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June 19, 1986

John D. Philips
Chief, Rules and Procedures Branch
Nuclear Regulatory Commission
Room 4000, MNBB
Washington, D.C. 20555

Subject: Comments on Draft NUREG/CR-3365

Dear John:

I am sorry that my comments are being provided after the close of the public comment period; however, I had difficulty in obtaining a copy of the draft NUREG/CR-3365 for review.

This handbook will be a welcomed document for the emergency planner.

No effort was made to correct administrative errors; however, I did make comments directly on the pages that are attached.

Sincerely,

Gordon M. Lodde

Gordon M. Lodde
Radiological Consulting Engineer

GML/pat
attachment (pages from NUREG/CR-3365)

BK6 - 6/24/86

factors. If computer studies fitting the desired scenario are not available, a similar manual calculation can be performed using the simplified methods and approximations or interpolation of data from more rigorous methods. Rough dose rate calculations for areas of the plant and the surrounding area involve summing the major contributors to dose rate for the simulated plant conditions.

The following major contributors should be considered:

- ~~dose~~ rate from airborne radioactive material AND THE AIRBORNE CONCENTRATION (μCi/cc) in the area
- ~~dose~~ rate from fluids in piping systems in the area (e.g., pipes and tanks)
- ~~dose~~ rate from major gamma sources outside the immediate area
- ~~dose~~ rate from contamination on floors and walls.

EXPOSURE ~~DOSE~~ RATE CALCULATIONS

The following four sections discuss the calculation of EXPOSURE ~~dose~~ rates from point sources, line sources, immersion in a radioactive cloud and dose reduction due to shielding.

1. Point Sources

A simple rule of thumb for approximating EXPOSURE ~~dose~~ rate from a point gamma source is:

$$\dot{D}\ (1\ \text{m}) = \text{Ci} \qquad (1)$$

where

$\dot{D}$ (1 m) = EXPOSURE ~~dose~~ rate at 1 m in R/hr
Ci = number of curies of gamma source.

This equation, often referred to as the "curie-meter" rule, is accurate for 2.2 MeV gammas and valid within a factor of 2 for 0.7 MeV to 6 MeV gammas.

A more accurate statement of this rule of thumb considers the energy of the point gamma source:

$$\dot{D} = 6\ \text{CiE}/d^2 \qquad (2)$$

where

$\dot{D}$ = EXPOSURE ~~dose~~ rate in R/hr at distance d (ft)
Ci = number of curies of the gamma source

E = total energy of emitted gamma rays in MeV
d = distance in feet.

For the approximate EXPOSURE ~~dose~~ rate from a point source when other EXPOSURE ~~dose~~ rate information is available, use the simple inverse square law:

$$\frac{\dot{D}_2}{\dot{D}_1} = \left(\frac{d_1}{d_2}\right)^2 \tag{3}$$

where

$\dot{D}$ = EXPOSURE ~~dose~~ rate
d = distance (ensure that the same units are used for d_1 and d_2).

2. Line Sources

For line sources such as pipes and fuel assemblies, the formulas for a point source are fairly accurate at distances greater than half the major dimension of the line source away (i.e., inverse square law). For distances closer than one-half the major dimension, an almost directly increasing ~~dose~~ EXPOSURE rate ratio applies until very near the source.

If L (length) is the major dimension of a line source, then at distances >1/2 L the line source may be treated as a point source,

$$\dot{D}_2 = \dot{D}_1 \left(\frac{d_1}{d_2}\right)^2 \tag{4}$$

and at distances <1/2 L,

$$\dot{D}_2 = \dot{D}_1 \frac{d_1}{d_2} \tag{5}$$

where

$\dot{D}$ = EXPOSURE ~~dose~~ rate
d = distance.

3. Immersion EXPOSURE ~~Dose~~ Rates

The following equations should provide approximate values for gamma EXPOSURE ~~dose~~ rates in clouds of radioactive gases and particulates:

For Infinite Clouds:

$$\dot{D} = 2 \cdot 10^6 (\bar{E}) (X) \tag{6}$$

where

$\dot{D}$ = gamma ~~dose~~ Exposure rate (mR/hr)

$\bar{E}$ = average gamma energy per disintegration (MeV/dis)

X = concentration of isotopes in the cloud (μCi/cc or Ci/m^3).

For Semi-Infinite Clouds:

$$\dot{D} = 10^6 (\bar{E}) (X) \quad (7)$$

When $\bar{E}$ has not been calculated, a less conservative estimation based on a representative mixture of postaccident fission products can be made using the following rough factors for airborne concentrations of radioactivity:

10^{-5} μCi/cc ≡ 0.5 mR/hr
10^{-4} μCi/cc ≡ 5 mR/hr
10^{-3} μCi/cc ≡ 50 mR/hr.

Approximate values for $\bar{E}$ describing a semi-infinite cloud of noble gas in a downwind plume are presented below (where $\bar{E}$ has not been determined by counting an in situ sample):

Hours Since Reactor Scram	$\bar{E}$ (MeV/dis)
0 - 12	0.40
12 - 24	0.20
48+	0.10

4. Shielding

The ability of shielding material to reduce the gamma flux of a specific-energy level emitter is usually expressed in half-value or tenth-value thickness. Formulas for determining dose rate reduction are:

$$\text{Half Thickness:} \quad D_2 = D_1 (1/2)^{T/T_{1/2}} \quad (8)$$

$$\text{Tenth Thickness:} \quad D_2 = D_1 (1/10)^{T/T_{1/10}} \quad (9)$$

where

D = ~~dose~~ Exposure rate
T = actual shield thickness
$(T_{1/2})$ = half-thicknesses of shield material
$(T_{1/10})$ = tenth-thicknesses of shield material.

TABLE A.1. Radiation Monitoring System Data

Unit No. 1 | Date | Time 4:00 am

Data Taken by G. W. Be[illegible]hke | Data Reviewed by G. F. Martin

1.	VRS-1101	1.44E0 mR/HR	Upper Containment Area
2.	VRS-1202	3.89E-1 mR/HR	Upper Containment Area
3.	ERS-1301	3.72E-2 μCi	Lower Containment Airborne Particulate
4.	ERS-1303	5.30E-3 μCi	Lower Containment Airborne Iodine
5.	ERS-1305	2.32E-5 μCi/cc	Lower Containment Airborne Noble Gas (LR)
6.	ERS-1307	2.97E-4 μCi/cc	Lower Containment Airborne Noble Gas (MR)
7.	ERS-1309	1.59E0 μCi/cc	Lower Containment Airborne Noble Gas (HR)
8.	ERS-1401	2.40-2 μCi	Lower Containment Airborne Particulate
9.	ERS-1403	5.91E-3 μCi	Lower Containment Airborne Iodine
10.	ERS-1405	1.59E-3 μCi/cc	Lower Containment Airborne Noble Gas (LR)
11.	ERS-1407	1.44E-4 μCi/cc	Lower Containment Airborne Noble Gas (MR)
12.	ERS-1409	1.34E-2 μCi/cc	Lower Containment Airborne Noble Gas (HR)
13.	VRS-1501	1.7E-4/1.62E-3 μCi	Unit Vent Effluent Particulate
14.	VRS-1502	1.7E-4/9.68E-4 μCi	Unit Vent Effluent Iodine
15.	VRS-1505	6.19E-8/1.03E-6 μCi/cc	Unit Vent Effluent Noble Gas (LR)
16.	VRS-1507	6.92E-5/8.29E-5 μCi/cc	Unit Vent Effluent Noble Gas (MR)
17.	VRS-1509	8.73E-1/2.14E0 μCi/cc	Unit Vent Effluent Noble Gas (HR)
18.	MRA-1601	4.16E0 μCi/cc	Steam Generator PORV Loop 1
19.	VRS-1602	5.99E-2 μCi/cc	Steam Generator PORV Loop 4
20.	MRA-1701	1.44E-2 μCi/cc	Steam Generator PORV Loop 2
21.	MRA-1702	1.99E-0 μCi/cc	Steam Generator PORV Loop 3
22.	SRA-1805	1.27E-6 μCi/cc	Gland Steam Leakoff Noble Gas (LR)
23.	SRA-1807	2.74E-4 μCi/cc	Gland Steam Leakoff Noble Gas (MR)
24.	SRA-1905	1.39E-6 μCi/cc	Steam Jet Air Ejector Noble Gas (LR)
25.	SRA-1907	3.91E-5 μCi/cc	Steam Jet Air Ejector Noble Gas (MR)
26.	VRS-1310	1.02E0/2.62E0 R/hr	Containment High Range Area
27.	VRA-1410	9.68E-1/1.17E0 R/hr	Containment High Range Area
28.	SFR-1810	4.52E2/4.1E2 CFM	Gland Steam Leakoff Flow
29.	SFR-1910	2.63E1/2.15E1 CFM	Steam Jet Air Ejector Flow
30.	VFR-1510	8.33E4/6.2E4 CFM	Unit Vent Effluent Flow
31.	Wind Speed	5 MPH	
32.	Wind Direction	235° (FROM)	
33.	Air Temp. ΔT	-0.72°C	

TABLE A.6. Typical Exposure Rates Within Containment Following Severe Core Accidents

Event	Maximum Exposure Rate in Containment Immediately Following Accident
100% Core Melt	4×10^6 R/hr
10% Core Melt	6×10^5 R/hr
1% Core Melt	3×10^5 R/hr
Gap Inventory Release	1×10^5 R/hr
LOCA (With No Gap Release)	4.0 R/hr

Note: The lowest predictions for this type of accident at any plant are approximately 25% the numbers listed. This assumes a plant size below 500 to 700 MWe rating and relatively large containments.

Estimation of Approximate Containment Activity Concentration: During the first few days after an accident, the following formulas should provide a rough order-of-magnitude estimate of containment conditions:

rem/hr (in containment) = (40) x (gross CONCENTRATION ~~activity~~ in μCi/cc) (10)

Table A.7 presents approximations for estimating core damage from inplant indicators.

TABLE A.7. Approximations for Estimating Core Damage

Core Conditions	Inplant Indicators	
	Fuel Temperature	Containment Radiation Level (R/hr)
1) Core Intact - Large Coolant Leak	600°F	$0.01 - 10^2$ Probably <50
2) Clad Failure (Rupture/Oxidation) (20% of Fuel Pins)	1300°F - 2000°F	$10^3 - 10^4$
3) TMI Like (Grain Boundary Release)	>2400°F for 10 min	10^5
4) Core Melt	>4500°F	10^6

5. Estimating Radioactive Material Content

The conversion factors presented below provide an approximate (~ 50% to 200%) estimate of the radioactive material content in some common containers of radioactive liquid. These conversion factors can be useful for developing data for postaccident sampling stations and laboratories.

Method

- Measurement: Contact gamma ~~dose~~ EXPOSURE rate D in mR/hr.
- ~~Activity~~ CONCENTRATION A of the sample (μCi/mL):

Container	Formula
100 mL Plastic Bottle (Full)	$5E{-}3\ \dot{D} \le A \le 1.5E{-}2\ \dot{D}$
250 mL Plastic Bottle (Full)	$6E{-}3\ \dot{D} \le A \le 1E{-}2\ \dot{D}$
1/2 in. Diameter Plastic Tubing	$3E{-}2\ \dot{D} \le A \le 7E{-}2\ \dot{D}$

PERIPHERAL EVENTS

Exercise scenarios frequently include peripheral events designed to evaluate emergency response teams. Peripheral events that may require the generation of radiological data include breach of security, medical emergency, and fire. The types of data that may be needed includes area dose rates, air monitoring results, surface contamination measurements, personnel contamination readings, and personnel exposures.

A typical example of a peripheral event is an inplant search and rescue of an injured and contaminated victim. As the players conduct the search for the victim, the controller can use inplant radiation zone maps to provide the exposure rates observed by the rescue team as the players traverse the areas being searched. If the victim were working on a high-pressure, high-temperature, contaminated fluid system that fractured, then the victim could suffer contaminated burns.

Assuming the gross activity of the fluid were 1 μCi/gm, typical of precladding failure in older plants, the contamination on the victim could be calculated as follows. Necessary assumptions are that a total of 10 gal of fluid was sprayed on the victim before the leak was isolated, that 10% of the activity remains distributed evenly over 2 ft^2 on the victim, and that 10% of activity remains airborne in a 10 x 10 x 10 ft room:

Count rate on victim:

$$(10\ \text{gal})\ (3.8E3\ \text{gm/gal})\ (10\%/2\ \text{ft}^2)\ (1\ \mu\text{Ci/gm})\ (1E - 3\ \text{ft}^2/\text{cm}^2) = 1.9\ \mu\text{Ci/cm}^2$$

assuming a Frisker using a pancake probe with a 10% counting efficiency and a surface area of 15 cm^2:

$(1.9\ \mu Ci/cm^2)\ (15\ cm^2)\ (2.2\ E6\ dpm/\mu Ci)\ (10\%) = 6E6\ cpm$

Airborne activity:

3.8E+3

1.3E-4 $(10\ gal)\ (3.8\ gm/gal)\ (10\%/1{,}000\ ft^3)\ (1\ \mu Ci/gm)\ (3.5E\text{-}5\ ft^3/cc) =$
$1.4E - 4\ \mu Ci/cc$

A diagram of the victim's injuries and contamination should be prepared for a controller illustrating the extent and nature of the injuries and the contamination levels consistent with the emergency response team's instrumentation. Similar data should be available for a whole-body count in the event of inhalation or ingestion of radioactive material. Tools and other equipment in the vicinity of a victim could be described as contaminated to the same approximate levels as the victim considering relative proximity.

Figures A.4, A.5, and A.6 show plots of normalized ground-level average concentrations for effective source heights of 10m, 30m, and 100m respectively (Hilsmeier and Gifford 1962).

The normalized ground-level average concentrations for a discrete effective stack height can be used as follows:

$$\bar{X} = \frac{1}{\pi \sigma_y \sigma_z} \exp - \left(\frac{h^2}{\sigma_z^2}\right) \frac{Q'}{U}$$

where

$\frac{1}{\pi \sigma_y \sigma_z} \exp - \left(\frac{h^2}{\sigma_z^2}\right)$ is the normalized ground-level average concentration for effective stack height h.

<u>Example</u>

Plant stack effluent monitors indicate that noble gases are being released at a rate 3 Ci/sec from a 100-m high stack. Calculate the radionuclide concentration at the plant boundary 1 km downwind from the stack.

The source of the noble gases is a waste gas decay storage tank containing Kr-85 (half-life 10.72 yr), Xe-131m (11.92 d), and Xe-132 (5.25 d). For adverse meteorolcgy, the wind speed is assumed to be low (1 m/sec) and the atmospheric stability class is slightly unstable to moderately unstable as determined from the lapse rate method (see Table A.8). From Figure A.6, the normalized ground-level average concentration for a source height of 100 m is about 1.5E-5 at a downwind distance of 1 km. Assuming an adverse wind speed of 1 m/sec and an effective source height of 100 m, the concentration of long-lived noble gases at the ground-level is:

$$\bar{X} = \frac{1}{\pi \sigma_y \sigma_z} \exp - \left(\frac{h^2}{\sigma_z^2}\right) \frac{Q'}{U}$$

therefore,

$$\bar{X} = 1.5E\text{-}5 \times \frac{3}{1} = 4.5E\text{-}5 \ \frac{Ci}{m^3}$$

TABLE A.14. Ratio of Noble Gas Gamma Dose Rate to Noble Gas Concentration, RGC_n, as a Function of Time After Shutdown (EPA 1979)

Time After Shutdown (hr)	RGC_n^{∞} $\frac{rem/hr}{Ci/m^3}$
0	5.3E + 02
1.5	5.0E + 02
2.5	4.3E + 02
3.5	3.7E + 02
4.5	3.1E + 02
6.5	2.3E + 02
12.5	1.2E + 02

Example

A loss-of-coolant accident (LOCA) releases noble gases, radioiodines, and particulates to the atmosphere. The cumulative activity of noble gases released after 1 hour is 3.1E7 Ci. After 4 hours, the cumulative activity is 8.4E7 Ci. The airborne radionuclide concentrations are dominated by the noble gases during the time of plume passage over a location 10 km downwind from the plant. The atmospheric stability category is neutral (D) and wind speeds are 6 m/s at the effective release height of 100 m. Two hours after the LOCA the release rate of noble gases is about 6.0E3 Ci/sec at the effective release height of 100 m. Calculate the centerline gamma exposure rate (mR/hr) at a downwind distance of 10 km at about 2.5 hours after the LOCA.

Since the time required for the plume to travel a distance of 10 km is about 0.5 hours, the decay of the noble gases is about 3% as indicated in Table A.14. Therefore, plume reduction is negligible for noble gases during the 0.5-hour time period. The normalizing factor for ground-level average concentration of noble gases is about 3.0E-6 (m^{-2}) at a distance of 10^4 m for a neutral (D) atmospheric stability category (see Figure A.6). The concentration of noble gases at the ground level is:

$$\overline{X} = 3.0E\text{-}6 \ \frac{Q'}{U}$$

where

$\overline{X}$ = concentration of noble gases (Ci/m^3)
* Q' = release rate (Ci/sec)
U = wind speed (m/sec)
3.0E-6 = normalizing factor for ground-level average concentration (m^{-2})

therefore

$$\overline{X} = 3E\text{-}6 \ \times \ \frac{6E+3}{6} \ = 3E\text{-}3 \ \frac{Ci}{m^3}$$

From Table A.14, the ratio of noble gas gamma dose rate to noble gas concentration 2.5 hours after shutdown is 4.3E2 rem/hr per Ci/m^3. The gamma exposure rate is therefore:

$$R = 4.3E2 \ \frac{rem/hr}{Ci/m^3} \ \times \ 3E\text{-}3 \ \frac{Ci}{m^3} \ \times \ 1.0 \ \frac{R}{rem} = 1.3 \ \frac{R}{hr}$$

2. Conversion to Meter Readings

Surface Contamination:

The conversion of area concentrations of radionuclides on the surface of the ground to survey instrument readings is based on the following equation for a G-M counter with a metal tube wall thickness of 30 mg/cm^2 (Vallario 1974).

$$R = \frac{D}{F} \tag{23}$$

Where

R = G-M background reading at 0 to 5 cm (100 counts/min)
D = ground deposition of radionuclides ($\mu Ci/m^2$)
F = ground contamination factor ($\mu Ci/m^2$ per 100 counts/min).

The area concentrations (Ci/m^2) are estimated by using the method recommended by the NRC in 1:111 (USNRC 1977) and described previously. The concentration values obtained from Equations (VI-6) and (VI-7) need to be increased by a factor of 10E6 to yield Ci/m^2-sec and Ci/m^2 values, respectively. The ground contamination factors of various radionuclides are given in Table A.15. The conversion ratio for radioiodine is about 1 Ci/m^2 per 100 counts/minute.

A comparison of survey readings obtained at the surface of the ground with various instruments is presented in Table A.15. The G-M meter conversion factors are the same as those given in Table A.17. The term "Minor Scale
* Division" is intended to mean per 2 MR/hr. A summary of ground contamination mR
factors for survey meter readings with windows closed at a distance of one meter (3 ft) above the surface is given in Table A.17. Note that the factors are Ci/m^2 per 10^3 counts/min. Equation (24) is used for estimating exposure rates at ground surface and at 3 feet above the surface.

TABLE A.17. Summary of Ground Contamination Factors[a] for Readings (Window Closed) at 3 ft Above Surface[a] (Vallario 1974)

Radionuclides	μCi/m² Per Minor Scale Division[a] CP or Juno	μCi/m² per 10^3 Counts/min, GM Meter, Window Open[b]
^{90}Y	15 (all β)	--
^{90}Sr-^{90}Y	30 (all β)	--
^{106}Ru-^{106}Rh	30 (mostly all β)	130 (all γ)
^{144}Ce-^{144}Pr, mixed Ce-Pr (σ 100 days) ^{141}Ce	350	370
Mixed FP (100 days) ^{132}Te-^{132}I, ^{134}I, ^{134}I 135	50	60
^{60}Co, ^{137}Cs, mixed iodines (1 hr to 1 week), ^{140}La, ^{140}Ba-^{140}La (σ 100 days) ^{95}Zr-^{95}Nb	50	15
^{131}I, ^{133}I, ^{140}Ba, ^{103}Ru-^{103m}Rh Mixed Rh-Rh (σ 100 days)	150	60

(a) Total activity (μCi/m²) in case of mixtures.
(b) Tube wall thickness 30 mg/cm².

Example:

The surface concentration of elemental radioiodine is 10^2 μCi/m². Calculate the readings obtained at the surface with the windows open and at 3 ft with the windows closed. From Equation (23) and Tables A.12 and A.13 the readings on a CP and Juno meter are:

CP meter reading at surface (window open) $R = \frac{100}{15} \times 2\ \frac{mR}{hr} = 13\ \frac{mR}{hr}$

Juno meter reading at surface (window open) $R = \frac{100}{50} \times 2 \ \frac{mR}{hr} = 40 \ \frac{\mu R}{hr}$

CP and Juno readings at 3 feet (window closed) $R = \frac{100}{50} \times 2 \ \frac{mR}{hr} = 4 \ \frac{mR}{hr}$

GM meter reading at 3 feet $R = \frac{100}{15} \times 1000 \text{ cpm} = 6{,}170 \text{ cpm}$

Example:

From a previous example it was determined 1E-4 Ci/m² that the concentration of radioiodine on the surface of the ground is 10E-4 Ci/m^2. Estimate the GM survey meter reading held <5 cm above the ground with the beta shield open. From Equation (23) and Table A.10 the conversion factor is 100 cpm per μCi/m^2 of ^{131}I.

$$R = 10^{-4} \text{ Ci/m}^2 \times 10^6 \ \mu\text{Ci/Ci} \times \frac{100 \text{ cpm}}{1 \ \mu\text{Ci/m}^2} = 10{,}000 \text{ cpm}$$

Estimating the G-M survey meter reading for contaminated vegetation samples is important because herbage provides an exposure pathway to man. The vegetation sample should be obtained from at least 1 m^2 of ground and equal approximately 0.3 kg. The radiation reading in counts per minute is obtained from Equation (24):

$$R = k\ c \tag{24}$$

where

R = G-M reading minus background reading
c = concentration per kg of vegetation (mCi/kg)
k = conversion factor (100 counts/min per μCi/kg)

and

$$c = \frac{(D \times f)}{d} \tag{25}$$

where

D = total ground concentration (μCi/m^2)
f = fraction of deposition on vegetation
d = density of vegetation cover (kg/m^2).

The fraction of iodine deposited on vegetation is about 0.25. Table A.18 provides the conversion factors for vegetation samples.

If the silver zeolite cartridge is measured using a survey instrument, the formula below provides the approximate relationship between iodine concentration and dose rates for contact readings on an iodine cartridge for a 1.0 cubic meter air sample.

$$mR/hr \sim \frac{\text{Iodine concentration } \mu Ci/cc}{1E6} \qquad (27)$$

If particulates are included in the chosen release for the scenario a rapid evaluation of air contamination from beta/gamma emitters is sometimes made in the field using a survey meter held in proximity to an exposed air filter paper. A reasonable assumption for filter collection efficiency (80%) and GM survey meter counter efficiency (2%) should be used. Table A.19, using these assumptions, denotes detection limits versus operating time for a 10 L/minute sample. Using these assumptions reasonable data can be generated for field surveys of particulate filters.

TABLE A.19. Meter Readings on Air Filter Samples Versus Air Concentrations (Vallario 1974)

Air Concentration ($\mu Ci/m^3$)	Operating Time at 10 L/min	GM Meter[a] Reading at Surface of Filter (counts/minute)
1E-6	1 min	400
1E-7	5 min	200
1E-8	30 min	100
1E-9	4 hr	100

(a) Tube wall thickness = 30 mg/cm^2

3. Reentry/Recovery Information

Scenarios that contain objectives to demonstrate recovery and reentry with the associated time lapse will need to provide more field sampling data to reflect the anticipated sampling occurring during the time lapse. If the time lapse is long, then additional data could be provided to reflect the extensive sampling and laboratory analysis that would be expected.

* Data supplied for the reentry and recovery portion of the exercise should be provided in a more refined form such as in units of $\mu Ci/cc$ or Ci/m^3 to reflect the data processing during time lapse. Tables A.20 through A.22 present examples of data that may be necessary for reentry and recovery.

Example:

A radwaste discharge has resulted in lakewater contamination of 0.5 µCi/mL. A man was known to be swimming in the lake for about two hours after the contamination occurred. What is his calculated dose to the whole body? what is the calculated dose to the skin of the whole body?

WHOLE BODY:

Dose rate = (0.5 µCi/mL) (7.8 rem-mL/µCi-hr) = 3.9 rem/hr

Dose = (3.9 rem/hr) (2 hours) = 7.8 rem Whole-Body Exposure

SKIN OF WHOLE BODY:

DOSE RATE = (0.5µCi/ml)(9.36 rem/mL/µCi-hr) = 4.68 rem/hr

DOSE = (4.68 rem/hr) (2 hours) = 9.36 rem SKIN EXPOSURE