INDUSTRIAL REACTOR LABORATORIES, INC.
Subsidiary of N. L. Industries Inc.
PLAINSBORO, NEW JERSEY 08536
609-799-1800

NL INDUSTRIES

3926

October 21, 1977

RECEIVED
OCT 26 1977
U. S. Nuclear Regulatory Commission
NMSS
Mail Section

United States
Nuclear Regulatory Commission
Radioisotopes Licensing Branch
Division of Fuel Cycle and
Material Safety
Washington, D.C. 20555

Attention: Mr. James A. Jones

Subject: Additional Safety Analysis Which Considers Potential Biological Pathways for the IRL Leaching Field and East Corridor.

Gentlemen:

Please find enclosed a corrected copy of Page -1-, Section 15.2, of the subject analysis stated above. Please add this page to your copy of the analysis and discard the present page. Thank you.

Very truly yours,

David W. Leigh

David W. Leigh
Decommissioning Project Manager

/ljl

Enclosure

b-1

INDUSTRIAL REACTOR LABORATORIES, INC.
Subsidiary of N. L. Industries Inc.
PLAINSBORO, NEW JERSEY 08536
609-799-1800

NL INDUSTRIES

3874

October 20, 1977

United States
Nuclear Regulatory Commission
Radioisotopes Licensing Branch
Division of Fuel Cycle and
Material Safety
Washington, D.C. 20555

Attention: Mr. James A. Jones

Subject: Additional Safety Analysis Which Considers Potential Biological Pathways for the IRL Leaching Field and East Corridor.

Reference: USNRC Correspondence Control No. 84939

Gentlemen:

Please find enclosed the Biological Pathway Analyses requested in the referenced correspondence. It is submitted as an addendum to the July 1, 1977, edition, of the report entitled <u>Final Survey Results After Decontamination</u>.

Very truly yours,

David W. Leigh
Decommissioning Project Manager

DWL/ljl

Enclosure

SECTION 15.1

3874

ESTIMATED DOSES FROM HYPOTHETICAL BIOLOGICAL PATHWAYS RESULTING FROM RADIOACTIVITY REMAINING IN LEACHING FIELD

DISCUSSION

Current Radiological Status of Leaching Field

The current radiological situation associated with the radioactivity remaining in the leaching field is summarized in Table 1 on page 187 and 188 of the IRL report.[1] In addition, a detailed radiation survey recently conducted over the entire leaching field at a height of three feet above the soil showed that external radiation varies from 0 to 0.05 mR/h, which was not distinguishable from the normal background radiation. Thus, none of the hypothetical pathways requested by the NRC will lead to an external radiation dose of any individual in excess of 0.5 rem/y.

Average concentration of radionuclides remaining in the soil as presented in Table 1 on pages 187 and 188 of the IRL report[1] are less than the applicable limit for a mixture (See Table 1 here.) Thus, none of the hypothetical pathways requested by the NRC will lead to an internal radiation dose in excess of applicable limits 10 CFR 20. The internal dose resulting from the use of the leaching field soil in a garden is summarized in Table 2 here. Individual organ and whole body dose rates due to the uptake of all organs may be obtained from the data presented in Table 2 here:

(1) Whole Body:

$\dot{H} = 1.06$ mrem/y.

(2) Lower Large Intestine of GI Tract:

$\dot{H} = 1.15 \times 10^{-2}$ mrem/y.

(3) Liver:

$\dot{H} = 3.23 \times 10^{-1}$ mrem/y.

(4) Bone:

$\dot{H} = 3.46$ mrem/y.

These dose estimates are much less than applicable limits, and actual doses would be considerably less than these values if more realistic assumptions were to be used.

Potential internal and external radiation doses to any individual from any reasonable pathway are very small and very difficult to even postulate. Doses will certainly be much less than any applicable limits of 10 CFR 20 and likely less than the ALARA Numerical Guidelines in Appendix I of 10 CFR 50.

REFERENCES

(1) Final Survey Results After Decontamination, Industrial Reactor Laboratory Facilities, Plainsboro, New Jersey, July 1, 1977.

TABLE 1

Average soil activity concentrations relative to the applicable MPC values

Radionuclide	C_i (1) (pCi/g)	MPCi (2) (uCi/cm^3)	fi (3)
^{60}Co	1.09×10^{-1}	3×10^{-5}	6.54×10^{-3}
^{134}Cs	4.46×10^{-2}	9×10^{-6}	8.92×10^{-3}
^{137}Cs	9.91×10^{-1}	2×10^{-5}	8.92×10^{-2}
^{90}Sr	9.5×10^{-2}	3×10^{-7}	5.70×10^{-1}
		Σ fi =	0.675

(1) Page 187 of IRL report[1].

(2) 10 CFR 20, Appendix B, Table II, Column 2.

(3) fi = fraction of MPC and calculated:

$$fi = \frac{(C_i)\ (1.8\ g/cm^3)\ (10^{-6}\ uCi/Pci)}{MPCi}$$

TABLE 2

Estimated Contamination Levels of Vegetables Grown in the Leaching Field Soil, Ingestion Rates, and Internal Radiation Dose Rates.

Radionuclide	(1) C_i (pCi/g)	(2) B_{iV}	(3) C_{iV} (pCi/kg)	(4) D_{ij} (mrem/pCi)	(5) $\dot{H}_i$ (mrem/y)	(6) Organ
^{60}Co	1.09×10^{-1}	9.4×10^{-3}	1.02	4.02×10^{-5}	1.15×10^{-2}	GI-LLI
				4.72×10^{-6}	1.35×10^{-3}	WB
^{134}Cs	4.46×10^{-2}	1×10^{-2}	4.46×10^{-1}	1.48×10^{-4}	1.85×10^{-2}	Liver
				1.21×10^{-4}	1.52×10^{-2}	WB
^{137}Cs	9.91×10^{-1}	1×10^{-2}	9.91	1.09×10^{-4}	3.04×10^{-1}	Liver
				7.15×10^{-5}	1.99×10^{-1}	WB
^{90}Sr	9.5×10^{-2}	1.7×10^{-2}	1.62	7.61×10^{-3}	3.46	Bone
				1.86×10^{-3}	8.47×10^{-1}	WB

(1) C_i from Table 1 here. (2) B_{iV} obtained from Table C-5 of Regulatory Guide 1.109.

(3) C_{iV} = # pCi/kg (wet weight) of vegetable crop and calculated: $C_{iV} = C_i \left(\frac{10^3 g}{kg}\right) B_{iV}$.

(4) Table A-3 of Regulatory Guide 1.109. (5) Calculated: $\dot{H}_i = C_{iV}$ (281kg/y) D_{ij}.

(6) WB ≡ Whole Body; GI-LLI ≡ Lower Large Intestine of GI Tract.

SECTION 15.2

3874

ESTIMATED DOSES FROM HYPOTHETICAL BIOLOGICAL PATHWAYS RESULTING FROM RADIOACTIVITY REMAINING IN EAST CORRIDOR

DISCUSSION

Current Radiological Status of East Corridor Excavation

The current radiological situation associated with the radioactivity remaining in the East Corridor excavation is summarized in Table 1, Table 2, and Reference 7. Average activity concentrations reported in Table 1 should relate to the average photon energy spatial equilibrium dose rate in the remaining contaminated soil.

The fractional contribution F_i of each radionuclide to the energy spatial equilibrium photon dose rate is also shown in Table 2 for the current radionuclide distribution in the soil. Because of differences in the halflife of each radionuclide, these fractional contributions will differ significantly with time. The radionuclide, ^{60}Co, currently presents the largest photon dose rate contribution. The average photon energy spatial equilibrium dose rate relative to the current average dose rate is expected to decrease with time:

$$F(t) = \sum_i F_i e^{-\lambda_i t} \qquad (1)$$

The value of F(t) is shown in Table 3 as a function of time t. The rapid initial decrease over the first thirty years is due primarily to the decay of the ^{60}Co contribution. The decrease in later years is due primarily to the decay of ^{137}Cs. This relative dose rate time history relates directly to the evaluation of future potential external radiation dose pathways. Because of the current commercial value of the IRL facility it is extremely unlikely that early intrusion into the contaminated soil will occur, probably not within the next 10 to 20 years. The photon dose rate will decrease to about 34% and 18% of its current value at the end of these times respectively. At the end of about 50 years the maximum surface exposure rate of 1mR/h observed in the excavation will have decreased to 6.9×10^{-2} mR/h (i.e., 604 mR/y). The maximum exposure rate of 0.18 mR/h observed at three feet from any surface in the excavated hole will have decreased to about 0.01mR/h. These considerations clearly demonstrate that no potential external radiation dose pathway is likely to cause the exposure of any individual in excess of 0.5 rem to the whole body in any one year provided that intrusion may be assumed to be delayed by 50 years. Since the contaminated soil will be buried under at least 6 feet of uncontaminated soil and a concrete floor and located under a building of considerable commercial value, intrusion will be extremely unlikely during this time frame. Since continuous exposure at the surface of maximum contamination is unlikely under any circumstance, it need not be assumed that intrusion is delayed at all. Such considerations are included in the pathway analyses requested by the NRC.

Use of Contaminated Soil as Building Material

The contamination remaining in the East Corridor excavation is fixed to soil comprised primarily of sand and smaller amounts of clay; it would not be considered as building material. If surrounding materials in the area of the IRL facility (e.g., gravel or sand) were to be used as building materials in the future, slight contamination would be possible. Such building materials would not be expected to contain more than 1% by weight of contaminated soil. The NRC dose pathway, however, suggests the use of the contaminated soil directly as building material. The most likely use of the contaminated soil would be as sand in concrete or concrete blocks. Normal concrete[4] contains 1 part cement, 2 parts sand, and 4 parts stone so that to a first approximation the current contamination would be diluted by the factor 2/7 or 0.286. Close to energy spatial equilibrium would be achieved at the surface of concrete blocks, walls, or floors made from such materials so that the maximum surface exposure rate could be as high as 2/7 of the current maximum exposure rate of 1 mR/h observed in the excavation or 0.29 mR/h, which is a factor of 3.5 less than the NRC proposed maximum surface radiation level of 1 mrad/h and slightly greater than the proposed average level of 0.2 mrad/h required for the release of a facility for unrestricted use[5]. An individual is not likely to be exposed continuously at the surface of such building materials, which presumably is reflected in the NRC proposed maximum surface contamination level of 1 mrad/h. An average annual exposure of 500 mrem would not be expected to be exceeded for exposure to a surface contaminated at the NRC limit of 1 mrad/hr; therefore, an individual exposed to building materials made from the contaminated soil would not be expected to receive a dose in excess of 143 mrem in any one year. Actual exposure would depend on the total area of building materials an individual is exposed to, the proximity of the individual to the surface, and the exposure time. An upper limit may be obtained by assuming the person is standing above an infinitely contaminated slab of such contaminated material. Assume that this slab is 4 inches thick. If no correction for absorption of photons in the slab is made, then the external dose factors for standing on contaminated ground as recommended by the NRC[3] In Table A-7 of Regulatory Guide 1.109 may be used directly to estimate the dose rate. Despite the gross conservatism involved in this calculation, the instantaneous whole body dose rate is only 1.97×10^{-1} mrem/h as shown in Table 4. For an occupancy of 8 hours/day, this corresponds to an annual dose of 575 mrem. A more realistic whole body dose via this pathway would be considerably less than 1 mrem/year for reasons including the following:

(1) intrusion is not likely to occur before 20 years (reduction factor of 0.179.)

(2) dilution of contaminated soil by soil which is actually more useful as building material is likely (reduction factor of at least 10^{-2});

(3) absorption of photons in slab will occur (reduction factor of about 0.5); and

(4) exposure will be limited to a finite area of building material (reduction factor not estimated).

Thus, a realistic pathway would reduce the annual dose rate by the factor of 9.0×10^{-4} or to less than 0.5 mrem/year.

Use of Contaminated Soil in a Garden

The contaminated soil remaining in the East Corridor excavation is of such characteristics that it would not normally be used in a garden. Certainly, it is inconceivable that any one would purposely dig several feet below the surface of the earth to obtain this material. If the present facility were razed and replaced by homes, slight contamination of the surface ground would be possible, perhaps containing as high as 1% by weight of contaminated soil. The NRC dose pathway, however, suggests the use of the contaminated soil directly in a garden. For the purpose of this evaluation it is assumed:

(1) the garden initially contains a 1 inch thick layer of contaminated soil;

(2) in plowing the garden the 1 inch of contaminated soil is mixed uniformly through a 6 inch thick layer of garden soil so that the concentration of contaminated soil in the garden is 1/6 of that in the excavation.

(3) an individual spends 2 hours per day for 5 months per year in the garden and receives a whole body external photon dose from the contaminated soil. This dose will be calculated without taking credit for absorption of photons in the soil.

(4) the individual eats vegetables grown in his garden at rates and contamination levels calculated according to Regulatory Guide 1.109. This ingestion gives an internal dose to the whole body and to specific organs.

Table 5 provides an estimate of the instantaneous dose rate to a person standing in the garden, which is assumed for simplicity to be an infinite contaminated plane. The average annual dose rate to this individual is calculated from the initial instanteous dose rate uncorrected for decay:

$$\bar{\dot{H}} = (1.32 \times 10^{-1}\ \text{mrem/h}) \left(\frac{2h}{d}\right) \left(\frac{5}{12} \times 365\ \frac{d}{y}\right),$$

$$\bar{\dot{H}} = 40.2\ \text{mrem/y}.$$

Table 6 gives estimates of contamination levels of vegetables grown in the contaminated garden. Table 7 gives estimates of ingestion rates and internal radiation dose rates of an individual who obtains all of his vegetables from the garden. Individual organ and whole body dose rates due to the uptake of all organs may be obtained from the data presented in Table 7:

(1) Whole Body:

$\dot{H} = 68.6$ mrem/y.

(2) Lower Large Intestine of Gastrointestinal Tract:

$\dot{H} = 1.97$ mrem/y.

(3) Liver:

$\dot{H} = 24.5$ mrem/y.

(4) Bone:

$\dot{H} = 218$ mrem/y.

Despite the fact that the bone receives the largest dose rate, due entirely to the uptake of ^{90}Sr, the whole body is the limiting internal dose pathway because of its lower maximum permissible dose rate and the external radiations received by the individual while working in the garden. The total whole body annual dose from the garden pathway due to internal and external radiation is 68.6 mrem/y + 40.2 mrem/y or about 100 mrem/y. Realistic total doses for this garden pathway would be considerably less than 1 mrem/y for many of the same reasons stated for the building material pathway. In addition, the vegetable ingestion rate of 281 kg/year is unrealistically high for the limited growing season in New Jersey.

<u>Use of the Location of Contaminated Soil as a Gravel Pit</u>

Assumptions used in this potential pathway are as follows:

(1) The building is razed now and the contaminated soil is uncovered in the process of establishing a gravel pit.

(2) The maximum surface exposure rate is that currently existing in the excavation (1 mR/h);

(3) The average exposure rate of any individual working in the area of contamination is the maximum value currently existing at three feet from any surface in the excavation (0.18 mR/h).

(4) A worker is exposed for 8 hours per day, 5 days per week, and 50 weeks per year to the average exposure rate indicated in assumption (3).

The annual exposure of the worker is calculated:

$$\dot{X} = (0.18\ \text{mR/h})\left(\frac{8\text{h}}{\text{d}}\right)\left(\frac{5\text{d}}{\text{week}}\right)\left(\frac{50\ \text{weeks}}{\text{y}}\right)\text{, or}$$

$$\dot{X} = 360\ \text{mR/y} \approx 0.36\ \text{rem/y}.$$

This dose is less than the 0.5 rem limit.

The actual dose for more realistic assumptions would be less than 1 mrem/y:

(1) The contaminated soil would more than likely be diluted and partially covered by uncontaminated soil (reduction factor of 10^{-2});

(2) Intrusion into the soil is not likely for at least 20 years (reduction factor of 0.179); and

(3) A worker would not normally be exposed for 2000 hours per year but only during the time that the area of contamination in the pit was being removed (reduction factor of 10^{-3}).

Use of the Location of Contaminated Soil as a Construction Site for An Individual Home

Assumptions used in this potential pathway are as follows:

(1) The building is razed now and replaced by an individual home whose basement floor is in direct contact with the contaminated soil remaining in the east corridor.

(2) Except for attenuation in a 4 inch concrete floor, the average exposure rate of an individual in the basement of the home is the maximum value currently existing at 3 feet from any surface in the excavation (0.18 mR/h).

(3) The overall transmission of photon radiation through the concrete floor is approximated from a weighted transmission of the ^{60}Co, ^{134}Cs and ^{137}Cs photon radiation:

$T = 0.62\ T60_{co} + 0.38\ T_{137_{Cs}}$, where 0.62 is the approximate fraction of exposure rate due to ^{60}Co and 0.38 is the approximate fraction of exposure rate due to ^{134}Cs and ^{137}Cs whose transmissions would be similar based upon a comparison of photon energies.

$T_{137_{Cs}} = 0.33$ and $T_{60_{Co}} = 0.49$ as determined from Figure 12 of NCRP No. 49[6].

Thus, the overall transmission T is obtained:

$T = (0.62)\ (0.33) + (0.48)\ (0.49) = 0.44.$

(4) An invalid is exposed in the basement continuously.

The annual exposure of this invalid is calculated:

$\dot{X} = (0.18\ mR/h)\ (0.44)\ (\frac{24h}{d})\ (\frac{365d}{y})$, or

$\dot{X} = 694\ mR/y \sim 0.7\ rem/y.$

The actual dose for more realistic assumptions would be less than 1 mrem/y:

(1) The contaminated soil would more than likely be somewhat diluted and partially covered by uncontaminated soil (reduction factor of 10^{-2});

(2) Intrusion into the soil is not likely for at least 20 years (reduction factor of 0.179); and

(3) A person would not normally be present continuously in the basement (reduction factor of 10^{-1}).

CONCLUSION

Potential internal and external radiation doses to any individual resulting from any reasonable pathway are very small and very difficult to even postulate. Doses will certainly be much less than any applicable limits of 10 CFR 20 and likely less than the ALARA Numerical Guidelines in Appendix I of 10 CFR 50.

REFERENCES

(1) Final Survey Results After Decontamination, Industrial Reactor Laboratory Facilities, Plainsboro, New Jersey, July 1, 1977.

(2) Values for Δ_i calculated from data provided in:

(a) L.T. Dillman and F.C. Vonderlage, "Radionuclide Decay Schemes and Nuclear Parameters for use in Radiation-Dose Estimation", MIRD Phamplet No. 10, Society of Nuclear Medicine, September, 1975; or

(b) Radiological Health Handbook, U.S. DHEW, 1970.

(3) Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I", March, 1976.

(4) Lionel S. Marks, Mechanical Engineer's Handbook, McGraw-Hill Book Co., Inc., New York, 1951.

(5) "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," U.S. Nuclear Regulatory Commission, Division of Fuel Cycle and Material Safety, Washington, D.C. 20555, December, 1975.

(6) Figure 12, NCRP Report No. 49, National Council on Radiation Protection and Measurements, 1976.

(7) Survey results reported for Vertical Section 3-3' as shown in "Final Survey Results After Decontamination, Industrial Reactor Laboratories Facilities, Plainsboro, New Jersey, July 1, 1977.

TABLE 1

Average Soil Activity Concentrations and Estimates of Total Activities Remaining in East Corridor Excavation

Radionuclide	t 1/2 (years)	C_i (pCi/g) (1)	A_i (mCi) (2)	$f_i = A_i/A_{^{137}Cs}$
^{54}Mn	8.58×10^{-1}	9.80	0.12	6.28×10^{-2}
^{60}Co	5.258	101.	1.24	6.49×10^{-1}
^{134}Cs	2.06	31.8	0.39	2.04×10^{-1}
^{137}Cs	30.2	156.	1.91	1
^{65}Zn	6.68×10^{-1}	22.0	0.27	1.41×10^{-1}
^{90}Sr	28.9	18.0	0.22	1.15×10^{-1}

(1) Calculated from average ^{137}Cs concentrations given on page 196 of IRL Report[1] and f_i value

$$C_i = f_i \frac{(2.81 \times 10^{-4}\ UC_i/cm^3)}{1.8\ g/cm^3}(10^6 pC_i/UC_i)$$

(2) Values from page 197 of IRL Report[1]

TABLE 2

Average Activity Concentration of ^{137}Cs Calculated from Average Energy Spatial Equilibrium Dose Rate

Radionuclide	$f_i^{(1)}$	$\Delta_i^{(2)}$ $\frac{rad/h}{uCi/g}$	$f_i\Delta_i$ $\frac{rad/h}{uCi/g}$	$F_i = \frac{f_i\Delta_i}{\sum_i f_i\Delta_i}$
^{54}Mn	6.28×10^{-2}	1.78	1.12×10^{-1}	1.99×10^{-2}
^{60}Co	6.49×10^{-1}	5.33	3.46	6.16×10^{-1}
^{134}Cs	2.04×10^{-1}	3.31	6.75×10^{-1}	1.20×10^{-1}
^{137}Cs	1	1.20	1.20	2.14×10^{-1}
^{65}Zn	1.41×10^{-1}	1.25	1.76×10^{-1}	3.13×10^{-2}
^{90}Sr	1.15×10^{-1}	---	---	---

(1) f_i obtained from Table 1 here. $\sum_i f_i\Delta_i = 5.62 \frac{rad/h}{uCi/g}$

(2) Δ_i = radionuclide mass activity concentration to photon energy spatial equilibrium dose rate conversion constant[2].

3874

TABLE 3

$F_{(t)}$, Photon Dose Rate Relative to Current Photon Dose Rate

t (years)	$F_{(t)}$
0	1.00
1	8.55×10^{-1}
2	7.47×10^{-1}
3	6.61×10^{-1}
4	5.91×10^{-1}
5	5.32×10^{-1}
10	3.39×10^{-1}
15	2.37×10^{-1}
20	1.79×10^{-1}
30	1.19×10^{-1}
40	8.84×10^{-2}
50	6.86×10^{-2}
100	2.15×10^{-2}
200	2.15×10^{-3}
300	2.16×10^{-4}
400	2.16×10^{-5}
500	2.17×10^{-6}

TABLE 4

Estimated Instantaneous Dose Rate Above Infinite Contaminated Slab of Building Material

Radionuclide	$C_i^{(1)}$ (pCi/g)	$C_i^{G(2)}$ (pCi/m^2)	$DFG_i^{(3)}$ $\frac{\text{mrem/h}}{\text{pCi/m}^2}$	$H_i^{(4)}$ (mrem/h)
^{54}Mn	9.80	6.68×10^5	5.80×10^{-9}	3.87×10^{-3}
^{60}Co	101	6.89×10^6	1.70×10^{-8}	1.17×10^{-1}
^{134}Cs	31.8	2.17×10^6	1.20×10^{-8}	2.60×10^{-2}
^{137}Cs	156	1.06×10^7	4.20×10^{-9}	4.45×10^{-2}
^{65}Zn	22	1.50×10^6	4.00×10^{-9}	6.00×10^{-3}.

$$H_T = \sum_i H_i = 1.97 \times 10^{-1} \text{ mrem/h.}$$

(1) See Table 1 above.

(2) C_i^G calculated from 2/7 C_i for 4 inch thick slab:

$$C_i^G = 2/7 C_i \text{ (4 inch)} \left(\frac{2.54 \text{ cm}}{\text{inch}}\right)\left(\frac{2.35 \text{ g}}{\text{cm}^3}\right)\left(\frac{10^4 \text{cm}^2}{\text{m}^2}\right) \text{ or } C_i^G = 6.82 \times 10^4 C_i.$$

(3) Regulatory Guide 1.109.

(4) $H_i = (C_i^G)\,(DFG_i)$.

TABLE 5

Estimated Instantaneous External Dose Rate
In Garden

Radionuclide	C_i (1) (pCi/g)	C_i^G (2) (pCi/m^2)	DFG_i (3) $\left(\frac{mrem/h}{pCi/m^2}\right)$	$\dot{H}_i$ (4) (mrem/h)
^{54}Mn	9.80	4.48×10^5	5.80×10^{-9}	2.60×10^{-3}
^{60}Co	101	4.62×10^6	1.70×10^{-8}	7.85×10^{-2}
^{134}Cs	31.8	1.45×10^6	1.20×10^{-8}	1.74×10^{-2}
^{137}Cs	156	7.13×10^6	4.20×10^{-9}	2.99×10^{-2}
^{65}Zn	22	1.01×10^6	4.00×10^{-9}	4.02×10^{-3}

$$H_T = \sum_i \dot{H}_i = 1.32 \times 10^{-1} \text{ mrem/h.}$$

(1) See Table 1 above.

(2) C_i^G calculated from C_i for 1 inch thickness of contaminated soil:

$$C_i^G = C_i \text{ (1 inch) } \left(\frac{2.54 \text{ cm}}{\text{inch}}\right) \left(\frac{1.8 g}{cm^3}\right) \left(\frac{10^4 cm^2}{m^2}\right) \text{ , or}$$

$$C_i^G = 4.57 \times 10^4 \; C_i$$

(3) Regulatory Guide 1.109[3].

(4) $\dot{H}_i = (C_i^G)\ (DFG_i)$.

TABLE 6

Estimated Contamination Levels of Vegetables Grown in Garden

Radionuclide	$\frac{1}{6} C_i$ (1) (pCi/g)	B_{iV} (2)	C_{iV} (3) (pCi/kg)
^{54}Mn	1.63	2.9×10^{-2}	47.3
^{60}Co	16.8	9.4×10^{-3}	158
^{134}Cs	5.30	1×10^{-2}	53
^{137}Cs	52.0	1×10^{-2}	520
^{65}Zn	3.67	4.0×10^{-1}	1470
^{90}Sr	6.00	1.7×10^{-2}	102

(1) C_i obtained from Table 1.

(2) B_{iV} obtained from Table C-5 of Regulatory Guide 1.109(3) and represents the concentration factor for uptake of radionuclide i from soil by edible parts of crops, in pCi/kg (wet weight) per pCi/kg dry soil.

(3) C_{iV} = #pCi/kg (wet weight) of vegetable crop and calculated:

$$C_{iV} = \left(\frac{1}{6} C_i\right)\left(\frac{10^3 g}{kg}\right) B_{iV}$$

3874

TABLE 7

The Estimated Ingestion Rates and Internal Radiation Dose Rates from Garden

Radionuclide	C_{iV} (1) (pCi/kg)	U (2) (kg/y)	D_{ij} (3) (mrem/pCi)	$\dot{H}_i$ (4) (mrem/y)	Organ (5)
^{54}Mn	47.3	281	1.4×10^{-5}	1.86×10^{-1}	GI-LLI
			8.73×10^{-7}	1.16×10^{-2}	WB
^{60}Co	158	281	4.02×10^{-5}	1.78	GI-LLI
			4.72×10^{-6}	2.10×10^{-1}	WB
^{134}Cs	53	281	1.48×10^{-4}	2.20	Liver
			1.21×10^{-4}	1.80	WB
^{137}Cs	520	281	1.09×10^{-4}	15.9	Liver
			7.15×10^{-5}	10.4	WB
^{65}Zn	1470	281	1.54×10^{-5}	6.36	Liver
			6.97×10^{-6}	2.88	WB
^{90}Sr	102	281	7.61×10^{-3}	218	Bone
			1.86×10^{-3}	53.3	WB

(1) C_{iV} obtained from Table 6 here.

(2) U ≡ usage factor that specifies intake rate of vegetables in kg/y and obtained from Table A-2 of Regulatory Guide 1.109(3) as (0.54)(520kg/y) for the adult or 281kg/y.

(3) D_{ij} ≡ adult ingestion dose factor for radionuclide i and organ j in mrem/pCi ingested and obtained from Table A-3 of Regulatory Guide 1.109(3).

(4) $\dot{H}_i$ calculated:

$$\dot{H}_i = C_{iV} U D_{ij}$$

(5) WB ≡ whole body; GI-LLI ≡ Lower Large Intestine of GI Tract