accumulation of one-day's worth of baghouse dust (4 truckloads) for 5 hours per week, 50 weeks per year. During the one-year period that SMC's entire stock is transferred, baghouse dust is continuously used by the cement manufacturer as new shipments arrive at the cement plant so that there is never an accumulation of more than 4 truckloads at any given time. With these assumptions, the resulting dose to the worker is 20 mrem/yr, as depicted in Scenario A5 of Table C.1. This value is below the Decommissioning Rule limit of 25 mrem/yr. Figure D.2 shows this dose to a cement worker as a function of time.

If the entire SMC stockpile of baghouse dust is used in 4 months (Ref. 3) instead of over a period of one year, the dose would be even less. Table C.1 shows that the factors that lower the dose to the cement worker include: (1) shortening the total length of time that the cement manufacturer uses the entire stockpile of baghouse dust, as shown in Scenarios A2, A4, and A6; (2) reducing of the amount of time a worker spends in the vicinity of the baghouse dust, as shown in Scenarios A3 and A4; and (3) reducing of the amount of baghouse dust at the cement plant at any given time, as shown in Scenarios A5 and A6. The doses from the modified cement worker scenarios with

more realistic assumptions are below the regulatory limit of 25 mrem/yr of the Decommissioning Rule.

Road Accident Scenario

The drivers of the trucks that transfer the baghouse dust from SMC to a local cement manufacturing firm could also receive radiological exposure from the dust if the baghouse dust spilled onto the roadside during transit as a result of a road accident.

The road accident scenario assumes that a truck overturns, the container that holds 20 cubic meters of the dust breaks, and all of the material spills onto the roadside. Then, the truck driver stands in close proximity to the baghouse dust while he waits for cleanup help and while the clean-up crew removes the baghouse dust from the roadside. Two weeks pass before all the spilled materials are removed.

Pathways through which the driver and cleanup crew could receive a radiological dose are direct radiation and inhalation. RESRAD's external ground radiation pathway assumes that the radiation field is at a distance of one meter above the ground surface and the source is approximated by a cylindrical contaminated zone of a defined radius and depth. RESRAD's inhalation pathway takes into consideration the resuspension factor and dilution of the baghouse dust after the truck overturns.

The dose assessment was performed by using the specific criteria for this scenario, the default values from the Worker Scenario of PG-8-08 (Ref. 4), and RESRAD defaults (Ref. 2) values. The resulting dose for two weeks to the truck driver, who is in continuous contact with the baghouse dust, is 21 mrem/yr, as depicted in Scenario B1 of Table C.2 in Appendix C. Figure D.3 in Appendix D shows the dose to the truck driver as a function of time. The dose is below the regulatory limit of 25 mrem/yr of the Decommissioning Rule.

NRC staff performed additional RESRAD assessments of the scenario with more realistic assumptions, such as a shorter cleanup time and the truck driver in shorter contact with the baghouse dust. Table C.2 shows that the factors that lower the dose to the truck driver include: (1) minimizing the amount of time required to remove all of the spilled baghouse dust from the road, as shown in Scenario B2; (2) reducing of the amount of time the driver spends in close vicinity to the spilled baghouse dust, as shown in Scenario B3; and (3) having less volume of baghouse dust spilled, as shown in Scenario B4. The doses from the modified road accident scenarios with more realistic assumptions are well below the regulatory limit of 25 mrem/yr.

Resident Farmer at Abandoned Cement Manufacturer Scenario

A scenario, in which a resident farmer moves onto and cultivates the land area containing the entire SMC stockpile of baghouse dust abandoned by the cement industry, is the most conservative case to determine the maximumly exposed individual as a result of the transfer of baghouse dust from SMC to a non-NRC facility. Although this scenario is much less probable than the cement worker

scenario or the road accident scenario, this case is analyzed because it is the most conservative situation.

The resident farmer at the abandoned cement manufacturer scenario assumes that 20,000 m^3 or 1,000 truckloads of the baghouse dust is transferred from SMC to the cement manufacturer and the plant does not use any of the dust in its cement production before the plant closes. The area where the baghouse dust is stored on-site is abandoned, and a farmer moves onto the site, builds a home, and raises crops and livestock for consumption. The top layer of soil is assumed to be 100 percent baghouse dust, and crops are assumed to be able to thrive on it.

For conservatism, both the resident farmer scenario described in PG-8-08 (Ref. 4) and the family-farm scenario described in the RESRAD manual (Ref. 2) were used. This resident farmer represents the maximum exposed individual in this analysis. Pathways through which the farmer could receive a radiological dose are direct radiation, inhalation, ingestion of plant foods grown on the contaminated soil, ingestion of milk and meat from livestock raised and fed from the contaminated area, ingestion of fish raised in a nearby pond, and ingestion of water from an on-site well.

The dose assessment was performed by using the specific criteria for this scenario, the default values from Resident Farmer Scenario of PG-8-08 (Ref. 4), and RESRAD defaults (Ref. 2) values. The resulting dose to the resident farmer is 667 mrem/yr, as depicted in Scenario C1 of Table C.3 in Appendix C. Figure D.4 in Appendix D shows the dose to a farmer as a function of time.

This scenario, in which a resident farmer resides on the entire SMC stockpile of baghouse dust at the abandoned cement manufacturer, results in a dose above the 25 mrem/yr limit of the Decommissioning Rule. However, the probability of the occurrence of this scenario is very small. SMC and a local cement manufacturer have a contract in which SMC would sell the dust to the cement plant as additive in cement production; therefore, abandonment is unlikely due to the commercial value of the baghouse dust purchased by the cement industry.

More realistic approaches result in doses that are much smaller. NRC staff performed additional RESRAD assessments with more realistic assumptions in the abandonment scenario. The cement manufacturing firm would not likely stockpile any of the material on-site so that a large accumulation would not occur and be abandoned. Also, mixing of the underlying soil would occur if a resident farmer was to build a house, to plant crops, or to raise livestock on the land. Therefore, the surface soil would not be 100 percent dust. The baghouse dust is a fine particulate and is not likely to support the foundation of a house or the growth of vegetation without combining the dust with fertile soil. As a result of mixing, the radionuclides in the soil would be diluted, and the concentrations decrease.

In a resident farmer scenario with more realistic assumptions, the cement plant abandons the site containing 1200 m^3 or 60 truckloads of baghouse dust, and a farmer moves onto the site, builds a home, and raises crops and livestock for consumption on the contaminated material. The resident farmer

plows through and mixes the dust with underlying soil. The contaminated volume of land has to have an area large enough to support a resident farmer and a depth deep enough from which plant roots obtain nutrients. Thus, the area is assumed to be 10,000 m^2, and the depth, one meter. The concentrations of Th-232 and U-238 in this modified resident farmer scenario are 1.8 pCi/g and 0.89 pCi/g, respectively. The RESRAD computer printout of the inputs for the dose assessment is included in Appendix B. With these assumptions, the resulting dose to the farmer is 24 mrem/yr, as depicted in Scenario C5 of Table C.3. This value is below the Decommissioning Rule limit of 25 mrem/yr. Figure D.5 shows this dose to a resident farmer as a function of time.

Table C.3 shows that the factors that lower the dose to the resident farmer include: (1) reducing the volume of baghouse dust abandoned at the cement plant, as shown in Scenario C2; (2) increasing the mixture between the soil and the baghouse dust, which results in larger area, as shown in Scenarios C2, C3, C4, and C5; and (3) increasing the depth of mixture between the soil and the baghouse dust, as shown in Scenario C6. The assumptions from Scenarios C2, C3, and C4 are not realistic because the area of the land is too small to completely support a resident farmer. The doses from the remaining modified farmer residing at the abandoned cement manufacturer scenarios are below the regulatory limit of 25 mrem/yr of the Decommissioning Rule.

Resident Farmer on One Truckload of Baghouse Dust Scenario

A scenario, in which a resident farmer moves onto and cultivates the area containing a truckload of spilled SMC baghouse dust, is another conservative case for determining a potential exposure as a result of the transfer of baghouse dust from SMC to a non-NRC facility. Although this scenario is much less probable than the cement worker scenario or the road accident scenario, it is also very conservative. The dose rate from this scenario is not likely to exceed that from the resident farmer at an abandoned cement manufacturer scenario because the baghouse dust is one one-thousandth of the volume.

The resident farmer on one truckload of baghouse dust scenario assumes that the truck carrying the contaminated materials spilled its entire content of 20 m^3 on a roadside, the driver of the truck leaves the site without informing anyone, and a farmer moves onto the site, builds a home, and raises crops and livestock for consumption. The top layer of soil is assumed to be 100 percent baghouse dust, and crops are assumed to be able to thrive on it.

For conservatism, both the resident farmer scenario described in PG-8-08 (Ref. 4) and the family-farm scenario described in the RESRAD manual (Ref. 2) were used. Pathways through which the farmer could receive a radiological dose are direct radiation, inhalation, ingestion of plant foods grown on the contaminated soil, ingestion of milk and meat from livestock raised and fed from the contaminated area, ingestion of fish raised in a nearby pond, and ingestion of water from an on-site well.

The dose assessment was performed by using the specific criteria for this scenario, the default values from the Resident Farmer Scenario of PG-8-08 (Ref. 4), and RESRAD default values (Ref. 2). The resulting dose to the resident farmer is 225 mrem/yr, as depicted in Scenario D1 of Table C.4 in

Appendix C. Figure D.6 in Appendix D shows the dose to a farmer as a function of time.

This scenario, in which a resident farmer resides on one truckload of spilled baghouse dust on the roadside, results in a dose above the 25 mrem/yr limit of the Decommissioning Rule. However, the probability of occurrence of this scenario is very small for the same reasons as that for the resident farmer at an abandoned cement manufacturer scenario. In addition, if all other assumptions remain the same, the resulting maximum dose in this scenario is much smaller than the one from the abandonment scenario because the volume of baghouse dust is much smaller, as shown in Table C.4.

Similar to the abandonment scenario, the resident farmer of this scenario, with more realistic assumptions, plows through and mixes the baghouse dust with underlying soil. The area and depth of the contaminated soil are assumed to be 10,000 m^2 and one meter, respectively. The concentrations of Th-232 and U-238 in this modified resident farmer scenario are 0.093 pCi/g and 0.045 pCi/g, respectively. With these assumptions, the resulting dose to the farmer is 1.3 mrem/yr, as depicted in Scenario D3 of Table C.4. This value is well below the Decommissioning Rule limit of 25 mrem/yr. Figure D.7 shows this dose to a resident farmer as a function of time.

Table C.4 shows that the factors that lower the dose to a resident farmer residing on one truckload of baghouse dust are the same as those for a resident farmer residing at the abandoned cement manufacturer. The assumptions from Scenario D2 are not realistic because the area of the land is too small to completely support a resident farmer. The dose from the remaining modified scenario is well below the regulatory limit of 25 mrem/yr of the Decommissioning Rule.

Conclusion

The resulting dose for the RESRAD assessment shows that, in very conservative scenarios, the dose is not within the Decommissioning Rule limit of 25 mrem/yr. The only very conservative scenario that had results of doses below the regulatory limit is the truck accident scenario. However, with more realistic assumptions (and still being conservative) in the cement worker scenario, the resident farmer at abandoned cement manufacturer scenario, and the resident farmer on one truckload of baghouse dust scenario, the doses are less than 25 mrem/yr. Any actual exposure rates would be significantly less than calculated because of the conservative approach.

References

[1] Letter from C.S. Eves of Shieldalloy Metallurgical Corporation to G.C. Comfort of U.S. Nuclear Regulatory Commission with attachment entitled, "Technical Basis for the Use of Baghouse Dust as an Additive in Concrete Production," June 24, 1996.

[2] Yu, C., et al., September 1993, *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0 Working Draft for Comment*, ANL/EAD/LD-2, Argonne National Laboratory, Argonne, Illinois.

[3] Phone conversation between C.S. Eves of Shieldalloy Metallurgical Corporation and H.M. Astwood and S.C. Wu of U.S. Nuclear Regulatory Commission, July 7, 1997.

[4] U.S. Nuclear Regulatory Commission, May 1994, Policy and Guidance Directive PG-8-08, *Scenarios for Assessing Potential Doses Associated with Residual Radioactivity*, Office of Nuclear Material Safety and Safeguards, Washington, D.C.

[5] Yu, C., et al., April 1993, *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*, ANL/EAIS-8, Argonne National Laboratory, Argonne, Illinois.

[6] Hornsby, R.T. and Ortloff, G.D., and Smith, M.L., May 1978, "A Highway Accident Which Involved a Spill of Natural Uranium Oxide Concentrate," *Proceedings of the Fifth International Symposium Packaging and Transportation of Radioactive Materials*, Las Vegas, NV.

[7] Kennedy, W.E. and Strenge, D.L., October 1992, *Residual Radioactive Contamination from Decommissioning*, NUREG/CR-5512, U.S. Nuclear Regulatory Commission, Washington, D.C.

APPENDIX A

ASSUMPTIONS OF SCENARIOS

Cement Worker Scenario

Situation:
1) A cement plant worker stands on top of an accumulation of baghouse dust at work

Pathways: (Ref. 4)
1) Direct Exposure
2) Inhalation

Erosion Rate:
0 m/yr

Principal Radionuclides and Concentrations: (Ref. 1)
46.5 pCi/g Th-232
22.4 pCi/g U-238
Secular Equilibrium with Daughter Radionuclides

Volume:
400 m^3
80 m^3 *

Depth: (Ref. 5)
1 m

Area:
400 m^2
80 m^2 *

Worker Exposure Time: (Ref. 4)
8 hrs/d, 5 d/wk, 50 wk/yr for 1 year
1 hr/d, 5 d/wk, 50 wk/yr for 1 year*

Time Spent Outdoors:
0.2283
0.0285*

Time Spent Indoors:
0

* Assumptions from the more realistic scenario

Road Accident Scenario

Situation:

1) A truck overturns
2) The container that holds 20 m^3 of the dust breaks
3) All of the material spills onto the roadside
4) The truck driver stands on top of the baghouse dust while he waits for cleanup help and while the clean up crew removes the baghouse dust from the roadside
5) Two weeks pass before all the spilled materials are removed

Pathways: (Ref. 4)

1) Direct Exposure
2) Inhalation

Erosion Rate:

0 m/yr

Principal Radionuclides and Concentrations: (Ref. 1)

46.5 pCi/g Th-232
22.4 pCi/g U-238
Secular Equilibrium with Daughter Radionuclides

Volume: (Ref. 3)

1 Truckload = 20 m^3

Depth: (Ref. 5)

1 m

Area:

20 m^2

Truck Driver Exposure Time: (Ref. 6)

2 weeks continuously

Time Spent Outdoors:

0.03836

Time Spent Indoors:

0

Resident Farmer at Abandoned Cement Manufacturer Scenario

Situation:

1) SMC's entire stockpile of the baghouse dust is transferred to the cement manufacturer
2) The cement plant does not use any of the dust in its cement production
3) The cement plant closes
4) Area where the baghouse dust is stored on-site is abandoned
5) A farmer moves onto the site, builds a home, and raises crops and livestock for consumption on the contaminated material

Pathways: (Ref. 2)

1) Direct Exposure
2) Inhalation
3) Ingestion of plant foods grown on the contaminated soil
4) Ingestion of milk from livestock raised and fed from the contaminated area
5) Ingestion of meat from livestock raised and fed from the contaminated area
6) Ingestion of fish raised in a nearby pond
7) Ingestion of water from an on-site well

Erosion Rate: (Ref. 4)

1×10^{-3} m/yr

Principal Radionuclides and Concentrations: (Ref. 1)

46.5 pCi/g Th-232	1.8 pCi/g Th-232*
22.4 pCi/g U-238	0.89 pCi/g U-238*

Secular Equilibrium with Daughter Radionuclides

Volume: (Ref. 1)

1,000 Truckload = 1000 × 20 m^3 = 20,000 m^3

Depth: (Ref. 5)

2 m
1 m*

Area:

10,000 m^2

Farmer Exposure Time:

1 year continuously

Time Spent Outdoors: (Ref. 4)

0.21

Time Spent Indoors: (Ref. 4)

0.55

* Assumptions from the more realistic scenario

Resident Farmer on One Truckload of Baghouse Dust Scenario

Situation:

1) The truck carrying the contaminated materials spilled its entire content of on a roadside
2) The driver of the truck leaves the site without informing anyone
3) A farmer moves onto the site, builds a home, and raises crops and livestock for consumption on the contaminated material

Pathways: (Ref. 2)

1) Direct Exposure
2) Inhalation
3) Ingestion of plant foods grown on the contaminated soil
4) Ingestion of milk from livestock raised and fed from the contaminated area
5) Ingestion of meat from livestock raised and fed from the contaminated area
6) Ingestion of fish raised in a nearby pond
7) Ingestion of water from an on-site well

Erosion Rate: (Ref. 4)

1×10^{-3} m/yr

Principal Radionuclides and Concentrations: (Ref. 1)

46.5 pCi/g Th-232	0.093 pCi/g Th-232*
22.4 pCi/g U-238	0.045 pCi/g U-238*

Secular Equilibrium with Daughter Radionuclides

Volume: (Ref. 3)

1 Truckload = 20 m^3

Depth: (Ref. 5)

1 m

Area:

20 m^2
10,000 m^2 *

Farmer Exposure Time:

1 year continuously

Time Spent Outdoors: (Ref. 4)

0.21

Time Spent Indoors: (Ref. 4)

0.55

* Assumptions from the more realistic scenario

APPENDIX B

RESRAD COMPUTER PRINTOUT FOR THE MORE REALISTIC RESIDENT FARMER AT ABANDONED CEMENT MANUFACTURER SCENARIO

RESRAD, Version 5.62 T½ Limit = 0.5 year 07/25/97 08:28 Page 1
Summary : SMC - Baghouse Dust Resident Farmer at Abandoned Cement Manufacturer Scenario
File : ABANDONR.RAD

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Dose Conversion Factor (and Related) Parameter Summary
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(3)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(4)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(5)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(6)
B-1	U-234	1.320E-01	1.320E-01	DCF2(7)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(8)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(3)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(4)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(5)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(6)
D-1	U-234	2.830E-04	2.830E-04	DCF3(7)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3(8)
D-34	Food transfer factors:			
D-34	Pb-210+D . plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D . beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
D-34	Pb-210+D . milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Ra-226+D . plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
D-34	Ra-226+D . beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
D-34	Ra-226+D . milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-34				
D-34	Ra-228+D . plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(3,1)
D-34	Ra-228+D . beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Ra-228+D . milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,3)
D-34				
D-34	Th-228+D . plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(4,1)
D-34	Th-228+D . beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(4,2)
D-34	Th-228+D . milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(4,3)
D-34				
D-34	Th-230 . plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(5,1)
D-34	Th-230 . beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(5,2)
D-34	Th-230 . milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(5,3)
D-34				
D-34	Th-232 . plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(6,1)
D-34	Th-232 . beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(6,2)
D-34	Th-232 . milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(6,3)
D-34				
D-34	U-234 . plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(7,1)
D-34	U-234 . beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(7,2)
D-34	U-234 . milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(7,3)
D-34				

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(8,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(8,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(8,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(3,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(3,2)
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(4,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(4,2)
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(5,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(5,2)
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(6,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(6,2)
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(7,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(7,2)
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(8,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(8,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.000E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	3.000E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.800E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): U-238	8.900E-01	0.000E+00	---	S1(8)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(8)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.630E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Humidity in air (g/cm**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	7.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.630E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	0.000E+00	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	1.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.630E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(6,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.975E-06	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.541E-03	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.778E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.821E-03	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.821E-03	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.975E-06	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.975E-06	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R016	Distribution coefficients for daughter U-234				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.541E-03	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R017	Inhalation rate (m**3/yr)	1.051E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	5.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	3.300E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.500E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.100E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	1 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.660E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.100E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	1.000E+02	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.825E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.300E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	1.000E+00	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	5.000E-01	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
R018	Contamination fraction of meat	-1	-1	0.500E+00	FMEAT
R018	Contamination fraction of milk	-1	-1	0.500E+00	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	1.000E+00	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	1.500E-01	1.500E-01	---	FLOOR
R021	Bulk density of building foundation (g/cm**3)	2.400E+00	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	1.000E-01	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	3.000E-02	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	3.000E-07	3.000E-07	---	DIFFL
R021	in contaminated zone soil	2.000E-06	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	2.000E+00	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	5.000E-01	5.000E-01	---	REXG
R021	Height of the building (room) (m)	2.500E+00	2.500E+00	---	HRM
R021	Building interior area factor	0.000E+00	0.000E+00	code computed (time dependent)	FAI
R021	Building depth below ground surface (m)	-1.000E+00	-1.000E+00	code computed (time dependent)	DMFL
R021	Emanating power of Rn-222 gas	3.500E-01	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	1.500E-01	1.500E-01	---	EMANA(2)

Summary of Pathway Selections

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

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	10000.00 square meters	Th-232	1.800E+00
Thickness:	1.00 meters	U-238	8.900E-01
Cover Depth:	0.00 meters		

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	3.650E+00	5.365E+00	8.806E+00	1.755E+01	2.384E+01	2.445E+01	2.255E+01	4.715E-02
M(t):	1.217E-01	1.788E-01	2.935E-01	5.849E-01	7.946E-01	8.151E-01	7.517E-01	1.572E-03

Maximum TDOSE(t): 2.445E+01 mrem/yr at t = 100.0 ± 0.1 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 100.0 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.016E+01	0.4156	3.510E+00	0.1435	5.694E-01	0.0233	9.264E+00	0.3789	2.586E-01	0.0106	3.282E-01	0.0134	1.212E-01	0.005(
U-238	1.734E-02	0.0007	4.005E-02	0.0016	9.155E-08	0.0000	2.046E-02	0.0008	6.637E-04	0.0000	1.768E-03	0.0001	1.279E-03	0.000
Total	1.018E+01	0.4163	3.550E+00	0.1452	5.694E-01	0.0233	9.285E+00	0.3797	2.593E-01	0.0106	3.300E-01	0.0135	1.225E-01	0.005(

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 100.0 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.425E-08	0.0000	1.835E-10	0.0000	9.735E-15	0.0000	1.074E-08	0.0000	1.192E-09	0.0000	1.982E-09	0.0000	2.421E+01	0.990
U-238	1.287E-01	0.0053	9.519E-05	0.0000	4.407E-10	0.0000	2.531E-02	0.0010	9.793E-04	0.0000	2.851E-03	0.0001	2.395E-01	0.009
Total	1.287E-01	0.0053	9.519E-05	0.0000	4.407E-10	0.0000	2.531E-02	0.0010	9.793E-04	0.0000	2.851E-03	0.0001	2.445E+01	1.000(

*Sum of all water independent and dependent pathways.

APPENDIX C

TABLES FROM RESRAD ANALYSIS

Table C.1: Dose to Cement Worker

Scenario Name	# of Month of Exposure[a]	# of Truck loads per week[b]	Time BHD at plant before use[c]	Volume of BHD at any given time (m^3)[d]	Exposure Time (hr/wk)[e]	Annual Exposure Time (hr/yr)[f]	Maximum Dose (mrem/yr)
A1	12	20	1 wk	400	40	2000	183
A2	4	60	1 wk	1200	40	680	65
A3	12	20	1 wk	400	5	250	23
A4	4	60	1 wk	1200	5	85	8.1
A5	12	20	1 day	80	5	250	20
A6	4	60	1 day	240	5	85	7.5

[a] # of Month of Exposure is the number of months required by the cement plant to use the entire SMC stock of baghouse dust. SMC said that it believes that all 20,000 m^3 of dust on-site would be transferred to the cement manufacturer in less than 12 months (Ref. 1), but it is more probable that the transfer would require about 4 months (Ref. 3).

[b] # of Truckloads per week is the approximate number of truckloads of baghouse dust transferred from SMC to a cement plant for one week. This value depends on the rate that the cement manufacturer uses the baghouse dust. If the entire SMC stockpile is used by the cement plant over a period of one year, then there is an average of 20 truckloads of dust transferred per week. Likewise, if the entire SMC stockpile is used in 4 months, then the average is 60 truckloads per week.

[c] Time BHD at plant before use is the time that the baghouse dust is stockpiled at the cement plant before the dust is used. This value quantifies the maximum volume of material of which a cement worker may be in the vicinity. Since SMC said that the cement manufacturer will not stockpile any baghouse dust, the one-week time range is very conservative. A one-day volume of dust is more realistic.

[d] Volume of BHD at any given time (m^3) is the maximum volume of baghouse dust of which a worker at the cement plant may be nearby. This volume is calculated by dividing the product of the volume of the entire SMC stockpile and the length of time baghouse dust is stored at plant before use by the total length of time to use the entire SMC stockpile. For example, the volume for Scenario A6 is:
$V = [(20{,}000\ m^3)(1\ day)(wk/5\ days)]/[(4\ month/yr)(4.2\ wks/month)] \approx 240\ m^3$.

[e] Exposure Time (hr/wk) is the length of time a cement worker is in the vicinity of the baghouse dust per week. If the worker is near the dust during his entire working hours, then the exposure time is 8 hours per day multiplied by 5 days per week or 40 hours per week.

[f] Annual Exposure Time (hr/yr) is the total length of time a cement worker is in the vicinity of the baghouse dust in a period of one year. *This factor takes into consideration the length of time cement workers are in near the baghouse dust, the volume of baghouse dust at the* cement plant, and the length of time the cement plant takes to use SMC's entire stockpile of dust. For example, the annual exposure time for Scenario A6 is: $T = (5\ hr/wk)(4\ month/yr)(4.2\ wk/month) \approx 85\ hr/yr$.

Table C.2: Dose to Truck Driver in Road Accident

Scenario Name	Volume (m^3)[g]	Time Taken to Clean Up Spill[h]	Maximum Dose (mrem/yr)
B1	20	2 weeks	21
B2	20	1 week	10
B3	20	1 day	1.5
B4	10	1 week	8.3

[g] Volume (m^3) is the volume of baghouse dust that spilled onto the roadside as a result of a road accident. The total content of dust on the truck is approximately 20 m^3.

[h] Time Taken to Clean Up Spill is the total length of time an individual is in the proximity of the spilled baghouse dust from the time of the truck accident to the time the entire spilled material is removed from the roadside. Reference 6 details the cleanup of a highway accident which involved a spill of natural uranium oxide concentrate. In this case, the total cleanup time for 29 55-gallon drums with opened lids took 14 days, from the moment of the truck accident to the end of final decontamination of cleaning equipments. In this analysis, the total length of exposure is much less than 14 days to any one individual. The total length of time is not necessarily continuous. For instance, if an individual cleans up the spill for 12 hours per day for 2 weeks, then the total length of time is equal to one week.

Table C.3: Dose to Resident Farmer Residing on Baghouse Dust Abandoned by the Cement Manufacturer

Scenario Name	Th-232 Conc. (pCi/g)[j]	U-238 Conc. (pCi/g)[k]	Area (m^2)[l]	Depth (m)[m]	# of Truckloads[n]	Maximum Dose (mrem/yr)
C1	46.5	22.4	10,000	2	1000	667
C2	46.5	22.4	400	1	60	426
C3	23.3	11.2	800	1	60	268
C4	4.6	2.2	4000	1	60	61
C5	1.8	0.89	10,000	1	60	24
C6	0.93	0.45	10,000	2	60	13

Table C.4: Dose to Resident Farmer Residing on One Truckload of Baghouse Dust

Scenario Name	Th-232 Conc. (pCi/g)[j]	U-238 Conc. (pCi/g)[k]	Area (m^2)[l]	Depth (m)[m]	Maximum Dose (mrem/yr)
D1	46.5	22.4	20	1	225
D2	4.65	2.24	200	1	36
D3	0.093	0.045	10,000	1	1.3
D4	0.047	0.022	10,000	2	0.7

[j] Th-232 Conc. (pCi/g) is the thorium-232 concentration in the soil on which the resident farmer builds a home and raises crops and livestock for consumption. The concentration in the soil decreases as mixing increases.

[k] U-238 Conc. (pCi/g) is the uranium-238 concentration in the soil on which the resident farmer builds a home and raises crops and livestock for consumption. The concentration in the soil decreases as mixing increases.

[l] Area (m^2) is the circular area that contains the locations of the baghouse dust on which the resident farmer resides and consumes crops and livestock raised on the land area (Ref. 5).

[m] Depth (m) is the distance from the surface, since there is no cover layer, to the lowermost depth of baghouse dust. The roots of plants, such as beets, carrots, and lettuce, do not extend below about 0.3 meter, but the roots of fruit trees may extend 2 or 3 meters below the surface (Ref. 5). Since most of the plant roots from which nutrients are obtained usually extend less than one meter below the surface, the depth of contamination was chosen to be at least one meter.

[n] # of Truckloads is the approximate number of truckloads of baghouse dust transferred from SMC to a cement plant that is at the cement plant at the time of abandonment. This value represents the volume of the contaminated material. The transfer of the entire SMC stock requires 1000 truckloads and a one-week amount requires 60 truckloads if the entire SMC supply is delivered in 4 months.

APPENDIX D

GRAPHS FROM RESRAD ANALYSIS

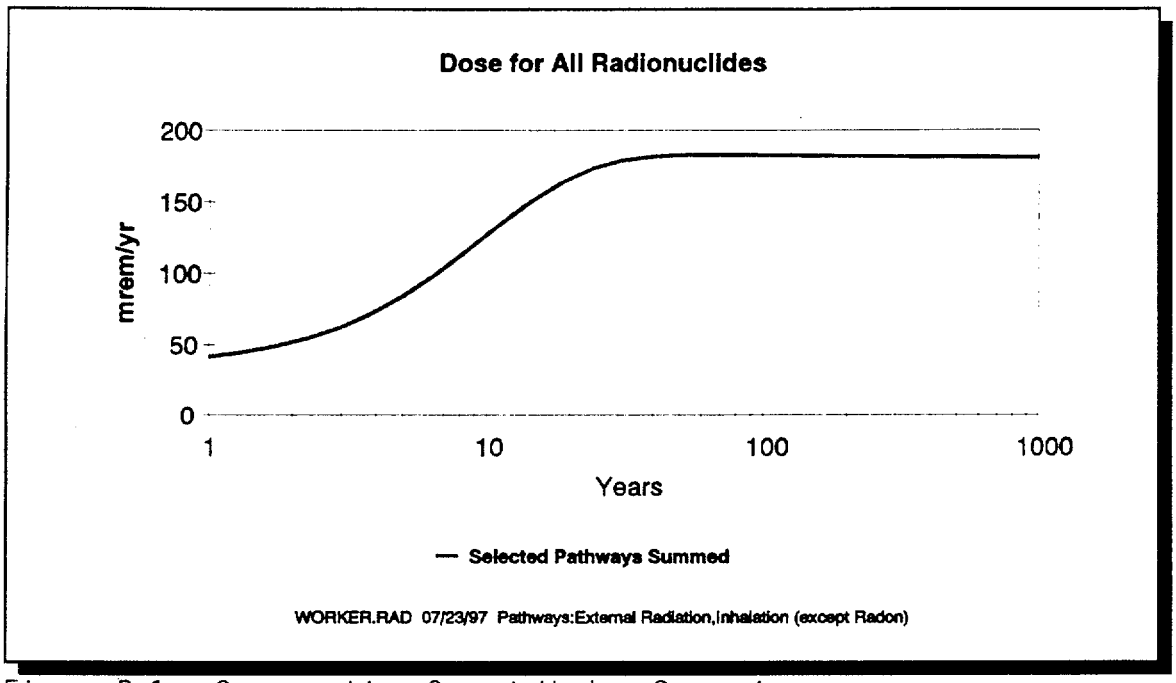

Figure D.1: Conservative Cement Worker Scenario

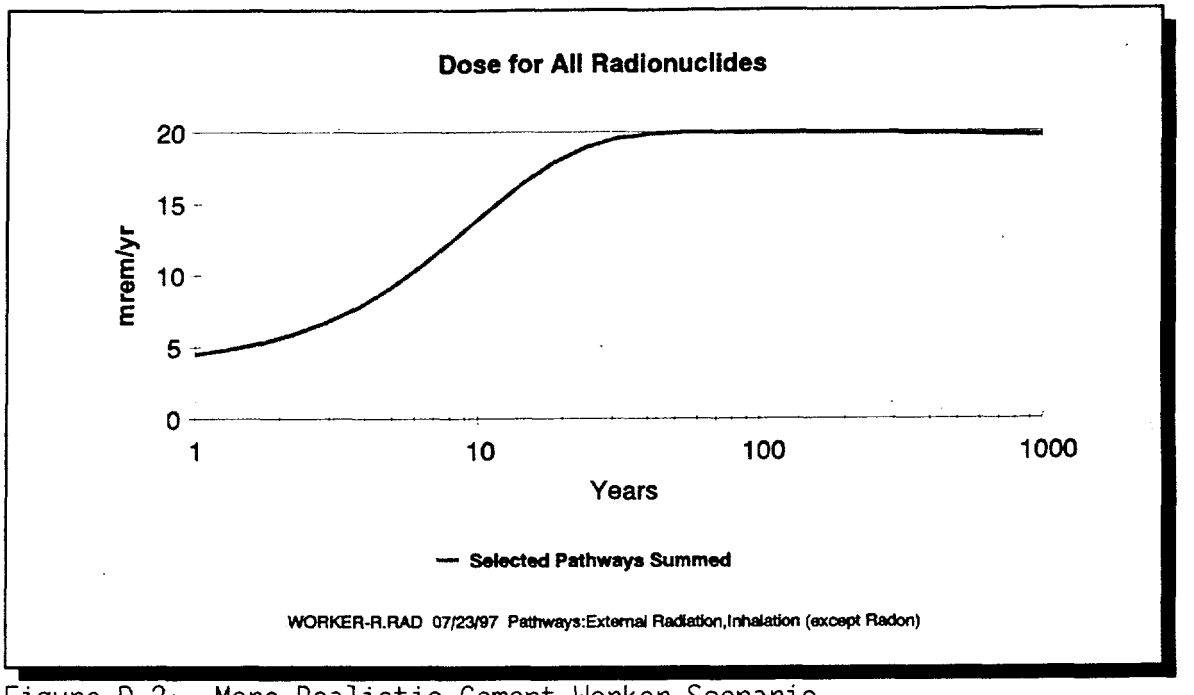

Figure D.2: More Realistic Cement Worker Scenario

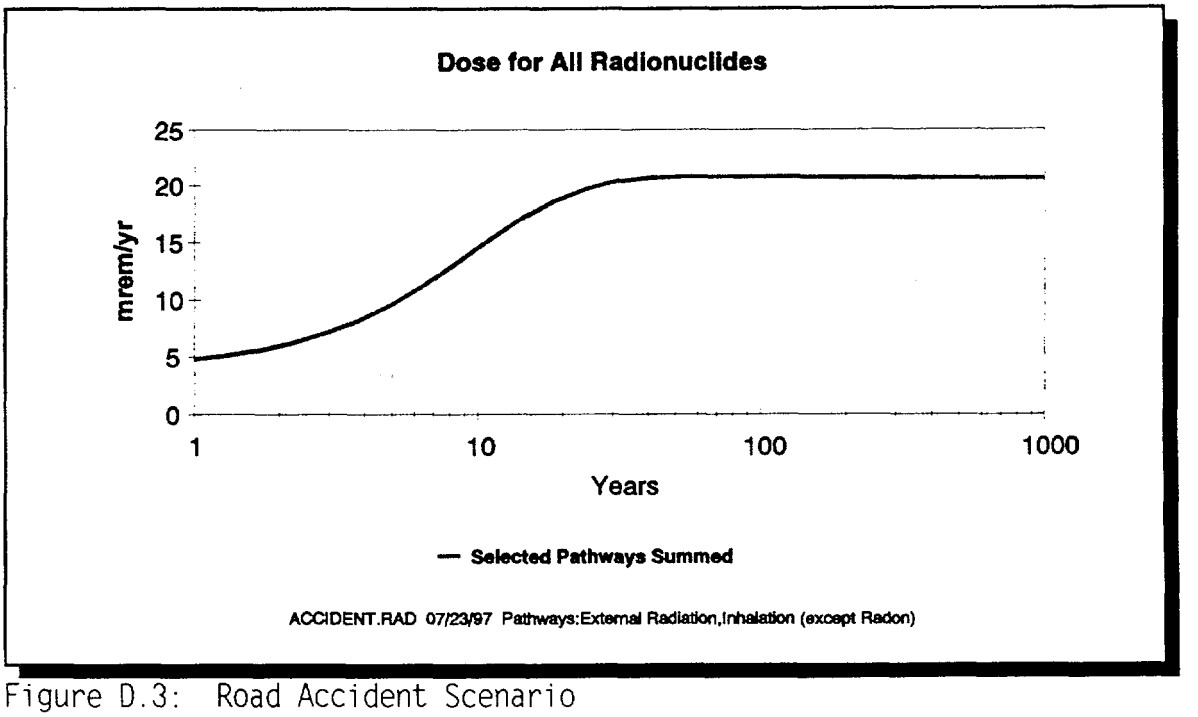

Figure D.3: Road Accident Scenario

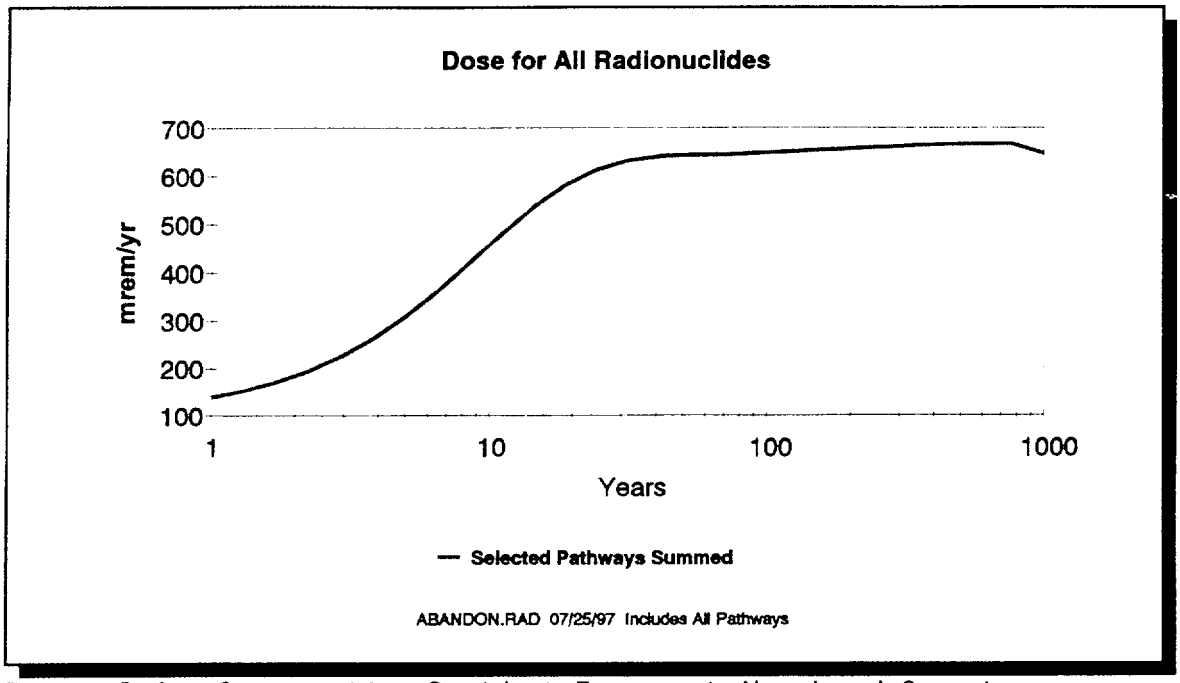

Figure D.4: Conservative Resident Farmer at Abandoned Cement Manufacturer Scenario

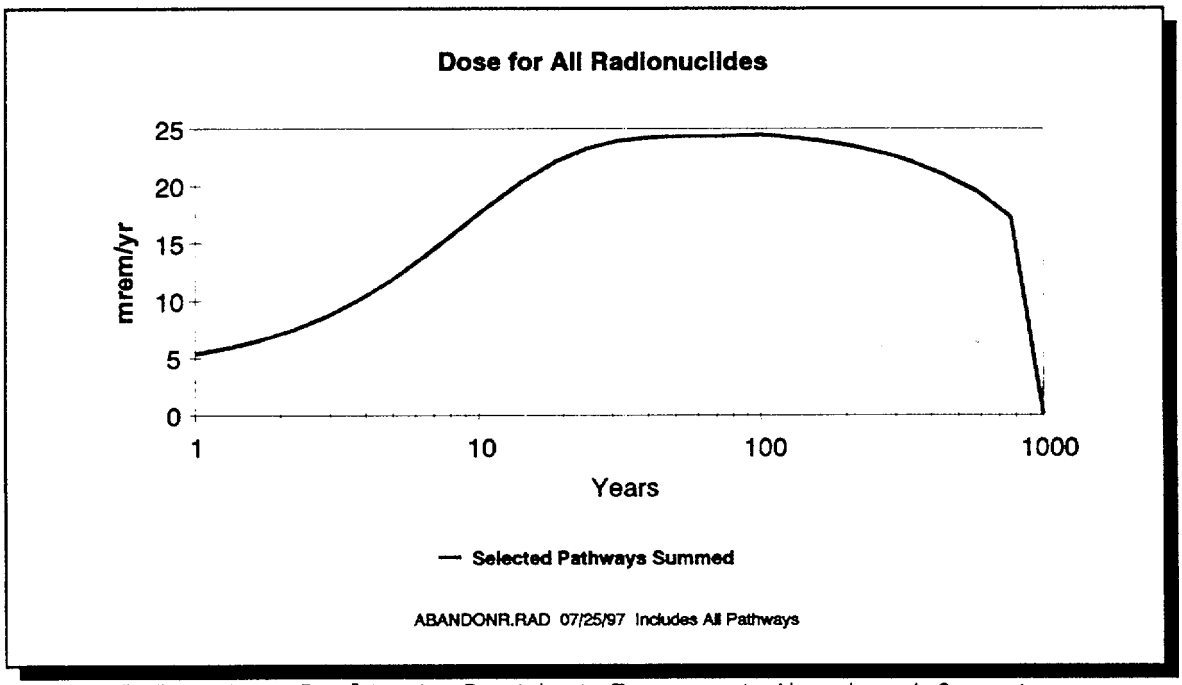

Figure D.5: More Realistic Resident Farmer at Abandoned Cement Manufacturer Scenario

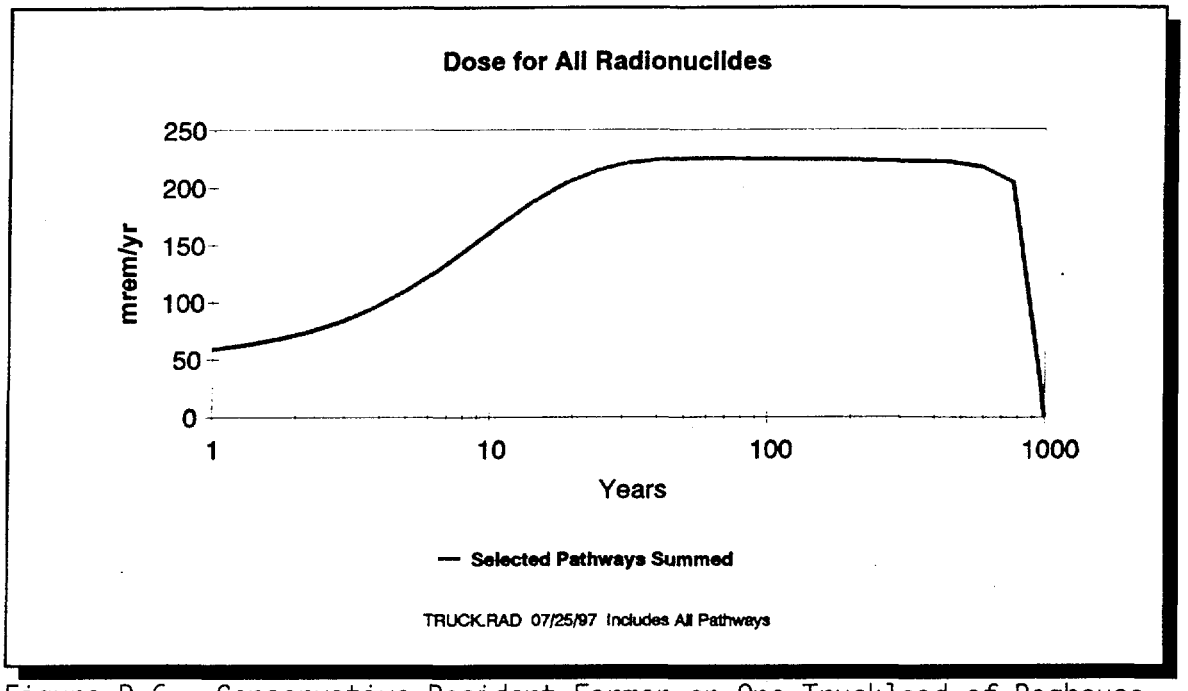

Figure D.6: Conservative Resident Farmer on One Truckload of Baghouse Dust Scenario

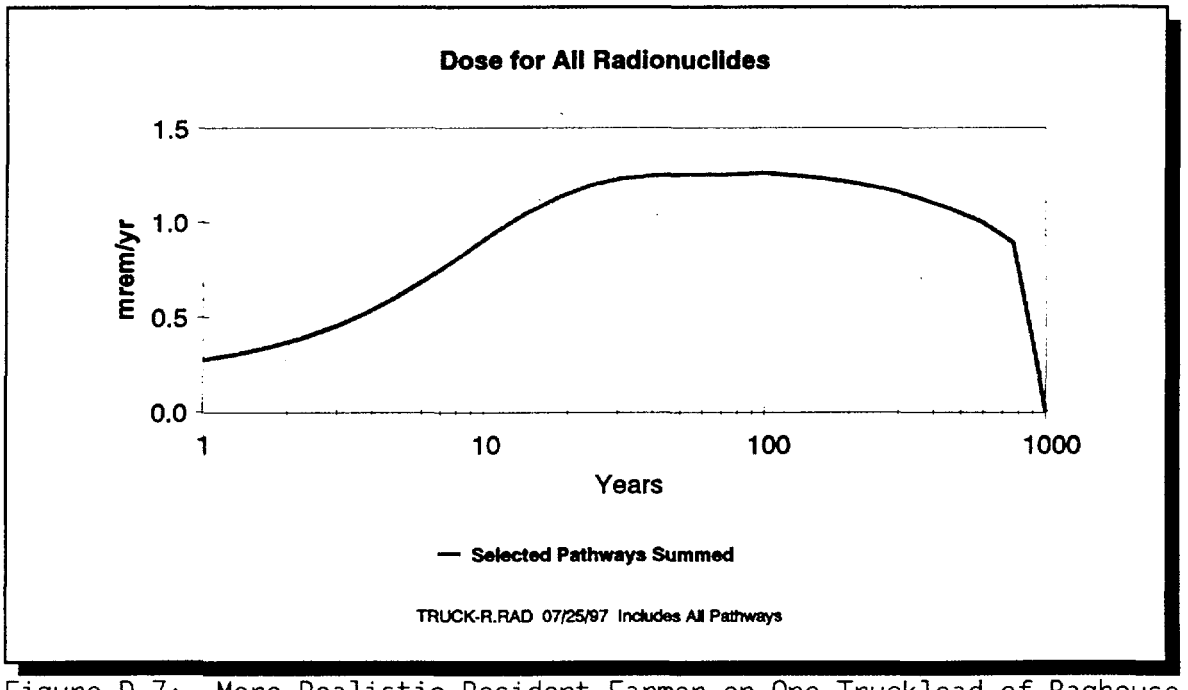

Figure D.7: More Realistic Resident Farmer on One Truckload of Baghouse Dust Scenario