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External Radiation

NRC (Nuclear Regulatory Commission) and DOE (Department of Energy) Limits

CALCULATING TEDE AND TODE

TEDE = total effective dose equivalent
TODE = total organ dose equivalent
DDE = deep dose equivalent
CDE = 50 year committed dose equivalent to a tissue or organ
CEDE = 50 year committed effective dose equivalent
TEDE = DDE + CEDE
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DOSE EQUIVALENT LIMITS
(10CFR20 & 10CFR835)

Dose Equivalent	Annual Limit	
TEDE	5 rem	50 mSv
TODE	50 rem	0.5 Sv
LDE	15 rem	0.15 Sv
SDE,WB	50 rem	0.5 Sv
SDE, ME	50 rem	0.5 Sv
TEDE (general public)	0.1 rem	1 mSv

DOSE EQUIVALENT MEASUREMENT

	Measurement Depth for External Sources (cm)	Density Thickness (mg / cm^2)
TEDE	1	1000
TODE	1	1000
LDE	0.3	300
SDE, WB[1]	0.007	7
SDE, ME[2]	0.007	7

[1] SDE, WB is the shallow dose equivalent to the skin of the whole body

[2] SDE, ME the shallow dose equivalent to a major extremity.

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NRC Area Posting from 10CFR20

Radiation area (RA) means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

High radiation area (HRA) means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or 30 centimeters from any surface that the radiation penetrates.

Very high radiation area(VHRA) means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 1 meter from a radiation source or 1 meter from any surface that the radiation penetrates.

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DOE Area Posting from 10CFR835

High radiation area (HRA) means any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.1 rems (0.001 Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

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Personal Protective Equipment (PPE)

Shielded gloves, bibs, and aprons are used when handling radioactive sources or working very near them. Lead (or other high Z material) is used as a filler in constructing PPE for gamma shielding. Polyethylene (or other hydrogenous material) with boron is used in constructing PPE for neutron shielding.

Finger ring or wrist band TLDs (thermo luminescent dosimeters) are worn to document extremity doses. Whole body dosimeters are worn to document whole body doses. Self-reading and electronic alarming dosimeters are worn for work in high and very high radiation areas or when the individual could receive a dose near or above an established limit.

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Time, Distance, Shielding, and Source Reduction

Stay-Time Calculation

Stay-time calculations are typically used to determine how long an individual can remain in an area with elevated radiation fields until they reach some pre-determined dose limit.

Stay-time = Allowable exposure/exposure rate
example: The administrative exposure limit for a particular job is 100 mR and the exposure rate in the work area is 25 mR/hr.

Stay-time = 100 mR / 25 mR/hr = 4 hours

Often the individual doing the work has already received some prior exposure. This prior exposure may reduce the allowable exposure for a particular job.

The Stay-time calculation can be rewritten to calculate what exposure the individual would receive for a job lasting a particular length of time in a work area with a particular exposure rate.

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Calculated Exposure = Stay-time x exposure rate
Calculated Exposure = 4 hours x 25 mR/hr = 100 mR

Stay-time calculations are very critical when the exposure rates are much higher. Typically electronic alarming dosimeters are worn by those individuals performing the work and providing the radiation monitoring during the work.

Stay-time = $\frac{\text{Allowable exposure}}{\text{exposure rate}}$

example: The administrative exposure limit for a particular job is 1,000 mR and the exposure rate in the work area is 100 R/hr.

Stay-time = 1,000 mR / 100 R/hr = 0.01 hours
Stay-time = 0.01 hours x 3600 sec/hr = 36 seconds

Planning for such high exposure rate work includes the use of mock-ups for training to do the work, maintaining greater distance from the radiation source, using shielding to reduce exposure rates, and evaluating ways to reduce the radioactive source itself. In work areas where radioactive material has been processed one way to reduce the radioactive source is to flush any transport lines that contain the radioactive materials.

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Inverse Square Law

$I (D_1)^2 = I_0 (D_2)^2$

I = Measured exposure rate
D_1 = Distance from source for the measured exposure rate
I_0 = Exposure rate to be calculated
D_2 = New distance from the source

example:
I = 278 mR/hr
D_1 = 10 meters
I_0 = Exposure rate to be calculated
D_2 = 30 centimeters

$I (D_1)^2 = I_0 (D_2)^2$
278 mR/hr x $(10 \text{ meters})^2 = I_0 \times (30 \text{ cm})^2$
278 mR/hr x 100 $\text{meter}^2 / (0.3 \text{ meter})^2 = I_0$
278 mR/hr x 100 $\text{meter}^2 / 0.09 \text{ meter}^2 = I_0$
278 mR/hr x 1111 = I_0 = 308,858 mR/hr

That radioactive source has an exposure rate of more than 300 R/hr at 30 cm so we definitely do NOT want to approach the source to verify the reading.

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What if we don't know the actual distance to the source ?

Applying the Inverse Square Law to Dose Reduction

Given: A high activity source at an unknown distance.
Find: Exposure rate from the source at 30 cm without approaching closer to the source.

I is the measured exposure rate at distance D
I_0 is the measured exposure rate at distance D + 100 cm
$I\ (D)^2 \quad = \quad I_0\ (D + 100\ \text{cm})^2$
$Y^2 \quad = \quad I_0\ (D + 100\ \text{cm})^2 / I$

Set up this equation by entering the exposure rates you measured at distances D and D + 100 cm

Let us assume 100 mR/hr and 50 mR/hr for those two points.
$D^2 = 50\ (D + 100\ \text{cm})^2 / 100 = 0.5D^2 + 100D + 5{,}000$
simplify this to $D^2 - 200D - 10{,}000 = 0$

This quadratic equation can be factored into two answers. The positive answer for D is 241.42 cm. Now we know the distance for exposure rate I_0 and we can calculate the exposure rate at any distance.

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I is the measured exposure rate at distance D
I_0 is the measured exposure rate at distance D + 100 cm
$I\ (D)^2 \quad = \quad I_0\ (D + 100\ \text{cm})^2$
$Y^2 \quad = \quad I_0\ (D + 100\ \text{cm})^2 / I$

Set up this equation by entering the exposure rates you measured at distances D and D + 100 cm

Let us assume 100 mR/hr and 50 mR/hr for those two points.
$D^2 = 50\ (D + 100\ \text{cm})^2 / 100 = 0.5D^2 + 100D + 5{,}000$
simplify this to $D^2 - 200D - 10{,}000 = 0$

This quadratic equation can be factored into two answers. The positive answer for D is 241.42 cm. Now we know the distance for exposure rate I_0 and we can calculate the exposure rate at any distance.

What if we don't know the actual distance to the source ?

Applying the Inverse Square Law to Dose Reduction

Given: A high activity source at an unknown distance.
Find: Exposure rate from the source at 30 cm without approaching closer to the source.

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I_0 is the measured exposure rate at distance D + 100 cm
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$I\ (D)^2 \ = \ I_0\ (30\ cm)^2$
$100\ mR/hr \times (241.42)^2 = \ I_0\ (30\ cm)^2$
$100\ mR/hr \times (241.42)^2 / (30\ cm)^2 \ = \ I_0$
$100\ mR/hr \times 58{,}284 / 900 = \ 6{,}476\ mR/hr \ = \ I_0$

The exposure rate at 30 cm would be 6,476 mR/hr but we are able to calculate that exposure rate without entering the High Radiation Area. A simpler method without having to factor a quadratic equation is to back AWAY from the source until the exposure rate is 1/4 of the initial rate. The distance you moved away is equal to the original distance to the source. Now you can use the inverse square law to calculate the 30 cm exposure rate.

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What if you have a high exposure rate source that cannot easily be shielded and you want to post the Very High Radiation Area, High Radiation Area, Radiation Area, and Controlled Area Radiation boundaries to limit people's exposure to that radioactive source?

Very High Radiation Area boundary should be posted at 500 rads/hr.

High Radiation Area boundary should be posted at 100 mRem/hr.

Radiation Area boundary should be posted for 5 mRem/hr.

Controlled Area should be posted at 0.05 mRem/hr.

example:

> The source is 100 Curie Co-60 radiography source that has become separated from its shielding. You need to control people's access to the source until some remote handling equipment can be brought to the scene. From the 6CEN equation you know this source would read 1,500 R/hr at 30 cm.

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1,500 R/hr x $(30\text{ cm})^2 = I_0 (D_2)^2$
1,500 R/hr x $(30\text{ cm})^2 / I_0 = (D_2)^2$

A Very High Radiation Area boundary is not required to be posted since the source will not meet the 500 rads/hr at 1 meter criteria.
1,500 R/hr x $(30\text{ cm})^2 = I_0 (100\text{ cm})^2$
1,500 R/hr x $(30\text{ cm})^2 / (100\text{ cm})^2 = I_0$
1,500 R/hr x 900 / 10,000 = 135 R/hr = I_0

A High Radiation Area boundary should be posted at 100 mRem/hr.
1,500 R/hr x $(30\text{ cm})^2$ / 100 mRem/hr = $(D_2)^2$
100 mRem/hr is 0.1 R/hr
1,500 R/hr x 900 cm^2 / 0.1 R/hr = 135,000 = $(D_2)^2$
$(D_2)^2$ = 135,000
D_2 = 367 cm = 3.67 meters

A Radiation Area boundary should be posted for 5 mRem/hr.
1,500 R/hr x $(30\text{ cm})^2$ / 5 mRem/hr = $(D_2)^2$
5 mRem/hr is 0.005 R/hr
1,500 R/hr x 900 cm^2 / 0.005 R/hr = 270,000,000 = $(D_2)^2$
$(D_2)^2$ = 270,000,000
D_2 = 16,432 cm = 164 meters

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1,500 R/hr x 900 cm^2/0.00005 R/hr = 2.7E10 = $(D_2)^2$
$(D_2)^2$ = 2.7E10 cm^2
D_2 = 164,317 cm = 1,643 meters

Emergency Actions

1 You need to evacuate the Radiation Area boundary which is anyone within 500 feet of the source.

2 You need to limit the amount of time anyone spends within the Controlled Area boundary which is anyone within a mile of the source.

3 Use stay-time calculations and electronic alarming dosimeters to limit any individual responder’s dose to 25 Rem.

4. **Guidelines for Control of Emergency Exposures**
Use a dose limit of:

5 rem (50 mSv)	for all emergency procedures
10 rem (100 mSv)	only for protecting major property
25 rem (250 mSv)	for lifesaving or protection of large populations
> 25 rem (250 mSv)	for lifesaving or protection of large populations only by volunteers and where the risks have been evaluated

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6CEN and 2TBqEN

The **6CEN** equation can be used to calculate the exposure rate in R/hr at one foot for x-ray and gamma radiation point sources with energies between 60 KeV and 2 MeV.

R/hr at 1 foot = 6CEN
where; C = curies of radioactive material
E = photon energy in MeV
N = abundance of that photon expressed as a decimal

example: A 5 Curie Ir-192 source which has gamma energies and abundances of 0.296 MeV at 29%, 0.308 MeV at 29.68%, 0.317 MeV at 82.85%, and 0.468 MeV at 48.1%.
Change the % to decimals for the equation.
We need to sum the photon energy times their abundances.

R/hr at 1 foot (~30 cm) = 6 x 5 x (0.296x0.29 + 0.308x0.2968 + 0.317x0.8285 + 0.468x0.481)

R/hr at 1 foot (~30 cm) = 30x(0.0858 + 0.0914 + 0.2626 + 0.2251)

R/hr at 1 foot (~30 cm) = 30 x 0.6649 = 19.9 R/hr

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2TBqEN

The same formula in Sv/h at 30 cm is given by 2 TBqEN, where TBq is the number of terabecquels.

Sv/hr at 30 cm = 2TBqEN

where; TBq = quantity of radioactive material
E = photon energy in MeV
N = abundance of that photon expressed as a decimal

example: A 3 TBq Co-60 source which has gamma energies and abundances of 1.173 MeV at 100% and 1.332 MeV at 100%.

Change the % to decimals for the equation.
We need to sum the photon energy times their abundances.

Sv/hr at 30 cm = 2 x 3 x (1.173x1 + 1.332x1)

Sv/hr at 30 cm = 6 x (2.5) = 15 Sv/hr

15 Sv/hr is 1,500 Rem/hr

In the example of the use of the Inverse Square Law a 100 Curie Co-60 source was used. The 6CEN calculation for that source gave us 1,500 Rem/hr at 1 foot distance. 100 Curies is 3.7 TBq. The two different methods yield results that are the same within 20%.

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Photon Fluence ϕ from a Point Source

$\phi = AY / 4\pi R^2$ = photon fluence rate (γ / cm^2-sec)
A = source activity in Bq (decays per second)
Y = photon yield (γ / decay)
R = distance from point source (cm)

example: A 1 Curie Cs-137 source calculated for a distance of 30 cm.
Activity = 1 Curie = 3.7E10 Bq
Y = 0.95 (Cs-137 decays 95% of the time to Ba-137m which is the real gamma emitter.)
R = 30 cm

$\phi = AY / 4\pi R^2$ = photon fluence rate (γ / cm^2-sec)
$\phi = 3.7E10 \times 0.95 / 4\pi 30^2$ γ / cm^2-sec
$\phi = 3.11E6$ γ / cm^2-sec

If you use a typical ion chamber with a 300 cc chamber the typical window surface area is 40 cm^2, the number of photons entering the chamber through the window from the source at a distance of 30 cm would be 1.24E8 per second.

When you stand near the source to make the measurement the number of photons entering your body would be approximately 1E10 per second. The exposure rate from a 1 Curie Cs-137 source is approximately 4 Rem/hr at 30 cm distance.

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A = source activity in Bq (decays per second)
Y = photon yield (γ / decay)
R = distance from point source (cm)

example: A 1 Curie Cs-137 source calculated for a distance of 30 cm.
Activity = 1 Curie = 3.7E10 Bq
Y = 0.95 (Cs-137 decays 95% of the time to Ba-137m which is the real gamma emitter.)
R = 30 cm

$\phi = AY / 4\pi R^2$ = photon fluence rate (γ / cm^2-sec)
$\phi = 3.7E10 \times 0.95 / 4\pi 30^2$ γ / cm^2-sec
$\phi = 3.11E6$ γ / cm^2-sec

If you use a typical ion chamber with a 300 cc chamber the typical window surface area is 40 cm^2, the number of photons entering the chamber through the window from the source at a distance of 30 cm would be 1.24E8 per second.

When you stand near the source to make the measurement the number of photons entering your body would be approximately 1E10 per second. The exposure rate from a 1 Curie Cs-137 source is approximately 4 Rem/hr at 30 cm distance.

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Exposure Rate from a Point Source

$R/hr = \Gamma A / r^2$
Γ = specific gamma ray constant (R/hr @ 30 cm per Ci)
A = activity of source in curies
r = distance from source in centimeters

example: A 50 Curie N-16 source which has a half-life of 7.13 seconds and a gamma ray constant of 16.5672. Calculate the exposure rate at 2 meters (200 cm) from the source.

R/hr for 50 Ci of N-16 = 16.5672 R/hr x 50 Ci / 200^2

R/hr = 16.5672 R/hr x 50 Ci / 200^2 = 0.0207 R/hr

N-16 is produced through the neutron activation of oxygen. N-16 is a personnel radiation hazard in BWR (boiling water reactors) and in accelerators.

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Exposure Rate from a Line Source

Rule of Thumb Method

Inside L / 2: $I\,(D_1) = I_0\,(D_2)$
Outside L / 2: $I\,(D_1)^2 = I_0\,(D_2)^2$
D_1 = distance from source at location 1
D_2 = distance from source at location 2
L = length of line

Note that outside of L / 2 the equation is the same as the inverse square law.

example:

Assume you have a radioactive material transport pipe 30 feet long that has a consistent level of radioactive material inside that transport pipe. The exposure rate closer than 15 feet from the pipe will vary linearly with distance from the pipe. The exposure rate beyond 15 feet from the pipe will vary with the square of the distance from the pipe.

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OR

Calculate the exposure rate from a line source

R/hr = $\Gamma A_L \times \ln(L^2 + R^2) / R^2$
Γ = R/hr @ 1 meter per Ci
A_L = activity per unit length (curies per meter)
L = length of the line in meters
R = distance from line in meters

example: Assume you have a radioactive material transport pipe 30 feet long that has a consistent level of Ac-228 inside that transport pipe.

R/hr = $\Gamma A_L \times \ln(L^2 + R^2) / R^2$
Γ = Ac-228 is 7.0977 R/hr @ 30 cm per Ci
A_L = 1 Curie per meter
L = 10 meters
R = 2 meters distance from line
First convert the Ac-228 gamma ray constant into R/hr at 1 meter.
7.0977 R/hr at 30 cm is 7.0977/11.11 R/hr at 1 meter.

R/hr = $(7.0977/11.11) \times 1$ Ci/meter $\times \ln(L^2 + R^2) / R^2$
R/hr = $0.639 \times 4.64 / 4$
R/hr = 0.741 R/hr

What would the source read at a distance of 2 meters if it was a point source?

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Exposure Rate from a Disk Source

R/hr = $\pi R^2 A_a \Gamma \times \ln[(R^2 + D^2) / D^2]/R^2$
Γ = R/hr @ 1 meter per Ci
A_a = activity per unit area (curies per sq. meter)
R = radius of source surface in meters
D = distance from source surface in meters

example: Assume you have a liquid rad material spill that has a consistent concentration of Be-7.

R/hr = $\pi R^2 A_a \Gamma \times \ln[(R^2 + D^2) / D^2]/R^2$
Γ = Be-7 is 0.0303 R/hr @ 1 meter per Ci
A_a = 1 Curie per square meter
R = 5 meters
D = 1 meter distance above the surface of the spill

$$R/hr = \frac{\pi R^2(0.0303) \times 1\ \text{Ci/sq. meter} \times \ln[(R^2 + D^2)/D^2]}{R^2}$$

The R^2 at top and bottom cancel each other.
R/hr = 3.14 x 0.0303 x 3.26
R/hr = 0.31 R/hr

What would the source read at a distance of 1 meter if it was a point source?

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BETA SHIELDING

Bremsstrahlung Fraction:
F = 3 (low Z) or 5 (high Z) x 1E-2 E_{max}

Activity_{gamma} = F x Activity_{beta}
Activity_{gamma} = (3 or 5 x 1E-4 Emax) x Activity_{beta}
Gamma energy is a function of the Z number of the shielding material.

example: Assume you have a P-32 source of 1 Curie in a glass container.
P-32 Emax is 1.71 MeV
The Z number of Silicon is in between low and high so we will use 4.
F = 4 x 1E-2 x 1.71 MeV
Activity_{gamma} = 4 x 1.71E-2 x 1 Ci
Activity_{gamma} = 6.84E-2 Ci
Assume the gamma energy emitted is between 40 and 100 keV.
Use 6CEN to calculate the gamma exposure rate.
6CE = 6 x 6.84E-2 x 0.07 = 29 mR/hr at 30 cm

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SHIELDING MATERIALS

α	a single sheet of paper
β^-	low Z, such as plastic or aluminum
γ	high Z, such as tungsten
mixed β^-/γ	low Z, then high Z
neutron	hydrogenous material to thermalize (such as polyethylene) then neutron absorber (such as Cd, B, Li, Hf), then high Z to absorb "capture gammas"

Photon Half-Value Layers in CM

	100 KeV	600 KeV	1 MeV	2 MeV
U	0.005	0.25	0.48	0.78
W	0.008	0.35	0.58	0.82
Pb	0.012	0.52	0.90	1.35
Sn	0.06	1.20	1.38	1.80
Cu	0.18	1.01	1.70	1.65
Fe	0.25	1.15	1.32	1.55
Al	1.12	3.30	4.45	5.90
Concrete	1.8	3.8	4.6	6.2
Water	4.2	7.8	9.6	14.2

This table applies to a thin shield and no provision is made for buildup factor. Always perform a radiation measurement to confirm adequacy of shield.

Tenth-Value Thickness

Simply multiply the half-value thickness by the square root of 10 (3.162) to get the tenth-value thickness.

Example: A half-value thickness of concrete for Cs-137 gamma radiation is 3.8 cm.
The tenth-value thickness is 3.8 cm x 3.162 = 12 cm.

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Photon Shielding Buildup Factors

MeV	Water	Aluminum	Concrete	Iron	Lead
0.5	2.52	2.37	2.19	1.98	1.24
1.0	2.13	2.02	1.94	1.87	1.37
2.0	1.83	1.75	1.75	1.76	1.39

Neutron and Gamma Shielding

SIMPLIFIED SHIELD THICKNESS CALCULATION

perform radiation measurements to verify these calculations

I = shielded exposure rate

I_0 = unshielded exposure rate

n = number of shielding layers (tenth or half)

$I = I_0 \times 0.1^n$ for tenth value thickness

$I = I_0 \times 0.5^n$ for half value thickness

Radiation Streaming

Consider the potential for radiation streaming thru gaps in the shielding. Design the shielding to minimize gaps and perform a comprehensive survey after the shielding is in place.

Stay-Time Calculation

Stay-time calculations are typically used to determine how long an individual can remain in an area with elevated radiation fieldsu ntil they reach some pre-determined dose limit. The principles can also be applied to airborne areas.

Stay-time = Allowable exposure/exposure rate
example; allowable exposure is 100 mR
exposure rate is 25 mR/hr
Stay-time = 100 mR / 25 mR/hr = 4 hours

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Stay-time = 100 mR / 25 mR/hr = 4 hours

Photon Shielding Buildup Factors

MeV	Water	Aluminum	Concrete	Iron	Lead
0.5	2.52	2.37	2.19	1.98	1.24
1.0	2.13	2.02	1.94	1.87	1.37
2.0	1.83	1.75	1.75	1.76	1.39

Neutron and Gamma Shielding

SIMPLIFIED SHIELD THICKNESS CALCULATION

perform radiation measurements to verify these calculations

I = shielded exposure rate

I_0 = unshielded exposure rate

n = number of shielding layers (tenth or half)

$I = I_0 \times 0.1^n$ for tenth value thickness

$I = I_0 \times 0.5^n$ for half value thickness

Radiation Streaming

Consider the potential for radiation streaming thru gaps in the shielding. Design the shielding to minimize gaps and perform a comprehensive survey after the shielding is in place.

Stay-Time Calculation

Stay-time calculations are typically used to determine how long an individual can remain in an area with elevated radiation fieldsu ntil they reach some pre-determined dose limit. The principles can also be applied to airborne areas.

Stay-time = Allowable exposure/exposure rate
example; allowable exposure is 100 mR
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Beta Dose Rates in rad/hr per mCi

MeV	1 cm	10 cm	30 cm	60 cm	90 cm	1.0 m
0.15	1,200	1.7	0	0	0	0
0.25	1,000	2.2	0.1	0	0	0
0.30	900	3.6	0.1	0	0	0
0.50	750	5.2	0.4	0.05	0.01	0
0.75	650	5.0	0.5	0.05	0.01	0
1.0	550	4.6	0.4	0.1	0	0
1.25	450	4.3	0.4	0.1	0.04	0.02
1.50	400	4.0	0.4	0.1	0.04	0.02
1.75	350	3.4	0.4	0.1	0.04	0.02
2.00	340	3.6	0.4	0.1	0.04	0.02
2.25	320	3.3	0.4	0.1	0.04	0.02

Beta dose should be treated as a “shallow” dose and should not be summed with “deep” doses. This chart should also be used to determine beta+ doses from positron emitters.

Half-value Thickness vs Beta Energy

Isotope	Emax (MeV)	Half-Value Thickness mg / cm^2
C-14	0.156	2
Tc-99	0.292	7.5
Cl-36	0.714	15
Sr/Y-90	0.546 / 2.284	150
U-238 Betas from short lived progeny		
	0.191 / 2.281	130
P-32	1.710	150

Estimate the half-value thickness for a beta emitter.
$mg/cm^2 = 50 \times E^2$
where E is Emax in MeV for the beta emitter
This equation tends to underestimate the half-value thickness for low energy betas and overestimate the half-value thickness for high energy betas.

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Positron Emitters Beta+ Energy and % Abundance

	Half-life	MeV (%)
C-11	20.3 m	0.960 (99.8%)
N-13	9.97 m	1.199 (99.8%)
O-15	122 s	1.732 (99.9%)
F-18	1.83 h	0.634 (96.7%)
Na-22	2.605 y	0.546 (89.8%)
Al-26	7.3E5 y	3.210 (100%)
V-48	15.98 d	0.697 (50.1%)
Mn-52	5.591 d	2.633 (94.9%)
Co-56	77.3 d	1.458 (19.0%)
Ni-57	35.6 h	0.737 (7.0%), 0.865 (35.3%)
Co-58	70.88 d	0.475 (14.9%)
Cu-62	9.74 m	2.926 (97.2%)
Zn-65	243.8 d	0.330 (1.4%)
Ga-68	67.7 m	0.822 (1.2%), 1.899 (89.1%)
As-74	17.8 d	0.945 (26.1%), 1.540 (3.0%)
Rb-82	1.26 m	2.601 (13.1%), 3.378 (81.8%)

Several of the positron emitters are useful in PET studies. That usefulness is somewhat offset by the cost of producing the radionuclides and the added complexity of radiation protection. For all of the positron emitters the energy of the Beta+ must be considered. Refer to the table of Beta Dose Rates for estimates of beta+ radiation exposure. Also, consider the annihilation photons when the positron comes into contact with a beta-, annihilating their masses and producing two 511 KeV photons. These photons present an external radiation hazard. For the patient undergoing a PET scan the combination of the positron energy and the photon energy must be considered.

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Combining Radiation Types to Determine Total Dose

An individual radionuclide may have several different types of emissions. Those different types of emissions and the short-lived progeny of the individual radionuclide must be considered when determining a total dose.

Particulate radiation should be treated as a “shallow” dose while photons and neutrons should be treated as a “deep” dose and these two types of doses should not be summed.

This example with sodium-22 will clarify this concept.

Na-22 2.605 y Beta+ 0.546 MeV (89.8% Abundance)
1 mCi Gamma 1.275 MeV (99.9% Abundance)

From the table of Beta Dose Rates we find 320 rad/hr at 1 cm and 0.4 rad/hr at 30 cm. The near contact dose rate is much higher than the dose rate at 30 cm.

Using 6CEN for the gamma dose rate we find;
6CEN = 6 x 1 mCi x 1.275 MeV x 0.999 = 7.64 mRem/hr at 30 cm.

We can also use 6CEN for the annihilation photons from the positron.
6CEN = 6 x 1 mCi x 0.511 MeV x 2 x 0.898 = 5.51 mRem/hr at 30 cm.

The “shallow” dose from the positron at 30 cm is 400 mrad/hr and the “deep” dose from the gamma and photon radiation is 7.64 mRem/hr + 5.51 mRem/hr = 13.15 mRem/hr.

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Shallow Dose Correction Factor

In accordance with 10CFR20 and 10CFR835 deep dose equivalent shall be used for posting of radiation areas. Shallow dose equivalent shall be reported separate from deep dose equivalent. Deep dose equivalent is the sum of the gamma and neutron deep dose equivalents. Shallow dose includes low-energy photons and charged particles such as betas, positrons, and protons. Alpha particles are not included in shallow dose.

The following applies to vented air ionization chambers with a window density thickness of 7 mg/cm^2 and a moveable shield with a density thickness of 1,000 mg/cm^2.

Determining the need to report a shallow dose;
If the Open Shield Reading divided by the Closed Shield Reading is equal to or greater than 1.2, then perform a shallow dose survey.
Calculate the shallow dose rate using this equation;
(Open Shield Reading - Closed Shield Reading) x CF
Obtain the **CF** (Correction Factor) from experimental or published data for the specific detector and radiation source(s).

Typical correction factors for betas range between 2 and 5 (multipliers).
Typical correction factors for low energy photons range between 0.1 and 1 (multipliers).

Low energy photons that penetrate the closed shield of the ion chamber and produce a response in the instrument are part of the “deep” dose.

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NEUTRON SHIELD THICKNESS

$I = I_0e^{-\sigma Nx}$
where; I = final neutron flux rate
I_0 = initial neutron flux rate
σ = shield cross section in square centimeters
N = number of atoms per cm^3 in the shield
x = shield thickness in centimeters

example:

A dosimetry phantom is designed to simulate the composition of the human body. Ten % by weight is hydrogen. Assume a density of 1 and a shield cross section of hydrogen of 0.1 barns. A barn is 1E-24 cm^2. N, the number of atoms per cm^3, is 10% of Avogadro's number, so N equals 6E22 hydrogen atoms per cm^3. Assume the phantom thickness is 30 cm.

I_0 = 5,000 n/cm^2 /s
σ = 1E-25 cm^2 (0.1 barns)
N = 6E22 atoms per cm^3
x = 30 centimeters thick

$-\sigma Nx$ = 1E-25 times 6E22 times 30 = -0.18
$I = I_0e^{-\sigma Nx}$
I = 5,000 n/cm^2 /s $e^{-0.18}$
I = 5,000 n/cm^2 /s x 0.835 = 4,175 n/cm^2 /s

The attenuation of the neutron flux by the phantom is about 16%.

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I = 5,000 n/cm^2 /s x 0.835 = 4,175 n/cm^2 /s

The attenuation of the neutron flux by the phantom is about 16%.

NEUTRON SHIELD THICKNESS

$I = I_0e^{-\sigma Nx}$
where; I = final neutron flux rate
I_0 = initial neutron flux rate
σ = shield cross section in square centimeters
N = number of atoms per cm^3 in the shield
x = shield thickness in centimeters

example:

A dosimetry phantom is designed to simulate the composition of the human body. Ten % by weight is hydrogen. Assume a density of 1 and a shield cross section of hydrogen of 0.1 barns. A barn is 1E-24 cm^2. N, the number of atoms per cm^3, is 10% of Avogadro's number, so N equals 6E22 hydrogen atoms per cm^3. Assume the phantom thickness is 30 cm.

I_0 = 5,000 n/cm^2 /s
σ = 1E-25 cm^2 (0.1 barns)
N = 6E22 atoms per cm^3
x = 30 centimeters thick

$-\sigma Nx$ = 1E-25 times 6E22 times 30 = -0.18
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The attenuation of the neutron flux by the phantom is about 16%.

Neutron Half-Value Layers in centimeters

Energy in MeV	1	5	10	15
Polyethylene	3.7	6.1	7.7	8.8
Water	4.3	6.9	8.8	10.1
Concrete	6.8	11	14	16
Damp soil	8.8	14.3	18.2	20.8

example:
How many half-value layers of polyethylene are needed to attenuate a 100 mRem/hr 5 MeV neutron source to 5 mRem/hr? How thick does the polyehylene need to be?

I = I_0 x 0.5^n
I = 5 mRem/hr
I_0 = 100 mRem/hr
n = the number of half-value layers

$I/I_0 = 0.5^n$
$5/100 = 0.05 = 0.5^n$
ln 0.05 = n x ln 0.5
ln 0.05/ln 0.5 = n
-2.996/-0.693 = n
4.32 = n
It will take 4.32 half-value layers of polyethylene to reduce attenuate the neutron source.
4.32 half-value layers is 4.32 x 6.1 cm = 26.4 cm

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SOURCE REDUCTION

The two main ways that radioactive source reduction is accomplished is through allowing the source to radioactively decay and by removing the source from the work area.

Radioactive Decay Calculation

$A_t = A_o e^{-\lambda t}$ $A_o = A_t / e^{-\lambda t}$
$t = \ln(A_t / A_0) / -\lambda$ half-life $= -t \times 0.693 / \ln(A_t/A_0)$

Where; A_t is the activity at the end of time ‘t’
A_o is the activity at the beginning
λ is 0.693 divided by the half-life
t is the decay time

example 1:
What is the activity of Co-60 remaining 12 years after the Co-60 was produced ?

$A_t = A_o e^{-\lambda t}$
λ is 0.693 divided by the half-life of Co-60 (5.271 y)
t is the decay time (12 years)
λ times t is 0.693/5.271 x 12 = 1.578
$e^{-\lambda t} = e^{-1.578} = 0.206$
$A_t = A_o \times 0.206$
20.6% of the Co-60 activity remains after 12 years

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example 2:
What is the half-life of a radionuclide that decayed to 32% in 28 days?
half-life = -t x 0.693 / ln(A_t/A_0)
half-life = -28 days x 0.693 / ln(32/100)
half-life = -19.404 days / -1.139 = 17.04 days

Removing the Source from the Work Area

Removing the radioactive source before the work begins could be accomplished by flushing radioactive material out of transfer lines or out of storage tanks. If there are radioactive sources in the work area that are not required, then consideration should be given to moving that source away from the work area.

For more information on exposure rates from radioactive sources refer to “Activity vs Exposure Rate” and “Activity vs Particle Size” in the TA and Overhoff Handbook of Radiation Data.

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Surface Radioactive Contamination

Limits

Table 1 of DOE 5400.5

Surface Activity Guidelines

Radionuclides	**Ave**	**Max**	**Removable**
Group 1: Transuranics, ^{125}I, ^{129}I, ^{227}Ac, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{231}Pa	100	300	20
Group 2: Th-natural, ^{90}Sr, ^{126}I, ^{131}I, ^{133}I, ^{223}Ra, ^{224}Ra, ^{232}U, ^{232}Th	1,000	3,000	200
Group 3: U-natural, ^{235}U, ^{238}U, and associated decay products, alpha emitters	5,000	15,000	1,000
Group 4: Beta/gamma emiters[1]	5,000	15,000	1,000
Tritium[2]	N/A	N/A	10,000

[1] radionuclides with decay modes other than alpha emission or spontaneous fission except ^{90}Sr and others noted above

[2] applicable to surface and subsurface

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Appendix D of 10CFR835

Nuclide	Removable	Total (fixed + removable)
Natural U, ^{235}U, ^{238}U, and associated decay products	1,000 alpha	5,000 alpha
Transuranics, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{228}Th, ^{231}Pa, ^{227}Ac, ^{125}I, ^{129}I	20	500
Natural Th, ^{232}Th, ^{90}Sr, ^{223}Ra, ^{224}Ra, ^{232}U, ^{126}I, ^{131}I, ^{133}I	200	1,000
Beta/gamma emitters[1]	1,000	5,000
Tritium[2]	10,000	10,000

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Contamination levels in dpm/100 cm^2

Appendix D of 10CFR835

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DOE Area Posting from 10CFR835

Contamination area (CA) means any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in appendix D of this part, but do not exceed 100 times those values.

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Personal Protective Equipment (PPE)

Gloves, booties, and lab coats are used when working in areas with removable (loose) surface contamination. Coveralls replace the lab coats if higher levels of contamination exist. Double gloves and double booties are used also if contamination levels warrant their use. Water resistant outerwear (coveralls) are used if the work involves coming in contact with contaminated liquids.

Respiratory protection is not required unless radioactive airborne contamination exists or may be created by the work activity.

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RESUSPENSION OF LOOSE SURFACE CONTAMINATION

Loose (or removable) surface contamination may be a contamination hazard and may become an airborne radioactivity hazard.

example:
A 100 ml solution of 0.10% P-32 falls to the floor and spreads across an area about 15 feet (450 cm) in diameter. The P-32 solution dries rapidly. What is the average surface contamination level?

Assume the 0.10% P-32 solution has a specific gravity of 1, therefore there is 0.10 grams of P-32 on the floor. The surface area is estimated by πR^2. The specific activity of P-32 is 2.86E5 curies per gram.

Calculate the average surface contamination like this;
DPM = 0.10 g x 2.86E5 Ci/g x 2.22E12 DPM /Ci = 6.3492E16 DPM
πR^2 = 3.14 x 225^2cm = 1.589625E5 cm^2
DPM per cm^2 = 6.35E16 DPM/1.59E5 cm^2
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πR^2 = 3.14 x 225^2cm = 1.589625E5 cm^2
DPM per cm^2 = 6.35E16 DPM/1.59E5 cm^2
DPM per cm^2 = 3.99E11 DPM/cm^2
convert this into units of DPM/100 cm^2
DPM per 100 cm^2 = 3.99E9 DPM/100 cm^2

This is definitely a surface contamination problem. The area should be controlled immediately to prevent anyone from entering the area until the spill is cleaned up.

Before cleaning up the spill make a determination whether an airborne radioactivity hazard exists.

EQ 1 to estimate the potential airborne concentration.
Concentration = # DPM /100 cm^2 x 1E-6 / M x 1 M per 100 cm x uCi / 2,22E6 DPM
Use the DPM/100 cm^2 calculated earlier.
1E-6 per meter is Alan Brodsky’s (and others) estimate of the amount of loose material that could become airborne under normal conditions.

Concentration in uCi / ml = DPM / 100 cm^2 x 4.5E-15
uCi/ml = 3.99E9 DPM/100 cm^2 x 4.5E-15
uCi/ml = 1.65E-5 uCi/ml

Now we convert the concentration into an estimation of the potential airborne hazard by calculating the number of DACs of airborne activity.

EQ 2 to convert the airborne concentration into DACs
Concentration in # DACs = uCi / ml x DAC factor
The DAC factor for P-32 is 2E-7 uCi/ml (10CFR20)
DACs = 1.65E-5/2E-7 = 82.5 DACs

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Time, Distance, Shielding, and Source Reduction

Stay-Time Calculation

Stay-time calculations are seldom used when the hazard is only surface contamination.

Distance

Distance is not typically a radiation protection problem for surface contamination. Only in the case of beta or gamma contamination would the surface contamination present a problem that could be addressed by using distance to reduce the exposure.

Shielding

Alpha Shielding

If the surface contamination is alpha emitting particles only the use of regular PPE would be sufficient to shield the individuals from becoming contaminated.

Beta Shielding

If the surface contamination is beta emitting particles, then eye protection (glasses, goggles, or face shields) would be used along with regular PPE.

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Gamma and Neutron Shielding

Shielding is usually not considered for surface contamination by gamma or neutron radiation.

SOURCE REDUCTION

The two main ways that radioactive source reduction is accomplished is through allowing the source to radioactively decay and by removing the source from the work area.

Radioactive Decay Calculation

$A_t = A_o e^{-\lambda t}$ $A_o = A_t / e^{-\lambda t}$

$t = \ln(A_t / A_0) / -\lambda$ half-life = $-t \times 0.693 / \ln(A_t/A_0)$

Where; A_t is the activity at the end of time 't'
A_o is the activity at the beginning
λ is 0.693 divided by the half-life
t is the decay time

example 1: What is the activity of Am-241 remaining 12 years after the Am-241 was produced ?

$A_t = A_o e^{-\lambda t}$
λ is 0.693 divided by the half-life of Am-241 (432.2 y)
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$e^{-\lambda t}$ = $e^{-0.0192}$ = 0.981
A_t = A_o x 0.981
98.1% of the Am-241 activity remains after 12 years

example 2: What is the half-life of a radionuclide that decayed to 89.5% in 280 days?

half-life = -t x 0.693 / ln(A_t/A_0)
half-life = -280 days x 0.693 / ln(89.5/100)
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Removing the Source from the Work Area

Removing the radioactive source before the work begins could be accomplished by washing radioactive material down a floor drain designated for that purpose. Most facilities do not have that luxury so alternate method of source reduction must be considered. Assuming the planned work does not require the presence of the external radiation source then consideration should be given to moving that source away from the work area.

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Airborne Radioactive Material

NRC Area Posting from 10CFR20

Airborne radioactivity area (ARA) means a room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations—
(1) In excess of the derived air concentrations (DACs) specified in appendix B, to §§ 20.1001–20.2401, or
(2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

DOE Area Posting from 10CFR835

Airborne radioactivity area (ARA) means any area, accessible to individuals, where:
(1) The concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in appendix A or appendix C of this part; or
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Personal Protective Equipment (PPE)

Gloves, booties, hoods, and coveralls are worn if respiratory protection equipment is used when working in areas with airborne radioactive materials. Double gloves, double booties, and double coveralls are used also if contamination levels warrant their use. Water resistant outerwear (coveralls) are used if the work involves coming in contact with contaminated liquids.

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Time, Distance, Shielding, and Source Reduction

Stay-Time Calculation

Stay-time calculations are sometimes used to determine how long an individual can remain in an area with airborne radioactivity. This is usually because the PF of the respiratory equipment does not reduce the airborne concentration inside the face mask to less than 1 DAC.

Stay-time = Allowable exposure/exposure rate

example:
The airborne concentration is 100 DAC
The PF of the full face respiratory is 50
Note that the airborne concentration inside the face mask will be 2 DAC
The administrative limit for the job is 8 DAC-hrs

$$\text{Stay-time} = \frac{8\text{ DAC-hrs}}{100\text{ DAC}/50} = \frac{8\text{ DAC-hrs}}{2\text{ DAC}} = 2\text{ hours}$$

Usually a respiratory protection device with a PF greater than the number of DACs in the atmosphere is used.

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Inverse Cube Rule

Similar to the Inverse Square Law the Inverse Cube Rule can be used to estimate the potential airborne radioactivity concentration at a distance from a source. This rule works best when the distance to the point of release of the airborne radioactivity is less than 30 feet and the local wind velocity is calm.

Inverse Cube Rule

$$C_1 (D_1)^3 = C_2 (D_2)^3$$

C_1 = Concentration at Distance 1
D_1 = Distance from point of airborne release for Concentration 1
C_2 = Concentration to be calculated
D_2 = New distance from the source

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Practical Application of the Inverse Cube Rule

Airborne Activity General Dispersion Model

Assume a 1 µCi (37 kBq) release of respirable Pu^{239} inside a large room measuring 12 x 12 x 3 meters with a ventilation turnover rate of 7 volumes per hour. The General Dispersion Model uses this 2π formula for volume.

$V = 2/3 \times \pi \times R^3$

Volume in cm^3	30 cm	1 M	10 M
@ distance R	5.65E4	2.09E6	2.09E9
Concentration @ distance R			
in µCi / cc	1.77E-5	4.78E-7	4.78E-10
in Bq / M^3	6.55E5	1.77E4	17.7
in DAC	8.85E6	2.39E5	239

Time for airborne wavefront to reach distance R

13 sec 43 sec 7.15 min

Refer to the Gilson and Voss Handbooks of Radiation Data and Air Monitoring for more information on using ventilation, air flow patterns, and other techniques as means to reduce potential exposures to airborne radioactivity.

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13 sec 43 sec 7.15 min

Refer to the Gilson and Voss Handbooks of Radiation Data and Air Monitoring for more information on using ventilation, air flow patterns, and other techniques as means to reduce potential exposures to airborne radioactivity.

RESPIRATORY PROTECTION FACTORS 10CFR20

Device	Mode	Particulates	Vapors	PF
Air-purifying				
half-mask	D	Y	N	10
full-face	D	Y	N	50
full-face	PP	Y	N	1000
Supplied-air				
hood	PP	Y	Y	1000*
full-face	PP	Y	Y	2000
SCBA	D	Y	N	50
SCBA	PD	Y	Y	10,000

D is Demand
PP is Positive Pressure
PD is Pressure Demand
* 2000 for supplied-air hood if run at max flow with calibrated flow gauge.
Bubble suits have been used in Pu atmospheres as high as 1,000,000 DAC. Supplied-air respirators are worn inside the bubble suits and real-time air monitoring INSIDE the bubble suits is performed.

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Medical Treatment for Radiation Exposure

External Exposure Treatment

There are several courses of action for medical treatment of persons exposed to high levels of external radiation.

Anti-oxidants

Anti-oxidants may be used to counteract the influence of free radicals formed as the result of radiation exposure. Free radicals react with (and change) body cells. Vitamins C and E are common treatments for reducing the effects of free radicals. How well this course of treatment may work in the case of external radiation exposure has not been fully evaluated.

Antibiotics

The use of antibiotics to prevent infection which may occur due to the exposed person’s depressed immune system needs to be evaluated carefully before pursuing this treatment. Perhaps minimizing the sources of infection would be a better treatment process.

Blood transfusion

Blood transfusion is used in those cases where the exposed person’s body cannot replenish the blood cells rapidly enough.

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Bone marrow transplant

Bone marrow transplants are performed when the exposed person’s bone marrow has been damaged by external radiation to the extent the marrow can no longer perform its function of making new cells.

The decision to pursue any of these courses of medical treatment must be carefully considered. Each of the procedures comes with its own potential negative effects. However, treatment must be started quickly in order to be most effective.

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Inhalation Treatment

There are several courses of action for medical treatment of persons who have inhaled high levels of contamination.

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Antibiotics

The use of antibiotics to prevent infection which may occur due to the exposed person's depressed immune system needs to be evaluated carefully before pursuing this treatment. Perhaps minimizing the sources of infection would be a better treatment process.

Dilution

Perhaps the most common application of dilution is when an individual has been exposed to tritium, either thru inhalation, ingestion, or absorption. Drinking a lot of water will act as a diuretic and the tritium, which has combined with oxygen to form tritiated water, will be flushed out of the individual's body.

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Substitution

The most recognizable application of substitution is the administration of potassium iodide to individuals who may be exposed to radioactive iodine. If the potassium iodide is administered before the potential intake then the thyroid will take up that iodine and not the radioactive iodine. If the potassium iodine is administered after the radioactive iodine intake then the non-radioactive iodine displaces the radioactive iodine to some extent.

Chelation

Chelation has proven successful for both radioactive and non-radioactive metals. Chelating agents similar to EDTA are used to make the radioactive metals in the exposed individual's body more soluble so they can be eliminated more efficiently by the body's mechanisms. For transuranic intakes chelation is most effective if administered within one hour of the intake. In those cases chelation has proven to remove as much as 90% of the radioactive material originally taken into the individual's body.

Lavage

Lung lavage is a somewhat extreme medical procedure. However lung lavage has proven to be effective in removing small particles from the lungs of individuals in cases such as coal miners or heavy tobacco smokers.

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In the medical procedure one lung is collapsed then filled with water (in the case of radioactive metals the water may contain a chelating agent) then the patient is gently rocked to get the water more deeply into the lung. The water is removed and the lung is reinflated with air. Then the same process is performed on the second lung. This procedure is not undertaken lightly and the patient must be in good physical condition.

Internal Exposure

Refer to the Gilson and Voss Handbook of Radiation Data for "Ingestion ALIs" for Ingestion, Injection, and Absorption and "Inhalation DACs" for Inhalation of Airborne Radioactive Material

Ingestion Treatment

There are several courses of action for medical treatment of persons who have ingested high levels of contamination.

Anti-oxidants, Antibiotics, Dilution, Substitution, and Chelation may be effective in minimizing the effect of ingestion of radioactive contamination.

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Injection Treatment

Excision

Excision is the first action taken in the event of an individual getting a piece of radioactive material into their skin. Following that the other courses of action; Anti-oxidants, Antibiotics, Dilution, Substitution, and Chelation may be effective in minimizing the effect of ingestion of radioactive contamination.

Absorption Treatment

Dilution

Tritium is the most commonly absorbed radioactive material. Dilution by drinking lots of water is the most effective method of reducing the effect of tritium absorption.

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ACUTE RADIATION EFFECTS

0 – 25 REM
minimal decrease in white blood cell count for ~ 2weeks
increase in risk of dying from cancer from US average risk of ~ 14 persons per 100 population to ~ 17 persons per 100 population (3 additional persons per 100 population will experience the onset of terminal cancer ~25 years after the acute exposure)

> 25 REM - ≤ 100 REM
small decrease in white blood cell count for > 2 weeks
increase in risk of dying from cancer to ~ 26 in 100

> 100 REM - ≤ 200 REM
moderate decrease in white blood cell count
25% of those exposed will experience nausea within a few hours
less than 5% of those exposed require hospitalization
increase in risk of dying from cancer to ~ 38 in 100

> 200 REM - ≤ 600 REM
major decrease in white blood cell count
~ 100% of those exposed will experience nausea within a few hours
appearance of bruises on skin (purpura)
pneumonia symptoms
hair loss
90% of those exposed require hospitalization
decrease in thinking ability for ~ 2 weeks
increase in risk of dying from cancer to ~ 74 in 100

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600 REM - ≤ 800 REM

all of the above symptoms will be present
100% of those exposed require hospitalization
~ 100% of those exposed will die within a few weeks without medical treatment
increase in risk of dying from cancer to ~ 98 in 100

800 REM - ≤ 2000 REM

all of the above symptoms will be present
diarrhea, fever, electrolytes imbalance, GI tract and respiratory system failure
100% of those exposed will be incapacitated within hours
very few of those exposed will survive

> 2000 REM

100% mortality within a few days

Lymphocyte - white blood cells
Leukopenia - abnormally low white blood cell count
Purpura - purple discoloration of skin caused by blood bleeding into the skin tissue
Pneumonia - inflammation of lung tissue, accompanied by fever, chills, cough, and difficulty in breathing
Hematopoietic – decrease in the formation of blood cells
Ataxia - inability to coordinate voluntary muscular movements
BEIR V 1990 800 excess deaths per 100,000 persons at 10 rem
4,000 Hiroshima survivors in excess of 50 rem dose had an extra 300 incidences of cancer
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Radioactive Sources

Medical Sources

RADIATION EXPOSURE FROM MEDICAL DIAGNOSTIC IMAGING PROCEDURES

HEALTH PHYSICS SOCIETY FACT SHEET

Ionizing radiation is used daily in hospitals and clinics to perform diagnostic imaging procedures. For the purposes of this fact sheet, the word radiation refers to ionizing radiation. The most commonly mentioned forms of ionizing radiation are x rays and gamma rays. Procedures that use radiation are necessary for accurate diagnosis of disease and injury. They provide important information about your health to your doctor and help ensure that you receive appropriate care. Physicians and technologists performing these procedures are trained to use the minimum amount of radiation necessary for the procedure. Benefits from the medical procedure greatly outweigh any potential small risk of harm from the amount of radiation used.

Which types of diagnostic imaging procedures use radiation?

- In x-ray procedures, x rays pass through the body to form pictures on film or on a computer or television monitor, which are viewed by a radiologist. If you have an x-ray test, it will be performed with a standard x-ray

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Radioactive Sources

Medical Sources

RADIATION EXPOSURE FROM MEDICAL DIAGNOSTIC IMAGING PROCEDURES

HEALTH PHYSICS SOCIETY FACT SHEET

Ionizing radiation is used daily in hospitals and clinics to perform diagnostic imaging procedures. For the purposes of this fact sheet, the word radiation refers to ionizing radiation. The most commonly mentioned forms of ionizing radiation are x rays and gamma rays. Procedures that use radiation are necessary for accurate diagnosis of disease and injury. They provide important information about your health to your doctor and help ensure that you receive appropriate care. Physicians and technologists performing these procedures are trained to use the minimum amount of radiation necessary for the procedure. Benefits from the medical procedure greatly outweigh any potential small risk of harm from the amount of radiation used.

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machine or with a more sophisticated x-ray machine called a CT or CAT scan machine.

- In nuclear medicine procedures, a very small amount of radioactive material is inhaled, injected, or swallowed by the patient. If you have a nuclear medicine exam, a special camera will be used to detect energy given off by the radioactive material in your body and form a picture of your organs and their function on a computer monitor. A nuclear medicine physician views these pictures. The radioactive material typically disappears from your body within a few hours or days.

Do magnetic resonance imaging (MRI) and ultrasound use radiation?
MRI and ultrasound procedures do not use ionizing radiation. If you have either of these types of studies, you are not exposed to radiation.

Do benefits from medical examinations using radiation outweigh the risks from the radiation?
Your doctor will order an x-ray test for you when it is needed for accurate diagnosis of your condition. Benefits from the medical procedure greatly outweigh any potential small risk of harm from the amount of radiation used. There is no conclusive evidence of radiation causing harm at the levels patients receive from diagnostic x-ray exams. Although high doses of radiation are linked to an increased risk of cancer, the

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effects of the low doses of radiation used in diagnostic imaging are not known. No one is certain if any real risks are involved. Many diagnostic exposures are similar to exposure that we receive from natural background radiation found all around us. You will note that a few of the diagnostic exposures are much higher than background or that multiple exposures will give an accumulated exposure higher than background. Nevertheless, benefits of diagnostic medical exams are vital to good patient care.

What are typical doses from medical procedures involving radiation?

Radiation dose can be estimated for some common diagnostic x-ray and nuclear medicine studies. It is important to note that these are only *typical* values. Radiation doses differ for each person because of differences in x-ray machines and their settings, the amount of radioactive material given in a nuclear medicine procedure, and the patient's metabolism. The tables below give dose estimates for typical diagnostic x-ray and nuclear medicine exams. For comparison, in the United States we receive about 3.0 mSv (300 mrem) of exposure from natural background radiation every year. The effective dose listed is a comparable whole-body dose from the exam.

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Typical Effective Radiation Dose from Diagnostic X Ray—Single Exposure

Exam	Effective Dose mSv (mrem)
Chest (LAT)	0.04 (4)
Chest (AP)	0.02 (2)
Skull (AP)	0.03 (3)
Skull (Lat)	0.01 (1)
Pelvis (AP)	0.7 (70)
Thoracic Spine (AP)	0.4 (40)
Lumbar Spine (AP)	0.7 (70)
Mammogram (four views)	0.7 (70)
Dental (lateral)	0.02 (2)
Dental (panoramic)	0.09 (9)
DEXA (whole body)	0.0004 (0.04)
Hip	0.8 (80)
Hand or Foot	0.005 (0.5)
Abdomen	1.2 (120)

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The following table shows the dose a patient could receive if undergoing an entire procedure. For example, a lumbar spine series usually consists of five x-ray exams. CT stands for computed tomography and is sometimes called a CAT scan.

Complete Exams	**Effective Dose mSv (mrem)**
Intravenous Pyelogram (kidneys, 6 films)	2.5 (250)
Barium Swallow (24 images, 106 sec. fluoroscopy)	1.5 (150)
Barium Enema (10 images, 137 sec. fluoroscopy)	7.0 (700)
CT Head	2.0 (200)
CT Chest	8.0 (800)
CT Abdomen	10.0 (1,000)
CT Pelvis	10.0 (1,000)
Angioplasty (heart study)	7.5 (750) - 57.0 (5,700)
Coronary Angiogram	4.6 (460) - 15.8 (1,580)

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Typical Effective Radiation Dose from Nuclear Medicine Examination

Nuclear Medicine Scan	**Radio-pharmaceutical**	**Effective Dose mSv (mrem)**
Brain (PET)	^{15}O water	1.0 (100)
Brain (perfusion)	^{99m}Tc HMPAO	6.9 (690)
Hepatobiliary (liver flow)	^{99m}Tc Sulfur Colloid	2.8 (280)
Bone	^{99m}Tc MDP	4.2 (420)
Lung Perfusion/ Ventilation	^{99m}Tc MAA & ^{133}Xe	2.0 (200)
Kidney (filtration rate)	^{99m}Tc DTPA	3.6 (360)
Kidney (tubular function)	^{99m}Tc MAG3	5.2 (520)
Tumor/Infection	^{67}Ga	18.5 (1,850)
Heart (rest)	^{99m}Tc Cardiolite	6.7 (670)
Heart (stress)	^{99m}Tc Cardiolite	5.85 (585)
Heart	^{201}Tl chloride	11.8 (1,180)
Heart (rest)	^{99m}Tc Myoview	5.6 (560)
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How can I obtain an estimate of my radiation dose from medical exams?
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Internet Resources
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CONSUMER PRODUCTS CONTAINING RADIOACTIVE MATERIALS

HEALTH PHYSICS SOCIETY FACT SHEET

Everything we encounter in our daily lives contains some radioactive material, some naturally occurring and some manmade: the air we breathe, the water we drink, the food we eat, the ground we walk upon, and the consumer products we purchase and use. Although they might be familiar with the use of radiation to diagnose disease and treat cancer, many people, when they hear the terms “radioactive” and “radiation,” tend to think of mushroom clouds and the monster mutants that inhabit the world of science fiction movies and comic books. Careful analyses can identify and quantify the radioactive material in just about anything.

Smoke Detectors. Most residential smoke detectors contain a low-activity americium-241 source. Alpha particles emitted by the americium ionize the air, making the air conductive. Any smoke particles that enter the unit reduce the current and set off an alarm. Despite the fact that these devices save lives, the question “are smoke detectors safe?” is still asked by those with an inordinate fear of radiation. The answer, of course, is “yes, they are safe.” Instructions for proper installation, handling, and disposal of smoke detectors are found on the package.

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Watches and Clocks. Modern watches and clocks sometimes use a small quantity of hydrogen-3 (tritium) or promethium-147 as a source of light. Older (for example, pre-1970) watches and clocks used radium-226 as a source of light. If these older timepieces are opened and the dial or hands handled, some of the radium could be picked up and possibly ingested. As such, caution should be exercised when handling these items.

Ceramics. Ceramic materials (for example, tiles, pottery) often contain elevated levels of naturally occurring uranium, thorium, and/or potassium. In many cases, the activity is concentrated in the glaze. Unless there is a large quantity of the material, readings above background are unlikely. Nevertheless, some older (for example, pre-1960) tiles and pottery, especially those with an orange-red glaze (for example, Fiesta® ware) can be quite radioactive.

Glass. Glassware, especially antique glassware with a yellow or greenish color, can contain easily detectable quantities of uranium. Such uranium-containing glass is often referred to as canary or vaseline glass. In part, collectors like uranium glass for the attractive glow that is produced when the glass is exposed to a black light. Even ordinary glass can contain high-enough levels of potassium-40 or thorium-232 to be detectable with a

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Ceramics. Ceramic materials (for example, tiles, pottery) often contain elevated levels of naturally occurring uranium, thorium, and/or potassium. In many cases, the activity is concentrated in the glaze. Unless there is a large quantity of the material, readings above background are unlikely. Nevertheless, some older (for example, pre-1960) tiles and pottery, especially those with an orange-red glaze (for example, Fiesta® ware) can be quite radioactive.

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survey instrument. Older camera lenses (1950s-1970s) often employed coatings of thorium-232 to alter the index of refraction.

Fertilizer. Commercial fertilizers are designed to provide varying levels of potassium, phosphorous, and nitrogen. Such fertilizers can be measurably radioactive for two reasons: potassium is naturally radioactive, and the phosphorous can be derived from phosphate ore that contains elevated levels of uranium.

Food. Food contains a variety of different types and amounts of naturally occurring radioactive materials. Although the relatively small quantities of food in the home contain too little radioactivity for the latter to be readily detectable, bulk shipments of food have been known to set off the alarms of radiation monitors at border crossings. One exception would be low-sodium salt substitutes that often contain enough potassium-40 to double the background count rate of a radiation detector.

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Gas Lantern Mantles. While it is less common than it once was, some brands of gas lantern mantles incorporate thorium-232. In fact it is the heating of the thorium by the burning gas that is responsible for the emission of light. Such mantles are sufficiently radioactive that they are often used as a check source for radiation detectors.

Antique Radioactive Curative Claims. In the past, primarily 1920 through 1950, a wide range of radioactive products were sold as cure-alls, for example, radium-containing pills, pads, solutions, and devices designed to add radon to drinking water. The states generally have regulatory authority over these devices. In some cases, a state might even require that these devices be registered or licensed. Most such devices are relatively harmless but occasionally one can be encountered that contains potentially hazardous levels of radium. If there is any question about the safety of such devices, the public is strongly encouraged to contact the state radiation-control program for advice.

For further information contact the following:
National Council on Radiation Protection and Measurements, “Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources,” NCRP Report No. 95, Bethesda, MD, 1987.
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Industrial Radiation Sources

Manufacturing

Thickness of metal, thickness of coatings, moisture content.
Ba-133, Co-60, Cs-134, Cs-137, Sb-124, Se-75, Sr-90, Tm-170

Chemical Processing

Density, Thickness of coatings, Specific Gravity, Level in process vessels
Gamma emitters as above plus neutron sources
AmBe, PuBe, RaBe, Cf-252

Construction

Moisture content, location of rebar
Gamma emitters as above plus neutron sources as above

Mineral Processing

Percent of minerals in process streams
Gamma emitters such as;
Am-241, Co-57, Cs-137

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Coastal Engineering

Measurement of environmental parameters, such as levels of sediments in rivers and estuaries, and mobilization of sediment.
Gamma emitters such as;
Am-241, Co-60, Cs-137

Non Destructive Examination

Radiography
Co-60, Cs-137, Ir-192

Oil Refining

Column scanning, level measurement
Gamma emitters as above
AmBe

Coal Fired Boilers

Percent of ash in coal, moisture content of coal
Gamma sources such as;
Cs-137, Am-241

Drilling

Borehole logging (hydrogen content)
Co-60, AmBe

Agriculture

Percent soil moisture
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Hydrology

Soil moisture
AmBe, PuBe, RaBe, Cf-252

Medical Care

Sterilization of syringes, surgical instruments, surgery consumables, pharmaceuticals
Co-60

Materials Processing

Thickness or weight of materials, consistency, moisture content
Am-241, Pr-147, Kr-85, Sr-90

The gamma and beta emitters listed range in activity from below 1 curie to 1,000 curies. The neutron sources range from less than 1 milli-curie to 1 curie. The range of gamma or neutron exposures from these sources is 0.05 rem/hr to 10,000 rem/hr at 30 centimeters distance.
Refer to the section on gamma ray constants for gamma exposure rates from these sources.

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Ci / g = 3.578E5 / ($T_{1/2}$ in years x atomic mass)
GBq / g = 1.324E7 / ($T_{1/2}$ in years x atomic mass)

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Ac^{227}	21.77y	72.40	N/A	2.68E3	N/A
Ac^{228}	6.15h	2.24E6	2.82	8.29E7	7.62E-4
Ag^{110}	24.6s	4.17E9	0.18	1.54E11	4.79E-5
Ag^{110m}	249.79d	13.03	14.66	482	3.97E-3
Ag^{111}	7.45d	65.79	0.16	2.43E3	4.20E-5
Al^{26}	7.3E5y	0.019	16.6	0.699	4.49E-3
Am^{241}	432.7y	3.43	0.19	127	5.04E-5
Am^{242}	16.02h	8.08E5	0.23	2.99E7	6.25E-5
Am^{243}	7370y	0.20	0.23	7.40	6.22E-5
Ar^{37}	35.04d	1.01E5	N/A	3.73E6	N/A
Ar^{39}	269.0y	34.14	N/A	1.26E3	N/A
Ar^{41}	1.82h	4.20E7	7.73	1.55E9	2.09E-3
Ar^{42}	32.90y	259.20	N/A	9.59E3	N/A
As^{74}	17.8d	9.91E4	0.586	3.67E6	1.58E-4
At^{215}	0.100us	5.25E14	N/A	1.94E16	N/A
At^{216}	300us	1.74E14	N/A	6.44E15	N/A
At^{218}	1.6s	3.23E10	N/A	1.20E12	N/A
Au^{198}	2.695d	2.12E10	0.279	7.84E11	7.55E-5
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Ba^{137m}	2.552m	5.37E8	4.44	1.99E10	1.20E-3
Ba^{139}	83.06m	1.63E7	0.173	6.03E8	4.68E-5
Ba^{140}	12.75d	7.32E4	0.871	2.71E6	2.36E-4
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Ba^{133}	10.52y	255.90	2.22	9.47E3	6.01E-4
Ba^{137m}	2.552m	5.37E8	4.44	1.99E10	1.20E-3
Ba^{139}	83.06m	1.63E7	0.173	6.03E8	4.68E-5
Ba^{140}	12.75d	7.32E4	0.871	2.71E6	2.36E-4
Ba^{141}	18.27m	7.31E7	2.4	2.70E9	6.50E-4

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	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Ba^{142}	10.6m	1.25E8	1.01	4.63E9	2.73E-4
Be^{7}	53.28d	3.50E5	0.38	1.30E7	1.03E-4
Be^{10}	1.51E6y	0.024	N/A	0.875	N/A
Bi^{210}	5.01d	1.24E5	N/A	4.59E6	N/A
Bi^{210m}	3.04E6y	5.61E-4	2.124	0.0207	5.75E-4
Bi^{211}	2.14m	4.17E8	0.273	1.54E10	7.39E-5
Bi^{212}	60.6m	1.47E7	N/A	5.44E8	N/A
Bi^{213}	45.59m	1.94E7	0.739	7.17E8	2.00E-4
Bi^{214}	19.9m	4.41E7	9.31	1.63E9	2.52E-3
Bk^{249}	320d	1.64E3	N/A	6.07E4	N/A
Br^{82}	17.68m	1.33E8	2.15	4.92E9	5.82E-4
Br^{84}	31.8m	7.05E7	0.172	2.61E9	4.66E-5
C^{11}	1223s	8.38E8	6.815	3.10E10	1.84E-3
C^{14}	5730y	4.46	N/A	165	N/A
Ca^{41}	1.03E5y	0.085	N/A	3.14	N/A
Ca^{47}	4.536d	6.13E5	0.198	2.27E7	5.36E-5
Cd^{113}	7.70E15y	4.12E-13	N/A	1.52E-11	N/A
Cd^{118}	50.3m	3.17E7	N/A	1.17E9	N/A
Ce^{141}	32.5d	2.85E4	0.422	1.06E6	1.14E-4
Ce^{143}	33.1h	6.63E5	1.19	2.45E7	3.22E-4
Cf^{249}	351y	4.09	1.98	151	5.35E-4
Cf^{252}	2.638y	538	N/A	1.99E4	N/A
Cf^{255}	85.0m	8.67E6	N/A	3.21E8	N/A
Cf^{256}	12.3m	5.97E7	N/A	2.21E9	N/A
Cl^{36}	3.01E5y	0.033	N/A	1.22	N/A
Cl^{38}	37.24m	1.33E8	8.92	4.92E9	2.41E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Ba^{142}	10.6m	1.25E8	1.01	4.63E9	2.73E-4
Be^{7}	53.28d	3.50E5	0.38	1.30E7	1.03E-4
Be^{10}	1.51E6y	0.024	N/A	0.875	N/A
Bi^{210}	5.01d	1.24E5	N/A	4.59E6	N/A
Bi^{210m}	3.04E6y	5.61E-4	2.124	0.0207	5.75E-4
Bi^{211}	2.14m	4.17E8	0.273	1.54E10	7.39E-5
Bi^{212}	60.6m	1.47E7	N/A	5.44E8	N/A
Bi^{213}	45.59m	1.94E7	0.739	7.17E8	2.00E-4
Bi^{214}	19.9m	4.41E7	9.31	1.63E9	2.52E-3
Bk^{249}	320d	1.64E3	N/A	6.07E4	N/A
Br^{82}	17.68m	1.33E8	2.15	4.92E9	5.82E-4
Br^{84}	31.8m	7.05E7	0.172	2.61E9	4.66E-5
C^{11}	1223s	8.38E8	6.815	3.10E10	1.84E-3
C^{14}	5730y	4.46	N/A	165	N/A
Ca^{41}	1.03E5y	0.085	N/A	3.14	N/A
Ca^{47}	4.536d	6.13E5	0.198	2.27E7	5.36E-5
Cd^{113}	7.70E15y	4.12E-13	N/A	1.52E-11	N/A
Cd^{118}	50.3m	3.17E7	N/A	1.17E9	N/A
Ce^{141}	32.5d	2.85E4	0.422	1.06E6	1.14E-4
Ce^{143}	33.1h	6.63E5	1.19	2.45E7	3.22E-4
Cf^{249}	351y	4.09	1.98	151	5.35E-4
Cf^{252}	2.638y	538	N/A	1.99E4	N/A
Cf^{255}	85.0m	8.67E6	N/A	3.21E8	N/A
Cf^{256}	12.3m	5.97E7	N/A	2.21E9	N/A
Cl^{36}	3.01E5y	0.033	N/A	1.22	N/A
Cl^{38}	37.24m	1.33E8	8.92	4.92E9	2.41E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Ba^{142}	10.6m	1.25E8	1.01	4.63E9	2.73E-4
Be^{7}	53.28d	3.50E5	0.38	1.30E7	1.03E-4
Be^{10}	1.51E6y	0.024	N/A	0.875	N/A
Bi^{210}	5.01d	1.24E5	N/A	4.59E6	N/A
Bi^{210m}	3.04E6y	5.61E-4	2.124	0.0207	5.75E-4
Bi^{211}	2.14m	4.17E8	0.273	1.54E10	7.39E-5
Bi^{212}	60.6m	1.47E7	N/A	5.44E8	N/A
Bi^{213}	45.59m	1.94E7	0.739	7.17E8	2.00E-4
Bi^{214}	19.9m	4.41E7	9.31	1.63E9	2.52E-3
Bk^{249}	320d	1.64E3	N/A	6.07E4	N/A
Br^{82}	17.68m	1.33E8	2.15	4.92E9	5.82E-4
Br^{84}	31.8m	7.05E7	0.172	2.61E9	4.66E-5
C^{11}	1223s	8.38E8	6.815	3.10E10	1.84E-3
C^{14}	5730y	4.46	N/A	165	N/A
Ca^{41}	1.03E5y	0.085	N/A	3.14	N/A
Ca^{47}	4.536d	6.13E5	0.198	2.27E7	5.36E-5
Cd^{113}	7.70E15y	4.12E-13	N/A	1.52E-11	N/A
Cd^{118}	50.3m	3.17E7	N/A	1.17E9	N/A
Ce^{141}	32.5d	2.85E4	0.422	1.06E6	1.14E-4
Ce^{143}	33.1h	6.63E5	1.19	2.45E7	3.22E-4
Cf^{249}	351y	4.09	1.98	151	5.35E-4
Cf^{252}	2.638y	538	N/A	1.99E4	N/A
Cf^{255}	85.0m	8.67E6	N/A	3.21E8	N/A
Cf^{256}	12.3m	5.97E7	N/A	2.21E9	N/A
Cl^{36}	3.01E5y	0.033	N/A	1.22	N/A
Cl^{38}	37.24m	1.33E8	8.92	4.92E9	2.41E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Ba^{142}	10.6m	1.25E8	1.01	4.63E9	2.73E-4
Be^{7}	53.28d	3.50E5	0.38	1.30E7	1.03E-4
Be^{10}	1.51E6y	0.024	N/A	0.875	N/A
Bi^{210}	5.01d	1.24E5	N/A	4.59E6	N/A
Bi^{210m}	3.04E6y	5.61E-4	2.124	0.0207	5.75E-4
Bi^{211}	2.14m	4.17E8	0.273	1.54E10	7.39E-5
Bi^{212}	60.6m	1.47E7	N/A	5.44E8	N/A
Bi^{213}	45.59m	1.94E7	0.739	7.17E8	2.00E-4
Bi^{214}	19.9m	4.41E7	9.31	1.63E9	2.52E-3
Bk^{249}	320d	1.64E3	N/A	6.07E4	N/A
Br^{82}	17.68m	1.33E8	2.15	4.92E9	5.82E-4
Br^{84}	31.8m	7.05E7	0.172	2.61E9	4.66E-5
C^{11}	1223s	8.38E8	6.815	3.10E10	1.84E-3
C^{14}	5730y	4.46	N/A	165	N/A
Ca^{41}	1.03E5y	0.085	N/A	3.14	N/A
Ca^{47}	4.536d	6.13E5	0.198	2.27E7	5.36E-5
Cd^{113}	7.70E15y	4.12E-13	N/A	1.52E-11	N/A
Cd^{118}	50.3m	3.17E7	N/A	1.17E9	N/A
Ce^{141}	32.5d	2.85E4	0.422	1.06E6	1.14E-4
Ce^{143}	33.1h	6.63E5	1.19	2.45E7	3.22E-4
Cf^{249}	351y	4.09	1.98	151	5.35E-4
Cf^{252}	2.638y	538	N/A	1.99E4	N/A
Cf^{255}	85.0m	8.67E6	N/A	3.21E8	N/A
Cf^{256}	12.3m	5.97E7	N/A	2.21E9	N/A
Cl^{36}	3.01E5y	0.033	N/A	1.22	N/A
Cl^{38}	37.24m	1.33E8	8.92	4.92E9	2.41E-3

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Cm^{242}	162.8d	3.31E3	N/A	1.22E5	N/A
Cm^{243}	29.1y	50.59	0.675	1.87E3	1.83E-4
Cm^{244}	18.1y	81.0	N/A	3.00E3	N/A
Cm^{245}	8500y	0.17	0.325	6.36	8.80E-5
Cm^{247}	1.56E7y	9.28E-5	1.87	3.43E-3	5.06E-4
Co^{56}	77.3d	3.02E4	21.36	1.12E6	5.77E-3
Co^{57}	271.8d	8.43E3	0.713	3.12E5	4.54E-4
Co^{58}	70.88d	3.18E4	6.81	1.18E6	1.84E-3
Co^{60}	5.271y	1.13E3	15.19	4.18E4	4.11E-3
Cr^{51}	27.70d	9.24E4	0.207	3.42E6	5.61E-5
Cs^{134}	2.0648y	1.29E3	10.25	4.79E4	2.77E-3
Cs^{134m}	2.903h	8.06E6	0.0986	2.98E8	2.67E-5
Cs^{135}	2.30E6y	1.15E-3	N/A	0.0427	N/A
Cs^{136}	13.16d	7.30E4	6.85	2.70E6	1.85E-3
Cs^{137}	30.17y	86.6	See Ba^{137m}	3.20E3	N/A
Cs^{138}	33.41m	4.08E7	2.31	1.51E9	6.25E-4
Cu^{61}	3.333h	1.54E7	1.05	5.71E8	2.84E-4
Cu^{62}	9.74m	3.11E8	7.85	3.39E7	2.12E-3
Cu^{64}	12.7h	3.86E6	1.228	1.43E8	3.33E-4
Dy^{154}	3.00E6y	7.75E-4	N/A	0.0287	N/A
Dy^{165}	2.334h	8.14E6	0.0918	3.01E8	2.49E-5
Es^{253}	20.47d	2.52E4	N/A	9.32E5	N/A
Es^{256}	25.4m	2.89E7	N/A	1.07E9	N/A
Eu^{152}	13.537y	174.0	5.82	6.44E3	1.58E-3
Eu^{154}	8.589y	270.6	7.06	1.00E4	1.91E-3
Eu^{155}	4.7611y	485.1	0.319	1.79E4	8.64E-5

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Cm^{242}	162.8d	3.31E3	N/A	1.22E5	N/A
Cm^{243}	29.1y	50.59	0.675	1.87E3	1.83E-4
Cm^{244}	18.1y	81.0	N/A	3.00E3	N/A
Cm^{245}	8500y	0.17	0.325	6.36	8.80E-5
Cm^{247}	1.56E7y	9.28E-5	1.87	3.43E-3	5.06E-4
Co^{56}	77.3d	3.02E4	21.36	1.12E6	5.77E-3
Co^{57}	271.8d	8.43E3	0.713	3.12E5	4.54E-4
Co^{58}	70.88d	3.18E4	6.81	1.18E6	1.84E-3
Co^{60}	5.271y	1.13E3	15.19	4.18E4	4.11E-3
Cr^{51}	27.70d	9.24E4	0.207	3.42E6	5.61E-5
Cs^{134}	2.0648y	1.29E3	10.25	4.79E4	2.77E-3
Cs^{134m}	2.903h	8.06E6	0.0986	2.98E8	2.67E-5
Cs^{135}	2.30E6y	1.15E-3	N/A	0.0427	N/A
Cs^{136}	13.16d	7.30E4	6.85	2.70E6	1.85E-3
Cs^{137}	30.17y	86.6	See Ba^{137m}	3.20E3	N/A
Cs^{138}	33.41m	4.08E7	2.31	1.51E9	6.25E-4
Cu^{61}	3.333h	1.54E7	1.05	5.71E8	2.84E-4
Cu^{62}	9.74m	3.11E8	7.85	3.39E7	2.12E-3
Cu^{64}	12.7h	3.86E6	1.228	1.43E8	3.33E-4
Dy^{154}	3.00E6y	7.75E-4	N/A	0.0287	N/A
Dy^{165}	2.334h	8.14E6	0.0918	3.01E8	2.49E-5
Es^{253}	20.47d	2.52E4	N/A	9.32E5	N/A
Es^{256}	25.4m	2.89E7	N/A	1.07E9	N/A
Eu^{152}	13.537y	174.0	5.82	6.44E3	1.58E-3
Eu^{154}	8.589y	270.6	7.06	1.00E4	1.91E-3
Eu^{155}	4.7611y	485.1	0.319	1.79E4	8.64E-5

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Cm^{242}	162.8d	3.31E3	N/A	1.22E5	N/A
Cm^{243}	29.1y	50.59	0.675	1.87E3	1.83E-4
Cm^{244}	18.1y	81.0	N/A	3.00E3	N/A
Cm^{245}	8500y	0.17	0.325	6.36	8.80E-5
Cm^{247}	1.56E7y	9.28E-5	1.87	3.43E-3	5.06E-4
Co^{56}	77.3d	3.02E4	21.36	1.12E6	5.77E-3
Co^{57}	271.8d	8.43E3	0.713	3.12E5	4.54E-4
Co^{58}	70.88d	3.18E4	6.81	1.18E6	1.84E-3
Co^{60}	5.271y	1.13E3	15.19	4.18E4	4.11E-3
Cr^{51}	27.70d	9.24E4	0.207	3.42E6	5.61E-5
Cs^{134}	2.0648y	1.29E3	10.25	4.79E4	2.77E-3
Cs^{134m}	2.903h	8.06E6	0.0986	2.98E8	2.67E-5
Cs^{135}	2.30E6y	1.15E-3	N/A	0.0427	N/A
Cs^{136}	13.16d	7.30E4	6.85	2.70E6	1.85E-3
Cs^{137}	30.17y	86.6	See Ba^{137m}	3.20E3	N/A
Cs^{138}	33.41m	4.08E7	2.31	1.51E9	6.25E-4
Cu^{61}	3.333h	1.54E7	1.05	5.71E8	2.84E-4
Cu^{62}	9.74m	3.11E8	7.85	3.39E7	2.12E-3
Cu^{64}	12.7h	3.86E6	1.228	1.43E8	3.33E-4
Dy^{154}	3.00E6y	7.75E-4	N/A	0.0287	N/A
Dy^{165}	2.334h	8.14E6	0.0918	3.01E8	2.49E-5
Es^{253}	20.47d	2.52E4	N/A	9.32E5	N/A
Es^{256}	25.4m	2.89E7	N/A	1.07E9	N/A
Eu^{152}	13.537y	174.0	5.82	6.44E3	1.58E-3
Eu^{154}	8.589y	270.6	7.06	1.00E4	1.91E-3
Eu^{155}	4.7611y	485.1	0.319	1.79E4	8.64E-5

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Cm^{242}	162.8d	3.31E3	N/A	1.22E5	N/A
Cm^{243}	29.1y	50.59	0.675	1.87E3	1.83E-4
Cm^{244}	18.1y	81.0	N/A	3.00E3	N/A
Cm^{245}	8500y	0.17	0.325	6.36	8.80E-5
Cm^{247}	1.56E7y	9.28E-5	1.87	3.43E-3	5.06E-4
Co^{56}	77.3d	3.02E4	21.36	1.12E6	5.77E-3
Co^{57}	271.8d	8.43E3	0.713	3.12E5	4.54E-4
Co^{58}	70.88d	3.18E4	6.81	1.18E6	1.84E-3
Co^{60}	5.271y	1.13E3	15.19	4.18E4	4.11E-3
Cr^{51}	27.70d	9.24E4	0.207	3.42E6	5.61E-5
Cs^{134}	2.0648y	1.29E3	10.25	4.79E4	2.77E-3
Cs^{134m}	2.903h	8.06E6	0.0986	2.98E8	2.67E-5
Cs^{135}	2.30E6y	1.15E-3	N/A	0.0427	N/A
Cs^{136}	13.16d	7.30E4	6.85	2.70E6	1.85E-3
Cs^{137}	30.17y	86.6	See Ba^{137m}	3.20E3	N/A
Cs^{138}	33.41m	4.08E7	2.31	1.51E9	6.25E-4
Cu^{61}	3.333h	1.54E7	1.05	5.71E8	2.84E-4
Cu^{62}	9.74m	3.11E8	7.85	3.39E7	2.12E-3
Cu^{64}	12.7h	3.86E6	1.228	1.43E8	3.33E-4
Dy^{154}	3.00E6y	7.75E-4	N/A	0.0287	N/A
Dy^{165}	2.334h	8.14E6	0.0918	3.01E8	2.49E-5
Es^{253}	20.47d	2.52E4	N/A	9.32E5	N/A
Es^{256}	25.4m	2.89E7	N/A	1.07E9	N/A
Eu^{152}	13.537y	174.0	5.82	6.44E3	1.58E-3
Eu^{154}	8.589y	270.6	7.06	1.00E4	1.91E-3
Eu^{155}	4.7611y	485.1	0.319	1.79E4	8.64E-5

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Eu^{156}	15.19d	5.51E4	1.3	2.04E6	3.52E-4
F^{18}	1.830h	9.52E7	7.72	3.52E9	2.09E-3
Fe^{55}	2.73y	2.38E3	N/A	8.81E4	N/A
Fe^{59}	44.51d	4.97E4	7.34	1.84E6	1.98E-3
Fe^{60}	1.50E6y	3.98E-3	N/A	0.147	N/A
Fm^{256}	157.6m	4.66E6	N/A	1.72E8	N/A
Fr^{219}	20.0ms	2.58E12	N/A	9.53E13	N/A
Fr^{221}	4.9m	1.74E8	0.163	6.43E9	4.41E-5
Fr^{223}	21.8m	3.87E7	0.0952	1.43E9	2.58E-5
Ga^{67}	3.2612d	5.98E5	0.9381	2.21E7	2.54E-4
Gd^{148}	75y	32.2	N/A	1.19E3	N/A
Gd^{150}	1.79E6y	1.33E-3	N/A	0.0493	N/A
Gd^{152}	1.08E14y	2.18E-11	N/A	8.07E-10	N/A
Ge^{68}	270.8d	7.09E3	N/A	2.62E5	N/A
H^{3}	12.3y	9.70E3	N/A	3.59E5	N/A
Hf^{174}	2.00E15y	1.03E-12	N/A	3.81E-11	N/A
Hg^{203}	46.612d	1.38E4	1.29	5.11E5	3.49E-4
Ho^{163}	4.57E3y	0.48	N/A	17.8	N/A
Ho^{166}	26.8h	7.05E5	0.1164	2.61E7	3.15E-5
Ho^{166m}	1200y	1.80	5.39	66.5	1.46E-3
I^{123}	13.27h	1.92E6	0.796	7.11E7	2.15E-4
I^{124}	4.176d	2.52E5	5.53	9.34E6	1.50E-3
I^{125}	60.1d	1.74E4	1.664	6.44E5	4.50E-4
I^{126}	12.93d	7.97E4	4.34	2.95E6	1.17E-3
I^{129}	1.57E7y	1.77E-4	0.736	6.55E-3	1.99E-4
I^{130}	12.36h	1.55E6	4.76	5.74E7	1.29E-3

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Eu^{156}	15.19d	5.51E4	1.3	2.04E6	3.52E-4
F^{18}	1.830h	9.52E7	7.72	3.52E9	2.09E-3
Fe^{55}	2.73y	2.38E3	N/A	8.81E4	N/A
Fe^{59}	44.51d	4.97E4	7.34	1.84E6	1.98E-3
Fe^{60}	1.50E6y	3.98E-3	N/A	0.147	N/A
Fm^{256}	157.6m	4.66E6	N/A	1.72E8	N/A
Fr^{219}	20.0ms	2.58E12	N/A	9.53E13	N/A
Fr^{221}	4.9m	1.74E8	0.163	6.43E9	4.41E-5
Fr^{223}	21.8m	3.87E7	0.0952	1.43E9	2.58E-5
Ga^{67}	3.2612d	5.98E5	0.9381	2.21E7	2.54E-4
Gd^{148}	75y	32.2	N/A	1.19E3	N/A
Gd^{150}	1.79E6y	1.33E-3	N/A	0.0493	N/A
Gd^{152}	1.08E14y	2.18E-11	N/A	8.07E-10	N/A
Ge^{68}	270.8d	7.09E3	N/A	2.62E5	N/A
H^{3}	12.3y	9.70E3	N/A	3.59E5	N/A
Hf^{174}	2.00E15y	1.03E-12	N/A	3.81E-11	N/A
Hg^{203}	46.612d	1.38E4	1.29	5.11E5	3.49E-4
Ho^{163}	4.57E3y	0.48	N/A	17.8	N/A
Ho^{166}	26.8h	7.05E5	0.1164	2.61E7	3.15E-5
Ho^{166m}	1200y	1.80	5.39	66.5	1.46E-3
I^{123}	13.27h	1.92E6	0.796	7.11E7	2.15E-4
I^{124}	4.176d	2.52E5	5.53	9.34E6	1.50E-3
I^{125}	60.1d	1.74E4	1.664	6.44E5	4.50E-4
I^{126}	12.93d	7.97E4	4.34	2.95E6	1.17E-3
I^{129}	1.57E7y	1.77E-4	0.736	6.55E-3	1.99E-4
I^{130}	12.36h	1.55E6	4.76	5.74E7	1.29E-3

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Eu^{156}	15.19d	5.51E4	1.3	2.04E6	3.52E-4
F^{18}	1.830h	9.52E7	7.72	3.52E9	2.09E-3
Fe^{55}	2.73y	2.38E3	N/A	8.81E4	N/A
Fe^{59}	44.51d	4.97E4	7.34	1.84E6	1.98E-3
Fe^{60}	1.50E6y	3.98E-3	N/A	0.147	N/A
Fm^{256}	157.6m	4.66E6	N/A	1.72E8	N/A
Fr^{219}	20.0ms	2.58E12	N/A	9.53E13	N/A
Fr^{221}	4.9m	1.74E8	0.163	6.43E9	4.41E-5
Fr^{223}	21.8m	3.87E7	0.0952	1.43E9	2.58E-5
Ga^{67}	3.2612d	5.98E5	0.9381	2.21E7	2.54E-4
Gd^{148}	75y	32.2	N/A	1.19E3	N/A
Gd^{150}	1.79E6y	1.33E-3	N/A	0.0493	N/A
Gd^{152}	1.08E14y	2.18E-11	N/A	8.07E-10	N/A
Ge^{68}	270.8d	7.09E3	N/A	2.62E5	N/A
H^{3}	12.3y	9.70E3	N/A	3.59E5	N/A
Hf^{174}	2.00E15y	1.03E-12	N/A	3.81E-11	N/A
Hg^{203}	46.612d	1.38E4	1.29	5.11E5	3.49E-4
Ho^{163}	4.57E3y	0.48	N/A	17.8	N/A
Ho^{166}	26.8h	7.05E5	0.1164	2.61E7	3.15E-5
Ho^{166m}	1200y	1.80	5.39	66.5	1.46E-3
I^{123}	13.27h	1.92E6	0.796	7.11E7	2.15E-4
I^{124}	4.176d	2.52E5	5.53	9.34E6	1.50E-3
I^{125}	60.1d	1.74E4	1.664	6.44E5	4.50E-4
I^{126}	12.93d	7.97E4	4.34	2.95E6	1.17E-3
I^{129}	1.57E7y	1.77E-4	0.736	6.55E-3	1.99E-4
I^{130}	12.36h	1.55E6	4.76	5.74E7	1.29E-3

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Eu^{156}	15.19d	5.51E4	1.3	2.04E6	3.52E-4
F^{18}	1.830h	9.52E7	7.72	3.52E9	2.09E-3
Fe^{55}	2.73y	2.38E3	N/A	8.81E4	N/A
Fe^{59}	44.51d	4.97E4	7.34	1.84E6	1.98E-3
Fe^{60}	1.50E6y	3.98E-3	N/A	0.147	N/A
Fm^{256}	157.6m	4.66E6	N/A	1.72E8	N/A
Fr^{219}	20.0ms	2.58E12	N/A	9.53E13	N/A
Fr^{221}	4.9m	1.74E8	0.163	6.43E9	4.41E-5
Fr^{223}	21.8m	3.87E7	0.0952	1.43E9	2.58E-5
Ga^{67}	3.2612d	5.98E5	0.9381	2.21E7	2.54E-4
Gd^{148}	75y	32.2	N/A	1.19E3	N/A
Gd^{150}	1.79E6y	1.33E-3	N/A	0.0493	N/A
Gd^{152}	1.08E14y	2.18E-11	N/A	8.07E-10	N/A
Ge^{68}	270.8d	7.09E3	N/A	2.62E5	N/A
H^{3}	12.3y	9.70E3	N/A	3.59E5	N/A
Hf^{174}	2.00E15y	1.03E-12	N/A	3.81E-11	N/A
Hg^{203}	46.612d	1.38E4	1.29	5.11E5	3.49E-4
Ho^{163}	4.57E3y	0.48	N/A	17.8	N/A
Ho^{166}	26.8h	7.05E5	0.1164	2.61E7	3.15E-5
Ho^{166m}	1200y	1.80	5.39	66.5	1.46E-3
I^{123}	13.27h	1.92E6	0.796	7.11E7	2.15E-4
I^{124}	4.176d	2.52E5	5.53	9.34E6	1.50E-3
I^{125}	60.1d	1.74E4	1.664	6.44E5	4.50E-4
I^{126}	12.93d	7.97E4	4.34	2.95E6	1.17E-3
I^{129}	1.57E7y	1.77E-4	0.736	6.55E-3	1.99E-4
I^{130}	12.36h	1.55E6	4.76	5.74E7	1.29E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
I^{131}	8.040d	1.24E5	3.14	4.59E6	8.49E-4
I^{132}	2.295h	1.04E7	5.17	3.83E8	1.40E-3
I^{133}	20.8h	1.13E6	4.54	4.18E7	1.23E-3
I^{134}	52.6m	2.67E7	17.47	9.88E8	4.72E-3
I^{135}	6.57h	3.53E6	9.57	1.31E8	2.59E-3
In^{111}	2.8047d	4.20E5	3.717	1.55E7	1.01E-3
In^{113m}	1.6582h	1.69E7	1.53	6.25E8	4.14E-4
In^{115}	4.41E14y	7.06E-12	N/A	2.61E-10	N/A
Ir^{192}	73.83d	9.21E3	6.56	3.41E5	1.77E-3
K^{40}	1.28E9y	6.99E-6	0.91	2.59E-4	2.46E-4
K^{42}	12.36h	6.04E6	1.4	2.23E8	3.78E-4
K^{43}	22.3h	3.27E6	5.6	1.21E8	1.51E-3
Kr^{85}	10.73y	392.0	0.02	1.45E4	5.40E-6
Kr^{85m}	4.48h	8.24E6	0.96	3.05E8	2.60E-4
Kr^{87}	76.3m	2.84E7	3.18	1.05E9	8.61E-4
Kr^{88}	2.84h	1.26E7	8.9	4.64E8	2.41E-3
Kr^{89}	3.15m	6.71E8	3.96	2.48E10	1.07E-3
La^{140}	1.678d	5.56E5	13.61	2.06E7	3.68E-3
La^{142}	91.1m	1.46E7	0.675	5.38E8	1.83E-4
Lu^{177}	6.73d	1.10E5	0.170	4.06E6	4.61E-5
Mn^{52}	5.591d	4.49E5	18.6	1.66E7	5.03E-3
Mn^{52m}	21.2m	1.72E8	1.48	6.35E9	4.01E-4
Mn^{53}	3.74E6y	1.81E-3	N/A	0.0669	N/A
Mn^{54}	312.2d	7.75E3	5.67	2.87E5	1.53E-3
Mn^{56}	2.578h	2.17E7	10.24	8.03E8	2.77E-3
Mo^{99}	67h	4.80E5	1.25	1.78E7	3.38E-4

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
I^{131}	8.040d	1.24E5	3.14	4.59E6	8.49E-4
I^{132}	2.295h	1.04E7	5.17	3.83E8	1.40E-3
I^{133}	20.8h	1.13E6	4.54	4.18E7	1.23E-3
I^{134}	52.6m	2.67E7	17.47	9.88E8	4.72E-3
I^{135}	6.57h	3.53E6	9.57	1.31E8	2.59E-3
In^{111}	2.8047d	4.20E5	3.717	1.55E7	1.01E-3
In^{113m}	1.6582h	1.69E7	1.53	6.25E8	4.14E-4
In^{115}	4.41E14y	7.06E-12	N/A	2.61E-10	N/A
Ir^{192}	73.83d	9.21E3	6.56	3.41E5	1.77E-3
K^{40}	1.28E9y	6.99E-6	0.91	2.59E-4	2.46E-4
K^{42}	12.36h	6.04E6	1.4	2.23E8	3.78E-4
K^{43}	22.3h	3.27E6	5.6	1.21E8	1.51E-3
Kr^{85}	10.73y	392.0	0.02	1.45E4	5.40E-6
Kr^{85m}	4.48h	8.24E6	0.96	3.05E8	2.60E-4
Kr^{87}	76.3m	2.84E7	3.18	1.05E9	8.61E-4
Kr^{88}	2.84h	1.26E7	8.9	4.64E8	2.41E-3
Kr^{89}	3.15m	6.71E8	3.96	2.48E10	1.07E-3
La^{140}	1.678d	5.56E5	13.61	2.06E7	3.68E-3
La^{142}	91.1m	1.46E7	0.675	5.38E8	1.83E-4
Lu^{177}	6.73d	1.10E5	0.170	4.06E6	4.61E-5
Mn^{52}	5.591d	4.49E5	18.6	1.66E7	5.03E-3
Mn^{52m}	21.2m	1.72E8	1.48	6.35E9	4.01E-4
Mn^{53}	3.74E6y	1.81E-3	N/A	0.0669	N/A
Mn^{54}	312.2d	7.75E3	5.67	2.87E5	1.53E-3
Mn^{56}	2.578h	2.17E7	10.24	8.03E8	2.77E-3
Mo^{99}	67h	4.80E5	1.25	1.78E7	3.38E-4

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
I^{131}	8.040d	1.24E5	3.14	4.59E6	8.49E-4
I^{132}	2.295h	1.04E7	5.17	3.83E8	1.40E-3
I^{133}	20.8h	1.13E6	4.54	4.18E7	1.23E-3
I^{134}	52.6m	2.67E7	17.47	9.88E8	4.72E-3
I^{135}	6.57h	3.53E6	9.57	1.31E8	2.59E-3
In^{111}	2.8047d	4.20E5	3.717	1.55E7	1.01E-3
In^{113m}	1.6582h	1.69E7	1.53	6.25E8	4.14E-4
In^{115}	4.41E14y	7.06E-12	N/A	2.61E-10	N/A
Ir^{192}	73.83d	9.21E3	6.56	3.41E5	1.77E-3
K^{40}	1.28E9y	6.99E-6	0.91	2.59E-4	2.46E-4
K^{42}	12.36h	6.04E6	1.4	2.23E8	3.78E-4
K^{43}	22.3h	3.27E6	5.6	1.21E8	1.51E-3
Kr^{85}	10.73y	392.0	0.02	1.45E4	5.40E-6
Kr^{85m}	4.48h	8.24E6	0.96	3.05E8	2.60E-4
Kr^{87}	76.3m	2.84E7	3.18	1.05E9	8.61E-4
Kr^{88}	2.84h	1.26E7	8.9	4.64E8	2.41E-3
Kr^{89}	3.15m	6.71E8	3.96	2.48E10	1.07E-3
La^{140}	1.678d	5.56E5	13.61	2.06E7	3.68E-3
La^{142}	91.1m	1.46E7	0.675	5.38E8	1.83E-4
Lu^{177}	6.73d	1.10E5	0.170	4.06E6	4.61E-5
Mn^{52}	5.591d	4.49E5	18.6	1.66E7	5.03E-3
Mn^{52m}	21.2m	1.72E8	1.48	6.35E9	4.01E-4
Mn^{53}	3.74E6y	1.81E-3	N/A	0.0669	N/A
Mn^{54}	312.2d	7.75E3	5.67	2.87E5	1.53E-3
Mn^{56}	2.578h	2.17E7	10.24	8.03E8	2.77E-3
Mo^{99}	67h	4.80E5	1.25	1.78E7	3.38E-4

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
I^{131}	8.040d	1.24E5	3.14	4.59E6	8.49E-4
I^{132}	2.295h	1.04E7	5.17	3.83E8	1.40E-3
I^{133}	20.8h	1.13E6	4.54	4.18E7	1.23E-3
I^{134}	52.6m	2.67E7	17.47	9.88E8	4.72E-3
I^{135}	6.57h	3.53E6	9.57	1.31E8	2.59E-3
In^{111}	2.8047d	4.20E5	3.717	1.55E7	1.01E-3
In^{113m}	1.6582h	1.69E7	1.53	6.25E8	4.14E-4
In^{115}	4.41E14y	7.06E-12	N/A	2.61E-10	N/A
Ir^{192}	73.83d	9.21E3	6.56	3.41E5	1.77E-3
K^{40}	1.28E9y	6.99E-6	0.91	2.59E-4	2.46E-4
K^{42}	12.36h	6.04E6	1.4	2.23E8	3.78E-4
K^{43}	22.3h	3.27E6	5.6	1.21E8	1.51E-3
Kr^{85}	10.73y	392.0	0.02	1.45E4	5.40E-6
Kr^{85m}	4.48h	8.24E6	0.96	3.05E8	2.60E-4
Kr^{87}	76.3m	2.84E7	3.18	1.05E9	8.61E-4
Kr^{88}	2.84h	1.26E7	8.9	4.64E8	2.41E-3
Kr^{89}	3.15m	6.71E8	3.96	2.48E10	1.07E-3
La^{140}	1.678d	5.56E5	13.61	2.06E7	3.68E-3
La^{142}	91.1m	1.46E7	0.675	5.38E8	1.83E-4
Lu^{177}	6.73d	1.10E5	0.170	4.06E6	4.61E-5
Mn^{52}	5.591d	4.49E5	18.6	1.66E7	5.03E-3
Mn^{52m}	21.2m	1.72E8	1.48	6.35E9	4.01E-4
Mn^{53}	3.74E6y	1.81E-3	N/A	0.0669	N/A
Mn^{54}	312.2d	7.75E3	5.67	2.87E5	1.53E-3
Mn^{56}	2.578h	2.17E7	10.24	8.03E8	2.77E-3
Mo^{99}	67h	4.80E5	1.25	1.78E7	3.38E-4

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
N^{13}	9.965m	1.45E9	6.814	5.37E10	1.84E-3
N^{16}	7.13s	9.89E10	16.57	3.66E12	4.48E-3
Na^{22}	2.605y	6.24E3	14.85	2.31E5	4.01E-3
Na^{24}	14.96h	8.73E6	20.55	3.23E8	5.55E-3
Nb^{94}	2.03E5y	0.19	10.20	6.94	2.76E-3
Nb^{95}	34.975d	3.93E4	4.74	1.46E6	1.28E-3
Nd^{144}	2.29E15y	1.09E-12	N/A	4.02E-11	N/A
Ni^{57}	35.6h	1.54E6	12	5.70E7	3.24E-3
Ni^{59}	7.60E4y	0.080	12.5	2.95	3.38E-3
Ni^{63}	101y	56.23	N/A	2.08E3	N/A
Ni^{65}	2.52h	1.91E7	3.4	7.07E8	9.19E-4
Ni^{66}	54.6h	8.71E5	N/A	3.22E7	N/A
Np^{237}	2.14E6y	7.05E-4	0.0868	0.0261	2.35E-5
Np^{238}	2.117d	2.59E5	0.018	9.59E6	4.87E-6
Np^{239}	2.355d	2.32E5	0.594	8.58E6	1.61E-4
Np^{240}	61.9m	1.27E7	0.863	4.68E8	2.34E-4
O^{15}	122.2s	6.15E9	7.98	2.29E11	2.16E-3
Os^{186}	2E15y	9.62E-13	0.613	3.56E-11	1.66E-4
P^{32}	14.28d	2.86E5	N/A	1.06E7	N/A
P^{33}	25.34d	1.56E5	N/A	5.78E6	N/A
Pa^{231}	3.28E4y	0.047	0.104	1.75	2.81E-5
Pa^{233}	26.967d	2.08E4	1.27	7.69E5	3.44E-4
Pa^{234}	6.69h	2.00E6	7.03	7.40E7	1.90E-3
Pa^{234m}	1.17m	6.86E8	0.05	2.54E10	1.35E-5
Pb^{209}	3.253h	4.61E6	N/A	1.71E8	N/A
Pb^{210}	22.3y	76.4	0.0203	2.83E3	5.50E-6

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
N^{13}	9.965m	1.45E9	6.814	5.37E10	1.84E-3
N^{16}	7.13s	9.89E10	16.57	3.66E12	4.48E-3
Na^{22}	2.605y	6.24E3	14.85	2.31E5	4.01E-3
Na^{24}	14.96h	8.73E6	20.55	3.23E8	5.55E-3
Nb^{94}	2.03E5y	0.19	10.20	6.94	2.76E-3
Nb^{95}	34.975d	3.93E4	4.74	1.46E6	1.28E-3
Nd^{144}	2.29E15y	1.09E-12	N/A	4.02E-11	N/A
Ni^{57}	35.6h	1.54E6	12	5.70E7	3.24E-3
Ni^{59}	7.60E4y	0.080	12.5	2.95	3.38E-3
Ni^{63}	101y	56.23	N/A	2.08E3	N/A
Ni^{65}	2.52h	1.91E7	3.4	7.07E8	9.19E-4
Ni^{66}	54.6h	8.71E5	N/A	3.22E7	N/A
Np^{237}	2.14E6y	7.05E-4	0.0868	0.0261	2.35E-5
Np^{238}	2.117d	2.59E5	0.018	9.59E6	4.87E-6
Np^{239}	2.355d	2.32E5	0.594	8.58E6	1.61E-4
Np^{240}	61.9m	1.27E7	0.863	4.68E8	2.34E-4
O^{15}	122.2s	6.15E9	7.98	2.29E11	2.16E-3
Os^{186}	2E15y	9.62E-13	0.613	3.56E-11	1.66E-4
P^{32}	14.28d	2.86E5	N/A	1.06E7	N/A
P^{33}	25.34d	1.56E5	N/A	5.78E6	N/A
Pa^{231}	3.28E4y	0.047	0.104	1.75	2.81E-5
Pa^{233}	26.967d	2.08E4	1.27	7.69E5	3.44E-4
Pa^{234}	6.69h	2.00E6	7.03	7.40E7	1.90E-3
Pa^{234m}	1.17m	6.86E8	0.05	2.54E10	1.35E-5
Pb^{209}	3.253h	4.61E6	N/A	1.71E8	N/A
Pb^{210}	22.3y	76.4	0.0203	2.83E3	5.50E-6

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
N^{13}	9.965m	1.45E9	6.814	5.37E10	1.84E-3
N^{16}	7.13s	9.89E10	16.57	3.66E12	4.48E-3
Na^{22}	2.605y	6.24E3	14.85	2.31E5	4.01E-3
Na^{24}	14.96h	8.73E6	20.55	3.23E8	5.55E-3
Nb^{94}	2.03E5y	0.19	10.20	6.94	2.76E-3
Nb^{95}	34.975d	3.93E4	4.74	1.46E6	1.28E-3
Nd^{144}	2.29E15y	1.09E-12	N/A	4.02E-11	N/A
Ni^{57}	35.6h	1.54E6	12	5.70E7	3.24E-3
Ni^{59}	7.60E4y	0.080	12.5	2.95	3.38E-3
Ni^{63}	101y	56.23	N/A	2.08E3	N/A
Ni^{65}	2.52h	1.91E7	3.4	7.07E8	9.19E-4
Ni^{66}	54.6h	8.71E5	N/A	3.22E7	N/A
Np^{237}	2.14E6y	7.05E-4	0.0868	0.0261	2.35E-5
Np^{238}	2.117d	2.59E5	0.018	9.59E6	4.87E-6
Np^{239}	2.355d	2.32E5	0.594	8.58E6	1.61E-4
Np^{240}	61.9m	1.27E7	0.863	4.68E8	2.34E-4
O^{15}	122.2s	6.15E9	7.98	2.29E11	2.16E-3
Os^{186}	2E15y	9.62E-13	0.613	3.56E-11	1.66E-4
P^{32}	14.28d	2.86E5	N/A	1.06E7	N/A
P^{33}	25.34d	1.56E5	N/A	5.78E6	N/A
Pa^{231}	3.28E4y	0.047	0.104	1.75	2.81E-5
Pa^{233}	26.967d	2.08E4	1.27	7.69E5	3.44E-4
Pa^{234}	6.69h	2.00E6	7.03	7.40E7	1.90E-3
Pa^{234m}	1.17m	6.86E8	0.05	2.54E10	1.35E-5
Pb^{209}	3.253h	4.61E6	N/A	1.71E8	N/A
Pb^{210}	22.3y	76.4	0.0203	2.83E3	5.50E-6

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
N^{13}	9.965m	1.45E9	6.814	5.37E10	1.84E-3
N^{16}	7.13s	9.89E10	16.57	3.66E12	4.48E-3
Na^{22}	2.605y	6.24E3	14.85	2.31E5	4.01E-3
Na^{24}	14.96h	8.73E6	20.55	3.23E8	5.55E-3
Nb^{94}	2.03E5y	0.19	10.20	6.94	2.76E-3
Nb^{95}	34.975d	3.93E4	4.74	1.46E6	1.28E-3
Nd^{144}	2.29E15y	1.09E-12	N/A	4.02E-11	N/A
Ni^{57}	35.6h	1.54E6	12	5.70E7	3.24E-3
Ni^{59}	7.60E4y	0.080	12.5	2.95	3.38E-3
Ni^{63}	101y	56.23	N/A	2.08E3	N/A
Ni^{65}	2.52h	1.91E7	3.4	7.07E8	9.19E-4
Ni^{66}	54.6h	8.71E5	N/A	3.22E7	N/A
Np^{237}	2.14E6y	7.05E-4	0.0868	0.0261	2.35E-5
Np^{238}	2.117d	2.59E5	0.018	9.59E6	4.87E-6
Np^{239}	2.355d	2.32E5	0.594	8.58E6	1.61E-4
Np^{240}	61.9m	1.27E7	0.863	4.68E8	2.34E-4
O^{15}	122.2s	6.15E9	7.98	2.29E11	2.16E-3
Os^{186}	2E15y	9.62E-13	0.613	3.56E-11	1.66E-4
P^{32}	14.28d	2.86E5	N/A	1.06E7	N/A
P^{33}	25.34d	1.56E5	N/A	5.78E6	N/A
Pa^{231}	3.28E4y	0.047	0.104	1.75	2.81E-5
Pa^{233}	26.967d	2.08E4	1.27	7.69E5	3.44E-4
Pa^{234}	6.69h	2.00E6	7.03	7.40E7	1.90E-3
Pa^{234m}	1.17m	6.86E8	0.05	2.54E10	1.35E-5
Pb^{209}	3.253h	4.61E6	N/A	1.71E8	N/A
Pb^{210}	22.3y	76.4	0.0203	2.83E3	5.50E-6

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Pb^{211}	36.1m	2.47E7	0.248	9.14E8	6.71E-5
Pb^{212}	10.64h	1.39E6	0.732	5.14E7	1.98E-4
Pb^{214}	27m	3.25E7	1.155	1.20E9	3.12E-4
Pd^{107}	6.50E6y	5.15E-4	N/A	0.0191	N/A
Pm^{147}	2.6234y	928.3	3.15E-5	3.43E4	8.53E-9
Pm^{149}	53.08h	3.97E5	0.0532	1.47E7	1.44E-5
Pm^{151}	4.12m	7.31E5	1.2	2.71E7	3.25E-4
Po^{210}	138.38d	4.49E3	N/A	1.66E5	N/A
Po^{212}	304ns	1.78E17	N/A	6.59E18	N/A
Po^{214}	164us	3.22E14	6.71E-4	1.19E16	1.81E-7
Po^{216}	145ms	3.60E11	9.95E-5	1.33E13	2.69E-9
Po^{218}	3.10m	2.78E8	N/A	1.03E10	N/A
Pr^{142m}	14.6m	9.08E7	N/A	3.36E9	N/A
Pt^{190}	6.50E11y	2.90E-9	N/A	1.07E-7	N/A
Pt^{202}	44.0h	3.53E5	N/A	1.30E7	N/A
Pu^{236}	2.87y	528	N/A	1.95E4	N/A
Pu^{238}	87.7y	17.1	N/A	633	N/A
Pu^{239}	2.41E4y	0.062	2.11E-4	2.30	5.71E-8
Pu^{240}	6560y	0.227	N/A	8.40	N/A
Pu^{241}	14.4y	103	N/A	3.81E3	N/A
Pu^{242}	3.75E5y	3.94E-3	N/A	0.146	N/A
Ra^{223}	11.435d	5.12E4	0.37	1.89E6	1.00E-4
Ra^{224}	3.66d	1.59E5	0.054	5.88E6	1.46E-5
Ra^{225}	14.9d	3.90E4	0.07	1.44E6	1.89E-5
Ra^{226}	1600y	0.99	0.045	36.6	1.22E-5
Ra^{228}	5.76y	272	N/A	1.01E4	N/A

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Pb^{211}	36.1m	2.47E7	0.248	9.14E8	6.71E-5
Pb^{212}	10.64h	1.39E6	0.732	5.14E7	1.98E-4
Pb^{214}	27m	3.25E7	1.155	1.20E9	3.12E-4
Pd^{107}	6.50E6y	5.15E-4	N/A	0.0191	N/A
Pm^{147}	2.6234y	928.3	3.15E-5	3.43E4	8.53E-9
Pm^{149}	53.08h	3.97E5	0.0532	1.47E7	1.44E-5
Pm^{151}	4.12m	7.31E5	1.2	2.71E7	3.25E-4
Po^{210}	138.38d	4.49E3	N/A	1.66E5	N/A
Po^{212}	304ns	1.78E17	N/A	6.59E18	N/A
Po^{214}	164us	3.22E14	6.71E-4	1.19E16	1.81E-7
Po^{216}	145ms	3.60E11	9.95E-5	1.33E13	2.69E-9
Po^{218}	3.10m	2.78E8	N/A	1.03E10	N/A
Pr^{142m}	14.6m	9.08E7	N/A	3.36E9	N/A
Pt^{190}	6.50E11y	2.90E-9	N/A	1.07E-7	N/A
Pt^{202}	44.0h	3.53E5	N/A	1.30E7	N/A
Pu^{236}	2.87y	528	N/A	1.95E4	N/A
Pu^{238}	87.7y	17.1	N/A	633	N/A
Pu^{239}	2.41E4y	0.062	2.11E-4	2.30	5.71E-8
Pu^{240}	6560y	0.227	N/A	8.40	N/A
Pu^{241}	14.4y	103	N/A	3.81E3	N/A
Pu^{242}	3.75E5y	3.94E-3	N/A	0.146	N/A
Ra^{223}	11.435d	5.12E4	0.37	1.89E6	1.00E-4
Ra^{224}	3.66d	1.59E5	0.054	5.88E6	1.46E-5
Ra^{225}	14.9d	3.90E4	0.07	1.44E6	1.89E-5
Ra^{226}	1600y	0.99	0.045	36.6	1.22E-5
Ra^{228}	5.76y	272	N/A	1.01E4	N/A

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Pb^{211}	36.1m	2.47E7	0.248	9.14E8	6.71E-5
Pb^{212}	10.64h	1.39E6	0.732	5.14E7	1.98E-4
Pb^{214}	27m	3.25E7	1.155	1.20E9	3.12E-4
Pd^{107}	6.50E6y	5.15E-4	N/A	0.0191	N/A
Pm^{147}	2.6234y	928.3	3.15E-5	3.43E4	8.53E-9
Pm^{149}	53.08h	3.97E5	0.0532	1.47E7	1.44E-5
Pm^{151}	4.12m	7.31E5	1.2	2.71E7	3.25E-4
Po^{210}	138.38d	4.49E3	N/A	1.66E5	N/A
Po^{212}	304ns	1.78E17	N/A	6.59E18	N/A
Po^{214}	164us	3.22E14	6.71E-4	1.19E16	1.81E-7
Po^{216}	145ms	3.60E11	9.95E-5	1.33E13	2.69E-9
Po^{218}	3.10m	2.78E8	N/A	1.03E10	N/A
Pr^{142m}	14.6m	9.08E7	N/A	3.36E9	N/A
Pt^{190}	6.50E11y	2.90E-9	N/A	1.07E-7	N/A
Pt^{202}	44.0h	3.53E5	N/A	1.30E7	N/A
Pu^{236}	2.87y	528	N/A	1.95E4	N/A
Pu^{238}	87.7y	17.1	N/A	633	N/A
Pu^{239}	2.41E4y	0.062	2.11E-4	2.30	5.71E-8
Pu^{240}	6560y	0.227	N/A	8.40	N/A
Pu^{241}	14.4y	103	N/A	3.81E3	N/A
Pu^{242}	3.75E5y	3.94E-3	N/A	0.146	N/A
Ra^{223}	11.435d	5.12E4	0.37	1.89E6	1.00E-4
Ra^{224}	3.66d	1.59E5	0.054	5.88E6	1.46E-5
Ra^{225}	14.9d	3.90E4	0.07	1.44E6	1.89E-5
Ra^{226}	1600y	0.99	0.045	36.6	1.22E-5
Ra^{228}	5.76y	272	N/A	1.01E4	N/A

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
Pb^{211}	36.1m	2.47E7	0.248	9.14E8	6.71E-5
Pb^{212}	10.64h	1.39E6	0.732	5.14E7	1.98E-4
Pb^{214}	27m	3.25E7	1.155	1.20E9	3.12E-4
Pd^{107}	6.50E6y	5.15E-4	N/A	0.0191	N/A
Pm^{147}	2.6234y	928.3	3.15E-5	3.43E4	8.53E-9
Pm^{149}	53.08h	3.97E5	0.0532	1.47E7	1.44E-5
Pm^{151}	4.12m	7.31E5	1.2	2.71E7	3.25E-4
Po^{210}	138.38d	4.49E3	N/A	1.66E5	N/A
Po^{212}	304ns	1.78E17	N/A	6.59E18	N/A
Po^{214}	164us	3.22E14	6.71E-4	1.19E16	1.81E-7
Po^{216}	145ms	3.60E11	9.95E-5	1.33E13	2.69E-9
Po^{218}	3.10m	2.78E8	N/A	1.03E10	N/A
Pr^{142m}	14.6m	9.08E7	N/A	3.36E9	N/A
Pt^{190}	6.50E11y	2.90E-9	N/A	1.07E-7	N/A
Pt^{202}	44.0h	3.53E5	N/A	1.30E7	N/A
Pu^{236}	2.87y	528	N/A	1.95E4	N/A
Pu^{238}	87.7y	17.1	N/A	633	N/A
Pu^{239}	2.41E4y	0.062	2.11E-4	2.30	5.71E-8
Pu^{240}	6560y	0.227	N/A	8.40	N/A
Pu^{241}	14.4y	103	N/A	3.81E3	N/A
Pu^{242}	3.75E5y	3.94E-3	N/A	0.146	N/A
Ra^{223}	11.435d	5.12E4	0.37	1.89E6	1.00E-4
Ra^{224}	3.66d	1.59E5	0.054	5.88E6	1.46E-5
Ra^{225}	14.9d	3.90E4	0.07	1.44E6	1.89E-5
Ra^{226}	1600y	0.99	0.045	36.6	1.22E-5
Ra^{228}	5.76y	272	N/A	1.01E4	N/A

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Rb^{81}	4.576h	8.47E6	3.628	3.13E8	9.82E-4
Rb^{82}	1.273m	1.80E9	7.452	6.67E10	2.02E-3
Rb^{83}	86.2d	1.83E4	3.135	6.76E5	8.49E-4
Rb^{87}	4.75E10y	8.67E-8	N/A	3.21E-6	N/A
Rb^{88}	17.7m	1.21E8	3.58	4.48E9	9.68E-4
Rb^{89}	15.4m	1.37E8	12.17	5.07E9	3.29E-3
Re^{187}	4.35E10y	4.40E-8	N/A	1.63E-6	N/A
Re^{188}	16.98h	9.82E5	0.2096	3.63E7	5.67E-5
Rh^{105}	35.36h	8.45E5	0.462	3.13E7	1.25E-4
Rh^{106}	29.8s	3.58E9	0.644	1.32E11	1.74E-4
Rn^{212}	23.9m	3.71E7	N/A	1.37E9	N/A
Rn^{216}	45.0us	1.16E15	N/A	4.30E16	N/A
Rn^{219}	3.96s	1.30E10	0.329	4.81E11	8.91E-5
Rn^{220}	55.6s	9.21E8	3.99E-3	3.41E10	1.08E-6
Rn^{222}	3.8235d	1.54E5	3.03E-3	5.70E6	8.19E-7
Ru^{97}	2.9d	4.65E5	1.32	1.72E7	3.57E-4
Ru^{103}	39.26d	3.23E4	2.65	1.20E6	7.17E-4
Ru^{105}	4.44h	6.73E6	1.93	2.49E8	5.22E-4
Ru^{106}	1.02y	3.31E3	N/A	1.22E5	N/A
S^{35}	87.51d	4.27E4	N/A	1.58E6	N/A
Sb^{122}	2.7238d	3.93E5	2.991	1.46E7	8.10E-4
Sb^{124}	60.2d	1.75E4	9.62	6.48E5	2.60E-3
Sb^{125}	1007.4d	1.04E3	2.57	3.84E4	6.96E-4
Sb^{126}	12.46d	8.33E4	11.5	3.08E6	3.11E-3
Sc^{44}	3.927h	1.82E7	0.579	6.72E8	1.57E-4
Sc^{46}	83.81d	3.39E4	10.9	1.25E6	2.95E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Rb^{81}	4.576h	8.47E6	3.628	3.13E8	9.82E-4
Rb^{82}	1.273m	1.80E9	7.452	6.67E10	2.02E-3
Rb^{83}	86.2d	1.83E4	3.135	6.76E5	8.49E-4
Rb^{87}	4.75E10y	8.67E-8	N/A	3.21E-6	N/A
Rb^{88}	17.7m	1.21E8	3.58	4.48E9	9.68E-4
Rb^{89}	15.4m	1.37E8	12.17	5.07E9	3.29E-3
Re^{187}	4.35E10y	4.40E-8	N/A	1.63E-6	N/A
Re^{188}	16.98h	9.82E5	0.2096	3.63E7	5.67E-5
Rh^{105}	35.36h	8.45E5	0.462	3.13E7	1.25E-4
Rh^{106}	29.8s	3.58E9	0.644	1.32E11	1.74E-4
Rn^{212}	23.9m	3.71E7	N/A	1.37E9	N/A
Rn^{216}	45.0us	1.16E15	N/A	4.30E16	N/A
Rn^{219}	3.96s	1.30E10	0.329	4.81E11	8.91E-5
Rn^{220}	55.6s	9.21E8	3.99E-3	3.41E10	1.08E-6
Rn^{222}	3.8235d	1.54E5	3.03E-3	5.70E6	8.19E-7
Ru^{97}	2.9d	4.65E5	1.32	1.72E7	3.57E-4
Ru^{103}	39.26d	3.23E4	2.65	1.20E6	7.17E-4
Ru^{105}	4.44h	6.73E6	1.93	2.49E8	5.22E-4
Ru^{106}	1.02y	3.31E3	N/A	1.22E5	N/A
S^{35}	87.51d	4.27E4	N/A	1.58E6	N/A
Sb^{122}	2.7238d	3.93E5	2.991	1.46E7	8.10E-4
Sb^{124}	60.2d	1.75E4	9.62	6.48E5	2.60E-3
Sb^{125}	1007.4d	1.04E3	2.57	3.84E4	6.96E-4
Sb^{126}	12.46d	8.33E4	11.5	3.08E6	3.11E-3
Sc^{44}	3.927h	1.82E7	0.579	6.72E8	1.57E-4
Sc^{46}	83.81d	3.39E4	10.9	1.25E6	2.95E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Rb^{81}	4.576h	8.47E6	3.628	3.13E8	9.82E-4
Rb^{82}	1.273m	1.80E9	7.452	6.67E10	2.02E-3
Rb^{83}	86.2d	1.83E4	3.135	6.76E5	8.49E-4
Rb^{87}	4.75E10y	8.67E-8	N/A	3.21E-6	N/A
Rb^{88}	17.7m	1.21E8	3.58	4.48E9	9.68E-4
Rb^{89}	15.4m	1.37E8	12.17	5.07E9	3.29E-3
Re^{187}	4.35E10y	4.40E-8	N/A	1.63E-6	N/A
Re^{188}	16.98h	9.82E5	0.2096	3.63E7	5.67E-5
Rh^{105}	35.36h	8.45E5	0.462	3.13E7	1.25E-4
Rh^{106}	29.8s	3.58E9	0.644	1.32E11	1.74E-4
Rn^{212}	23.9m	3.71E7	N/A	1.37E9	N/A
Rn^{216}	45.0us	1.16E15	N/A	4.30E16	N/A
Rn^{219}	3.96s	1.30E10	0.329	4.81E11	8.91E-5
Rn^{220}	55.6s	9.21E8	3.99E-3	3.41E10	1.08E-6
Rn^{222}	3.8235d	1.54E5	3.03E-3	5.70E6	8.19E-7
Ru^{97}	2.9d	4.65E5	1.32	1.72E7	3.57E-4
Ru^{103}	39.26d	3.23E4	2.65	1.20E6	7.17E-4
Ru^{105}	4.44h	6.73E6	1.93	2.49E8	5.22E-4
Ru^{106}	1.02y	3.31E3	N/A	1.22E5	N/A
S^{35}	87.51d	4.27E4	N/A	1.58E6	N/A
Sb^{122}	2.7238d	3.93E5	2.991	1.46E7	8.10E-4
Sb^{124}	60.2d	1.75E4	9.62	6.48E5	2.60E-3
Sb^{125}	1007.4d	1.04E3	2.57	3.84E4	6.96E-4
Sb^{126}	12.46d	8.33E4	11.5	3.08E6	3.11E-3
Sc^{44}	3.927h	1.82E7	0.579	6.72E8	1.57E-4
Sc^{46}	83.81d	3.39E4	10.9	1.25E6	2.95E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Rb^{81}	4.576h	8.47E6	3.628	3.13E8	9.82E-4
Rb^{82}	1.273m	1.80E9	7.452	6.67E10	2.02E-3
Rb^{83}	86.2d	1.83E4	3.135	6.76E5	8.49E-4
Rb^{87}	4.75E10y	8.67E-8	N/A	3.21E-6	N/A
Rb^{88}	17.7m	1.21E8	3.58	4.48E9	9.68E-4
Rb^{89}	15.4m	1.37E8	12.17	5.07E9	3.29E-3
Re^{187}	4.35E10y	4.40E-8	N/A	1.63E-6	N/A
Re^{188}	16.98h	9.82E5	0.2096	3.63E7	5.67E-5
Rh^{105}	35.36h	8.45E5	0.462	3.13E7	1.25E-4
Rh^{106}	29.8s	3.58E9	0.644	1.32E11	1.74E-4
Rn^{212}	23.9m	3.71E7	N/A	1.37E9	N/A
Rn^{216}	45.0us	1.16E15	N/A	4.30E16	N/A
Rn^{219}	3.96s	1.30E10	0.329	4.81E11	8.91E-5
Rn^{220}	55.6s	9.21E8	3.99E-3	3.41E10	1.08E-6
Rn^{222}	3.8235d	1.54E5	3.03E-3	5.70E6	8.19E-7
Ru^{97}	2.9d	4.65E5	1.32	1.72E7	3.57E-4
Ru^{103}	39.26d	3.23E4	2.65	1.20E6	7.17E-4
Ru^{105}	4.44h	6.73E6	1.93	2.49E8	5.22E-4
Ru^{106}	1.02y	3.31E3	N/A	1.22E5	N/A
S^{35}	87.51d	4.27E4	N/A	1.58E6	N/A
Sb^{122}	2.7238d	3.93E5	2.991	1.46E7	8.10E-4
Sb^{124}	60.2d	1.75E4	9.62	6.48E5	2.60E-3
Sb^{125}	1007.4d	1.04E3	2.57	3.84E4	6.96E-4
Sb^{126}	12.46d	8.33E4	11.5	3.08E6	3.11E-3
Sc^{44}	3.927h	1.82E7	0.579	6.72E8	1.57E-4
Sc^{46}	83.81d	3.39E4	10.9	1.25E6	2.95E-3

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Sc^{47}	3.349d	8.30E5	0.56	3.07E7	1.51E-4
Sc^{48}	43.7h	1.49E6	21	5.51E7	5.68E-3
Se^{75}	119.78d	1.45E4	9.53	5.37E5	2.58E-3
Se^{79}	6.50E5y	6.98E-3	N/A	0.258	N/A
Si^{32}	132y	84.77	N/A	3.14E3	N/A
Sm^{146}	1.031E8y	2.38E-5	N/A	8.80E-4	N/A
Sm^{147}	1.06E11y	2.30E-8	N/A	8.50E-7	N/A
Sm^{148}	7.00E15y	3.46E-13	N/A	1.28E-11	N/A
Sm^{153}	46.27h	4.43E5	0.175	1.64E7	4.74E-5
Sn^{121}	27.06h	9.58E5	N/A	3.54E7	N/A
Sn^{125}	9.64d	1.09E5	0.33	4.01E6	8.93E-5
Sr^{85}	64.84d	2.37E4	3.06	8.78E5	8.28E-4
Sr^{87m}	2.803h	1.32E7	1.92	4.87E8	5.20E-4
Sr^{89}	50.52d	2.90E4	5.29E-3	1.07E6	1.43E-6
Sr^{90}	29.1y	137.0	N/A	5.07E3	N/A
Sr^{91}	9.63h	3.58E6	0.635	1.32E8	1.72E-4
Sr^{92}	2.71h	1.26E7	7.8942	4.65E8	2.14E-3
Tb^{160}	72.3d	1.13E4	0.635	4.18E5	1.72E-4
Tc^{99}	2.13E5y	0.017	N/A	0.629	N/A
Tc^{99m}	6.01h	5.27E6	0.896	1.95E8	2.42E-4
Tc^{101}	14.2m	1.31E8	1.71	4.85E9	4.63E-4
Te^{123m}	119.7d	8.88E3	1.365	3.28E5	3.69E-4
Te^{127}	9.35h	2.64E6	0.0335	9.78E7	9.06E-6
Te^{129}	69.6m	2.10E7	0.5717	7.76E8	1.55E-4
Te^{129m}	33.6d	3.02E4	0.137	1.12E6	3.71E-5
Te^{131}	25m	5.75E7	1.57	2.13E9	4.25E-4

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Sc^{47}	3.349d	8.30E5	0.56	3.07E7	1.51E-4
Sc^{48}	43.7h	1.49E6	21	5.51E7	5.68E-3
Se^{75}	119.78d	1.45E4	9.53	5.37E5	2.58E-3
Se^{79}	6.50E5y	6.98E-3	N/A	0.258	N/A
Si^{32}	132y	84.77	N/A	3.14E3	N/A
Sm^{146}	1.031E8y	2.38E-5	N/A	8.80E-4	N/A
Sm^{147}	1.06E11y	2.30E-8	N/A	8.50E-7	N/A
Sm^{148}	7.00E15y	3.46E-13	N/A	1.28E-11	N/A
Sm^{153}	46.27h	4.43E5	0.175	1.64E7	4.74E-5
Sn^{121}	27.06h	9.58E5	N/A	3.54E7	N/A
Sn^{125}	9.64d	1.09E5	0.33	4.01E6	8.93E-5
Sr^{85}	64.84d	2.37E4	3.06	8.78E5	8.28E-4
Sr^{87m}	2.803h	1.32E7	1.92	4.87E8	5.20E-4
Sr^{89}	50.52d	2.90E4	5.29E-3	1.07E6	1.43E-6
Sr^{90}	29.1y	137.0	N/A	5.07E3	N/A
Sr^{91}	9.63h	3.58E6	0.635	1.32E8	1.72E-4
Sr^{92}	2.71h	1.26E7	7.8942	4.65E8	2.14E-3
Tb^{160}	72.3d	1.13E4	0.635	4.18E5	1.72E-4
Tc^{99}	2.13E5y	0.017	N/A	0.629	N/A
Tc^{99m}	6.01h	5.27E6	0.896	1.95E8	2.42E-4
Tc^{101}	14.2m	1.31E8	1.71	4.85E9	4.63E-4
Te^{123m}	119.7d	8.88E3	1.365	3.28E5	3.69E-4
Te^{127}	9.35h	2.64E6	0.0335	9.78E7	9.06E-6
Te^{129}	69.6m	2.10E7	0.5717	7.76E8	1.55E-4
Te^{129m}	33.6d	3.02E4	0.137	1.12E6	3.71E-5
Te^{131}	25m	5.75E7	1.57	2.13E9	4.25E-4

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Sc^{47}	3.349d	8.30E5	0.56	3.07E7	1.51E-4
Sc^{48}	43.7h	1.49E6	21	5.51E7	5.68E-3
Se^{75}	119.78d	1.45E4	9.53	5.37E5	2.58E-3
Se^{79}	6.50E5y	6.98E-3	N/A	0.258	N/A
Si^{32}	132y	84.77	N/A	3.14E3	N/A
Sm^{146}	1.031E8y	2.38E-5	N/A	8.80E-4	N/A
Sm^{147}	1.06E11y	2.30E-8	N/A	8.50E-7	N/A
Sm^{148}	7.00E15y	3.46E-13	N/A	1.28E-11	N/A
Sm^{153}	46.27h	4.43E5	0.175	1.64E7	4.74E-5
Sn^{121}	27.06h	9.58E5	N/A	3.54E7	N/A
Sn^{125}	9.64d	1.09E5	0.33	4.01E6	8.93E-5
Sr^{85}	64.84d	2.37E4	3.06	8.78E5	8.28E-4
Sr^{87m}	2.803h	1.32E7	1.92	4.87E8	5.20E-4
Sr^{89}	50.52d	2.90E4	5.29E-3	1.07E6	1.43E-6
Sr^{90}	29.1y	137.0	N/A	5.07E3	N/A
Sr^{91}	9.63h	3.58E6	0.635	1.32E8	1.72E-4
Sr^{92}	2.71h	1.26E7	7.8942	4.65E8	2.14E-3
Tb^{160}	72.3d	1.13E4	0.635	4.18E5	1.72E-4
Tc^{99}	2.13E5y	0.017	N/A	0.629	N/A
Tc^{99m}	6.01h	5.27E6	0.896	1.95E8	2.42E-4
Tc^{101}	14.2m	1.31E8	1.71	4.85E9	4.63E-4
Te^{123m}	119.7d	8.88E3	1.365	3.28E5	3.69E-4
Te^{127}	9.35h	2.64E6	0.0335	9.78E7	9.06E-6
Te^{129}	69.6m	2.10E7	0.5717	7.76E8	1.55E-4
Te^{129m}	33.6d	3.02E4	0.137	1.12E6	3.71E-5
Te^{131}	25m	5.75E7	1.57	2.13E9	4.25E-4

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Sc^{47}	3.349d	8.30E5	0.56	3.07E7	1.51E-4
Sc^{48}	43.7h	1.49E6	21	5.51E7	5.68E-3
Se^{75}	119.78d	1.45E4	9.53	5.37E5	2.58E-3
Se^{79}	6.50E5y	6.98E-3	N/A	0.258	N/A
Si^{32}	132y	84.77	N/A	3.14E3	N/A
Sm^{146}	1.031E8y	2.38E-5	N/A	8.80E-4	N/A
Sm^{147}	1.06E11y	2.30E-8	N/A	8.50E-7	N/A
Sm^{148}	7.00E15y	3.46E-13	N/A	1.28E-11	N/A
Sm^{153}	46.27h	4.43E5	0.175	1.64E7	4.74E-5
Sn^{121}	27.06h	9.58E5	N/A	3.54E7	N/A
Sn^{125}	9.64d	1.09E5	0.33	4.01E6	8.93E-5
Sr^{85}	64.84d	2.37E4	3.06	8.78E5	8.28E-4
Sr^{87m}	2.803h	1.32E7	1.92	4.87E8	5.20E-4
Sr^{89}	50.52d	2.90E4	5.29E-3	1.07E6	1.43E-6
Sr^{90}	29.1y	137.0	N/A	5.07E3	N/A
Sr^{91}	9.63h	3.58E6	0.635	1.32E8	1.72E-4
Sr^{92}	2.71h	1.26E7	7.8942	4.65E8	2.14E-3
Tb^{160}	72.3d	1.13E4	0.635	4.18E5	1.72E-4
Tc^{99}	2.13E5y	0.017	N/A	0.629	N/A
Tc^{99m}	6.01h	5.27E6	0.896	1.95E8	2.42E-4
Tc^{101}	14.2m	1.31E8	1.71	4.85E9	4.63E-4
Te^{123m}	119.7d	8.88E3	1.365	3.28E5	3.69E-4
Te^{127}	9.35h	2.64E6	0.0335	9.78E7	9.06E-6
Te^{129}	69.6m	2.10E7	0.5717	7.76E8	1.55E-4
Te^{129m}	33.6d	3.02E4	0.137	1.12E6	3.71E-5
Te^{131}	25m	5.75E7	1.57	2.13E9	4.25E-4

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Te^{131m}	30h	7.98E5	2.18	2.95E7	5.90E-4
Te^{132}	3.204d	3.09E5	2.124	1.14E7	5.75E-4
Te^{133}	12.5m	1.13E8	2.32	4.19E9	6.28E-4
Te^{133m}	55.4m	2.55E7	3.11	9.45E8	8.42E-4
Te^{134}	41.8m	3.36E7	1.77	1.24E9	4.79E-4
Te^{135}	19s	4.40E9	0.195	1.63E11	5.28E-5
Th^{227}	18.72d	3.07E4	0.39	1.14E6	1.05E-4
Th^{228}	1.913y	820.0	0.014	3.03E4	3.78E-6
Th^{229}	7300y	0.214	0.145	7.92	3.92E-5
Th^{230}	7.54E4y	0.021	2.07E-3	0.762	5.60E-7
Th^{231}	25.55h	5.32E5	0.0480	1.97E7	1.30E-5
Th^{232}	1.40E10y	1.10E-7	7.62E-4	4.07E-6	2.06E-7
Th^{234}	24.10d	2.32E4	0.0356	8.58E5	9.62E-6
Tl^{201}	72.912h	2.14E5	0.122	7.91E6	3.30E-5
Tl^{204}	3.78y	464.0	0.0124	1.72E4	3.35E-6
Tl^{206}	4.20m	2.17E8	N/A	8.03E9	N/A
Tl^{208}	3.053m	2.96E8	18.89	1.10E10	5.11E-3
Tl^{209}	2.161m	4.16E8	4.17	1.54E10	1.13E-3
Tl^{210}	1.30m	6.88E8	7.82	2.55E10	2.11E-3
U^{230}	20.8d	2.73E4	2.00E-3	1.01E6	5.41E-7
U^{232}	70y	22.0	0.0731	814	1.98E-5
U^{233}	1.592E5y	9.65E-3	N/A	0.357	N/A
U^{234}	2.46E5y	6.22E-3	N/A	0.230	N/A
U^{235}	7.04E8y	2.16E-6	0.755	7.99E-5	2.04E-4
U^{235m}	25.0m	3.20E7	N/A	1.18E9	N/A
U^{236}	2.342E7y	6.47E-5	1.10E-4	2.40E-3	2.98E-8

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Te^{131m}	30h	7.98E5	2.18	2.95E7	5.90E-4
Te^{132}	3.204d	3.09E5	2.124	1.14E7	5.75E-4
Te^{133}	12.5m	1.13E8	2.32	4.19E9	6.28E-4
Te^{133m}	55.4m	2.55E7	3.11	9.45E8	8.42E-4
Te^{134}	41.8m	3.36E7	1.77	1.24E9	4.79E-4
Te^{135}	19s	4.40E9	0.195	1.63E11	5.28E-5
Th^{227}	18.72d	3.07E4	0.39	1.14E6	1.05E-4
Th^{228}	1.913y	820.0	0.014	3.03E4	3.78E-6
Th^{229}	7300y	0.214	0.145	7.92	3.92E-5
Th^{230}	7.54E4y	0.021	2.07E-3	0.762	5.60E-7
Th^{231}	25.55h	5.32E5	0.0480	1.97E7	1.30E-5
Th^{232}	1.40E10y	1.10E-7	7.62E-4	4.07E-6	2.06E-7
Th^{234}	24.10d	2.32E4	0.0356	8.58E5	9.62E-6
Tl^{201}	72.912h	2.14E5	0.122	7.91E6	3.30E-5
Tl^{204}	3.78y	464.0	0.0124	1.72E4	3.35E-6
Tl^{206}	4.20m	2.17E8	N/A	8.03E9	N/A
Tl^{208}	3.053m	2.96E8	18.89	1.10E10	5.11E-3
Tl^{209}	2.161m	4.16E8	4.17	1.54E10	1.13E-3
Tl^{210}	1.30m	6.88E8	7.82	2.55E10	2.11E-3
U^{230}	20.8d	2.73E4	2.00E-3	1.01E6	5.41E-7
U^{232}	70y	22.0	0.0731	814	1.98E-5
U^{233}	1.592E5y	9.65E-3	N/A	0.357	N/A
U^{234}	2.46E5y	6.22E-3	N/A	0.230	N/A
U^{235}	7.04E8y	2.16E-6	0.755	7.99E-5	2.04E-4
U^{235m}	25.0m	3.20E7	N/A	1.18E9	N/A
U^{236}	2.342E7y	6.47E-5	1.10E-4	2.40E-3	2.98E-8

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Te^{131m}	30h	7.98E5	2.18	2.95E7	5.90E-4
Te^{132}	3.204d	3.09E5	2.124	1.14E7	5.75E-4
Te^{133}	12.5m	1.13E8	2.32	4.19E9	6.28E-4
Te^{133m}	55.4m	2.55E7	3.11	9.45E8	8.42E-4
Te^{134}	41.8m	3.36E7	1.77	1.24E9	4.79E-4
Te^{135}	19s	4.40E9	0.195	1.63E11	5.28E-5
Th^{227}	18.72d	3.07E4	0.39	1.14E6	1.05E-4
Th^{228}	1.913y	820.0	0.014	3.03E4	3.78E-6
Th^{229}	7300y	0.214	0.145	7.92	3.92E-5
Th^{230}	7.54E4y	0.021	2.07E-3	0.762	5.60E-7
Th^{231}	25.55h	5.32E5	0.0480	1.97E7	1.30E-5
Th^{232}	1.40E10y	1.10E-7	7.62E-4	4.07E-6	2.06E-7
Th^{234}	24.10d	2.32E4	0.0356	8.58E5	9.62E-6
Tl^{201}	72.912h	2.14E5	0.122	7.91E6	3.30E-5
Tl^{204}	3.78y	464.0	0.0124	1.72E4	3.35E-6
Tl^{206}	4.20m	2.17E8	N/A	8.03E9	N/A
Tl^{208}	3.053m	2.96E8	18.89	1.10E10	5.11E-3
Tl^{209}	2.161m	4.16E8	4.17	1.54E10	1.13E-3
Tl^{210}	1.30m	6.88E8	7.82	2.55E10	2.11E-3
U^{230}	20.8d	2.73E4	2.00E-3	1.01E6	5.41E-7
U^{232}	70y	22.0	0.0731	814	1.98E-5
U^{233}	1.592E5y	9.65E-3	N/A	0.357	N/A
U^{234}	2.46E5y	6.22E-3	N/A	0.230	N/A
U^{235}	7.04E8y	2.16E-6	0.755	7.99E-5	2.04E-4
U^{235m}	25.0m	3.20E7	N/A	1.18E9	N/A
U^{236}	2.342E7y	6.47E-5	1.10E-4	2.40E-3	2.98E-8

	Half-Life	Ci/g	Rem/hr / Ci @ 30 cm	GBq/g	Sv/hr / GBq @ 30cm
Te^{131m}	30h	7.98E5	2.18	2.95E7	5.90E-4
Te^{132}	3.204d	3.09E5	2.124	1.14E7	5.75E-4
Te^{133}	12.5m	1.13E8	2.32	4.19E9	6.28E-4
Te^{133m}	55.4m	2.55E7	3.11	9.45E8	8.42E-4
Te^{134}	41.8m	3.36E7	1.77	1.24E9	4.79E-4
Te^{135}	19s	4.40E9	0.195	1.63E11	5.28E-5
Th^{227}	18.72d	3.07E4	0.39	1.14E6	1.05E-4
Th^{228}	1.913y	820.0	0.014	3.03E4	3.78E-6
Th^{229}	7300y	0.214	0.145	7.92	3.92E-5
Th^{230}	7.54E4y	0.021	2.07E-3	0.762	5.60E-7
Th^{231}	25.55h	5.32E5	0.0480	1.97E7	1.30E-5
Th^{232}	1.40E10y	1.10E-7	7.62E-4	4.07E-6	2.06E-7
Th^{234}	24.10d	2.32E4	0.0356	8.58E5	9.62E-6
Tl^{201}	72.912h	2.14E5	0.122	7.91E6	3.30E-5
Tl^{204}	3.78y	464.0	0.0124	1.72E4	3.35E-6
Tl^{206}	4.20m	2.17E8	N/A	8.03E9	N/A
Tl^{208}	3.053m	2.96E8	18.89	1.10E10	5.11E-3
Tl^{209}	2.161m	4.16E8	4.17	1.54E10	1.13E-3
Tl^{210}	1.30m	6.88E8	7.82	2.55E10	2.11E-3
U^{230}	20.8d	2.73E4	2.00E-3	1.01E6	5.41E-7
U^{232}	70y	22.0	0.0731	814	1.98E-5
U^{233}	1.592E5y	9.65E-3	N/A	0.357	N/A
U^{234}	2.46E5y	6.22E-3	N/A	0.230	N/A
U^{235}	7.04E8y	2.16E-6	0.755	7.99E-5	2.04E-4
U^{235m}	25.0m	3.20E7	N/A	1.18E9	N/A
U^{236}	2.342E7y	6.47E-5	1.10E-4	2.40E-3	2.98E-8

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
U^{237}	6.75d	8.16E4	0.561	3.02E6	1.52E-4
U^{238}	4.47E9y	3.36E-7	N/A	1.24E-5	N/A
V^{48}	15.98d	1.70E5	15.6	6.29E6	4.22E-3
V^{49}	330d	8.09E3	N/A	2.99E5	N/A
W^{187}	23.72d	7.07E5	2.82	2.62E7	7.63E-4
Xe^{131m}	11.84d	8.69E4	0.5664	3.22E6	1.53E-4
Xe^{133}	5.243d	1.87E5	0.6248	6.93E6	1.69E-4
Xe^{133m}	2.19d	4.49E5	0.7027	1.66E7	1.90E-4
Xe^{135}	9.14h	2.54E6	1.6178	9.41E7	4.38E-4
Xe^{135m}	15.29m	9.12E7	2.9736	3.37E9	8.05E-4
Xe^{138}	14.08m	9.69E7	1.36	3.58E9	3.68E-4
Y^{88}	106.65d	1.39E4	14.83	5.15E5	4.01E-3
Y^{90}	64.1h	5.43E5	N/A	2.01E7	N/A
Y^{92}	3.54h	9.63E6	0.126	3.56E8	3.41E-5
Y^{93}	10.18h	3.31E6	0.11	1.23E8	2.98E-5
Yb^{169}	32.026d	2.41E4	1.219	8.93E5	3.30E-4
Zn^{65}	243.8d	8.24E3	3.575	3.05E5	9.68E-4
Zr^{89}	78.41h	4.50E5	5.65	1.66E7	1.53E-3
Zr^{93}	1.53E6y	2.52E-3	N/A	0.0931	N/A
Zr^{95}	64.02d	2.15E4	5.16	7.96E5	1.39E-3
Zr^{97}	16.91h	1.91E6	0.236	7.08E7	6.39E-5

The exposure rate from these radionuclides do not include their short-lived progeny. Spontaneous fission, isotopic mixtures, impurities in mixtures, and shielding (including self shielding) should also be taken into account when estimating exposure rate.

			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
U^{237}	6.75d	8.16E4	0.561	3.02E6	1.52E-4
U^{238}	4.47E9y	3.36E-7	N/A	1.24E-5	N/A
V^{48}	15.98d	1.70E5	15.6	6.29E6	4.22E-3
V^{49}	330d	8.09E3	N/A	2.99E5	N/A
W^{187}	23.72d	7.07E5	2.82	2.62E7	7.63E-4
Xe^{131m}	11.84d	8.69E4	0.5664	3.22E6	1.53E-4
Xe^{133}	5.243d	1.87E5	0.6248	6.93E6	1.69E-4
Xe^{133m}	2.19d	4.49E5	0.7027	1.66E7	1.90E-4
Xe^{135}	9.14h	2.54E6	1.6178	9.41E7	4.38E-4
Xe^{135m}	15.29m	9.12E7	2.9736	3.37E9	8.05E-4
Xe^{138}	14.08m	9.69E7	1.36	3.58E9	3.68E-4
Y^{88}	106.65d	1.39E4	14.83	5.15E5	4.01E-3
Y^{90}	64.1h	5.43E5	N/A	2.01E7	N/A
Y^{92}	3.54h	9.63E6	0.126	3.56E8	3.41E-5
Y^{93}	10.18h	3.31E6	0.11	1.23E8	2.98E-5
Yb^{169}	32.026d	2.41E4	1.219	8.93E5	3.30E-4
Zn^{65}	243.8d	8.24E3	3.575	3.05E5	9.68E-4
Zr^{89}	78.41h	4.50E5	5.65	1.66E7	1.53E-3
Zr^{93}	1.53E6y	2.52E-3	N/A	0.0931	N/A
Zr^{95}	64.02d	2.15E4	5.16	7.96E5	1.39E-3
Zr^{97}	16.91h	1.91E6	0.236	7.08E7	6.39E-5

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			Rem/hr / Ci		Sv/hr / GBq
	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
U^{237}	6.75d	8.16E4	0.561	3.02E6	1.52E-4
U^{238}	4.47E9y	3.36E-7	N/A	1.24E-5	N/A
V^{48}	15.98d	1.70E5	15.6	6.29E6	4.22E-3
V^{49}	330d	8.09E3	N/A	2.99E5	N/A
W^{187}	23.72d	7.07E5	2.82	2.62E7	7.63E-4
Xe^{131m}	11.84d	8.69E4	0.5664	3.22E6	1.53E-4
Xe^{133}	5.243d	1.87E5	0.6248	6.93E6	1.69E-4
Xe^{133m}	2.19d	4.49E5	0.7027	1.66E7	1.90E-4
Xe^{135}	9.14h	2.54E6	1.6178	9.41E7	4.38E-4
Xe^{135m}	15.29m	9.12E7	2.9736	3.37E9	8.05E-4
Xe^{138}	14.08m	9.69E7	1.36	3.58E9	3.68E-4
Y^{88}	106.65d	1.39E4	14.83	5.15E5	4.01E-3
Y^{90}	64.1h	5.43E5	N/A	2.01E7	N/A
Y^{92}	3.54h	9.63E6	0.126	3.56E8	3.41E-5
Y^{93}	10.18h	3.31E6	0.11	1.23E8	2.98E-5
Yb^{169}	32.026d	2.41E4	1.219	8.93E5	3.30E-4
Zn^{65}	243.8d	8.24E3	3.575	3.05E5	9.68E-4
Zr^{89}	78.41h	4.50E5	5.65	1.66E7	1.53E-3
Zr^{93}	1.53E6y	2.52E-3	N/A	0.0931	N/A
Zr^{95}	64.02d	2.15E4	5.16	7.96E5	1.39E-3
Zr^{97}	16.91h	1.91E6	0.236	7.08E7	6.39E-5

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	Half-Life	Ci/g	@ 30 cm	GBq/g	@ 30cm
U^{237}	6.75d	8.16E4	0.561	3.02E6	1.52E-4
U^{238}	4.47E9y	3.36E-7	N/A	1.24E-5	N/A
V^{48}	15.98d	1.70E5	15.6	6.29E6	4.22E-3
V^{49}	330d	8.09E3	N/A	2.99E5	N/A
W^{187}	23.72d	7.07E5	2.82	2.62E7	7.63E-4
Xe^{131m}	11.84d	8.69E4	0.5664	3.22E6	1.53E-4
Xe^{133}	5.243d	1.87E5	0.6248	6.93E6	1.69E-4
Xe^{133m}	2.19d	4.49E5	0.7027	1.66E7	1.90E-4
Xe^{135}	9.14h	2.54E6	1.6178	9.41E7	4.38E-4
Xe^{135m}	15.29m	9.12E7	2.9736	3.37E9	8.05E-4
Xe^{138}	14.08m	9.69E7	1.36	3.58E9	3.68E-4
Y^{88}	106.65d	1.39E4	14.83	5.15E5	4.01E-3
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Y^{93}	10.18h	3.31E6	0.11	1.23E8	2.98E-5
Yb^{169}	32.026d	2.41E4	1.219	8.93E5	3.30E-4
Zn^{65}	243.8d	8.24E3	3.575	3.05E5	9.68E-4
Zr^{89}	78.41h	4.50E5	5.65	1.66E7	1.53E-3
Zr^{93}	1.53E6y	2.52E-3	N/A	0.0931	N/A
Zr^{95}	64.02d	2.15E4	5.16	7.96E5	1.39E-3
Zr^{97}	16.91h	1.91E6	0.236	7.08E7	6.39E-5

The exposure rate from these radionuclides do not include their short-lived progeny. Spontaneous fission, isotopic mixtures, impurities in mixtures, and shielding (including self shielding) should also be taken into account when estimating exposure rate.

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
H^{3}	2E-5	2E-5	7E5
Be^{7}	9E-6	1E-5	4E5
C^{14}	1E-6	9E-7	3E4
F^{18}	3E-5	3E-6	1E5
Na^{22}	3E-7	2E-7	1E4
Na^{24}	2E-6	4E-7	1E4
Al^{26}	3E-8	4E-8	1E3
P^{32}	2E-7	1E-7	7E3
Cl^{36}	1E-7	1E-7	4E3
K^{40}	2E-7	1E-7	6E3
K^{42}	2E-6	2E-6	1E5
K^{43}	4E-6	9E-7	3E4
Sc^{46}	1E-7	1E-7	4E3
Sc^{47}	1E-6	7E-7	2E4
Sc^{48}	6E-7	2E-7	1E4
V^{48}	3E-7	2E-7	7E3
Cr^{51}	8E-6	1E-5	5E5
Mn^{52}	4E-7	2E-7	8E3
Mn^{54}	3E-7	4E-7	1E4
Fe^{55}	8E-7	6E-7	2E4
Mn^{56}	6E-6	2E-6	8E4
Co^{56}	8E-8	1E-7	4E3
Co^{57}	3E-7	9E-7	3E4
Ni^{57}	1E-6	7E-7	2E4

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
Co^{58}	3E-7	3E-7	1E4
Ni^{59}	8E-7	6E-7	2E4
Fe^{59}	1E-7	1E-7	6E3
Co^{60}	1E-8	3E-8	1E3
Zn^{62}	1E-6	8E-7	3E4
Zn^{65}	1E-7	2E-7	7E3
Ge^{68}	4E-8	1E-8	2E3
Se^{75}	3E-7	3E-7	1E4
Rb^{88}	3E-5	1E-5	5E5
Rb^{89}	6E-5	1E-5	3E5
Sr^{89}	6E-8	1E-7	3E3
Sr^{90}	2E-9	7E-9	2E2
Y^{90}	3E-7	3E-7	1E4
Nb^{94}	6E-9	2E-8	8E2
Zr^{95}	5E-8	9E-8	3E3
Tc^{99}	3E-7	1E-7	6E3
Mo^{99}	6E-7	5E-7	1E4
Tc^{99m}	6E-5	1E-5	4E5
Ru^{106}	5E-9	1E-8	1E3
I^{125}	3E-8	2E-8	1E3
I^{126}	1E-8	1E-8	4E2
I^{129}	4E-9	2E-9	1E2
I^{131}	2E-8	1E-8	5E2
I^{133}	1E-7	7E-8	5E3

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
H^{3}	2E-5	2E-5	7E5
Be^{7}	9E-6	1E-5	4E5
C^{14}	1E-6	9E-7	3E4
F^{18}	3E-5	3E-6	1E5
Na^{22}	3E-7	2E-7	1E4
Na^{24}	2E-6	4E-7	1E4
Al^{26}	3E-8	4E-8	1E3
P^{32}	2E-7	1E-7	7E3
Cl^{36}	1E-7	1E-7	4E3
K^{40}	2E-7	1E-7	6E3
K^{42}	2E-6	2E-6	1E5
K^{43}	4E-6	9E-7	3E4
Sc^{46}	1E-7	1E-7	4E3
Sc^{47}	1E-6	7E-7	2E4
Sc^{48}	6E-7	2E-7	1E4
V^{48}	3E-7	2E-7	7E3
Cr^{51}	8E-6	1E-5	5E5
Mn^{52}	4E-7	2E-7	8E3
Mn^{54}	3E-7	4E-7	1E4
Fe^{55}	8E-7	6E-7	2E4
Mn^{56}	6E-6	2E-6	8E4
Co^{56}	8E-8	1E-7	4E3
Co^{57}	3E-7	9E-7	3E4
Ni^{57}	1E-6	7E-7	2E4

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
Co^{58}	3E-7	3E-7	1E4
Ni^{59}	8E-7	6E-7	2E4
Fe^{59}	1E-7	1E-7	6E3
Co^{60}	1E-8	3E-8	1E3
Zn^{62}	1E-6	8E-7	3E4
Zn^{65}	1E-7	2E-7	7E3
Ge^{68}	4E-8	1E-8	2E3
Se^{75}	3E-7	3E-7	1E4
Rb^{88}	3E-5	1E-5	5E5
Rb^{89}	6E-5	1E-5	3E5
Sr^{89}	6E-8	1E-7	3E3
Sr^{90}	2E-9	7E-9	2E2
Y^{90}	3E-7	3E-7	1E4
Nb^{94}	6E-9	2E-8	8E2
Zr^{95}	5E-8	9E-8	3E3
Tc^{99}	3E-7	1E-7	6E3
Mo^{99}	6E-7	5E-7	1E4
Tc^{99m}	6E-5	1E-5	4E5
Ru^{106}	5E-9	1E-8	1E3
I^{125}	3E-8	2E-8	1E3
I^{126}	1E-8	1E-8	4E2
I^{129}	4E-9	2E-9	1E2
I^{131}	2E-8	1E-8	5E2
I^{133}	1E-7	7E-8	5E3

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
H^{3}	2E-5	2E-5	7E5
Be^{7}	9E-6	1E-5	4E5
C^{14}	1E-6	9E-7	3E4
F^{18}	3E-5	3E-6	1E5
Na^{22}	3E-7	2E-7	1E4
Na^{24}	2E-6	4E-7	1E4
Al^{26}	3E-8	4E-8	1E3
P^{32}	2E-7	1E-7	7E3
Cl^{36}	1E-7	1E-7	4E3
K^{40}	2E-7	1E-7	6E3
K^{42}	2E-6	2E-6	1E5
K^{43}	4E-6	9E-7	3E4
Sc^{46}	1E-7	1E-7	4E3
Sc^{47}	1E-6	7E-7	2E4
Sc^{48}	6E-7	2E-7	1E4
V^{48}	3E-7	2E-7	7E3
Cr^{51}	8E-6	1E-5	5E5
Mn^{52}	4E-7	2E-7	8E3
Mn^{54}	3E-7	4E-7	1E4
Fe^{55}	8E-7	6E-7	2E4
Mn^{56}	6E-6	2E-6	8E4
Co^{56}	8E-8	1E-7	4E3
Co^{57}	3E-7	9E-7	3E4
Ni^{57}	1E-6	7E-7	2E4

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
Co^{58}	3E-7	3E-7	1E4
Ni^{59}	8E-7	6E-7	2E4
Fe^{59}	1E-7	1E-7	6E3
Co^{60}	1E-8	3E-8	1E3
Zn^{62}	1E-6	8E-7	3E4
Zn^{65}	1E-7	2E-7	7E3
Ge^{68}	4E-8	1E-8	2E3
Se^{75}	3E-7	3E-7	1E4
Rb^{88}	3E-5	1E-5	5E5
Rb^{89}	6E-5	1E-5	3E5
Sr^{89}	6E-8	1E-7	3E3
Sr^{90}	2E-9	7E-9	2E2
Y^{90}	3E-7	3E-7	1E4
Nb^{94}	6E-9	2E-8	8E2
Zr^{95}	5E-8	9E-8	3E3
Tc^{99}	3E-7	1E-7	6E3
Mo^{99}	6E-7	5E-7	1E4
Tc^{99m}	6E-5	1E-5	4E5
Ru^{106}	5E-9	1E-8	1E3
I^{125}	3E-8	2E-8	1E3
I^{126}	1E-8	1E-8	4E2
I^{129}	4E-9	2E-9	1E2
I^{131}	2E-8	1E-8	5E2
I^{133}	1E-7	7E-8	5E3

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
H^{3}	2E-5	2E-5	7E5
Be^{7}	9E-6	1E-5	4E5
C^{14}	1E-6	9E-7	3E4
F^{18}	3E-5	3E-6	1E5
Na^{22}	3E-7	2E-7	1E4
Na^{24}	2E-6	4E-7	1E4
Al^{26}	3E-8	4E-8	1E3
P^{32}	2E-7	1E-7	7E3
Cl^{36}	1E-7	1E-7	4E3
K^{40}	2E-7	1E-7	6E3
K^{42}	2E-6	2E-6	1E5
K^{43}	4E-6	9E-7	3E4
Sc^{46}	1E-7	1E-7	4E3
Sc^{47}	1E-6	7E-7	2E4
Sc^{48}	6E-7	2E-7	1E4
V^{48}	3E-7	2E-7	7E3
Cr^{51}	8E-6	1E-5	5E5
Mn^{52}	4E-7	2E-7	8E3
Mn^{54}	3E-7	4E-7	1E4
Fe^{55}	8E-7	6E-7	2E4
Mn^{56}	6E-6	2E-6	8E4
Co^{56}	8E-8	1E-7	4E3
Co^{57}	3E-7	9E-7	3E4
Ni^{57}	1E-6	7E-7	2E4

	DAC Factors		
	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
Co^{58}	3E-7	3E-7	1E4
Ni^{59}	8E-7	6E-7	2E4
Fe^{59}	1E-7	1E-7	6E3
Co^{60}	1E-8	3E-8	1E3
Zn^{62}	1E-6	8E-7	3E4
Zn^{65}	1E-7	2E-7	7E3
Ge^{68}	4E-8	1E-8	2E3
Se^{75}	3E-7	3E-7	1E4
Rb^{88}	3E-5	1E-5	5E5
Rb^{89}	6E-5	1E-5	3E5
Sr^{89}	6E-8	1E-7	3E3
Sr^{90}	2E-9	7E-9	2E2
Y^{90}	3E-7	3E-7	1E4
Nb^{94}	6E-9	2E-8	8E2
Zr^{95}	5E-8	9E-8	3E3
Tc^{99}	3E-7	1E-7	6E3
Mo^{99}	6E-7	5E-7	1E4
Tc^{99m}	6E-5	1E-5	4E5
Ru^{106}	5E-9	1E-8	1E3
I^{125}	3E-8	2E-8	1E3
I^{126}	1E-8	1E-8	4E2
I^{129}	4E-9	2E-9	1E2
I^{131}	2E-8	1E-8	5E2
I^{133}	1E-7	7E-8	5E3

DAC Factors

	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
I^{134}	2E-5	3E-6	1E5
I^{135}	7E-7	3E-7	1E4
Cs^{137}	6E-8	8E-8	3E3
Ba^{140}	6E-7	3E-7	1E4
La^{140}	5E-7	3E-7	1E4
Gd^{148}	3E-12	5E-12	0.2
Ir^{192}	9E-8	1E-7	4E3
Tl^{204}	9E-7	9E-7	3E4
Pb^{210}	1E-10	1E-10	5
Po^{210}	3E-10	2E-10	9
Bi^{210}	1E-8	9E-9	3E2
B^{i212}	1E-7	8E-9	3E2
Pb^{212}	1E-8	5E-9	2E2
Bi^{214}	3E-7	1E-8	4E2
Pb^{214}	3E-7	4E-8	1E3
Rn^{220}	9E-9	1E-8	6E2
Rn^{222}	3E-8	8E-8	3E3
Ra^{223}	3E-10	9E-11	3
Ra^{224}	7E-10	2E-10	8
Ra^{225}	3E-10	1E-10	4
Ra^{226}	3E-10	2E-10	9
Ac^{227}	2E-13	2E-13	1E-2
Th^{227}	1E-10	7E-11	2
Ac^{228}	4E-9	6E-9	2E2

DAC Factors

	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
Ra^{228}	5E-10	1E-10	5
Th^{228}	4E-12	2E-11	0.7
Th^{229}	4E-13	2E-12	7E-2
Th^{230}	3E-12	3E-12	0.1
U^{230}	1E-10	4E-11	1
Pa^{231}	6E-13	1E-12	4E-2
Th^{232}	5E-13	3E-12	0.1
U^{232}	3E-12	4E-11	0.7
U^{233}	2E-11	7E-11	2
U^{234}	2E-11	7E-11	2
Pa^{234}	3E-6	7E-7	2E4
Th^{234}	6E-8	9E-8	3E3
U^{235}	2E-11	8E-11	3
Pu^{236}	8E-12	1E-11	0.6
Np^{237}	2E-12	8E-12	0.3
U^{238}	2E-11	8E-11	3
Pu^{238}	3E-12	6E-12	0.2
Pu^{239}	3E-12	5E-12	0.2
Np^{239}	9E-7	5E-7	4E3
Pu^{240}	3E-12	5E-12	0.2
Pu^{241}	1E-10	2E-10	10
Am^{241}	3E-12	5E-12	0.1
Pu^{242}	3E-12	5E-12	0.2
Cm^{242}	1E-10	1E-10	5

DAC Factors

	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
I^{134}	2E-5	3E-6	1E5
I^{135}	7E-7	3E-7	1E4
Cs^{137}	6E-8	8E-8	3E3
Ba^{140}	6E-7	3E-7	1E4
La^{140}	5E-7	3E-7	1E4
Gd^{148}	3E-12	5E-12	0.2
Ir^{192}	9E-8	1E-7	4E3
Tl^{204}	9E-7	9E-7	3E4
Pb^{210}	1E-10	1E-10	5
Po^{210}	3E-10	2E-10	9
Bi^{210}	1E-8	9E-9	3E2
B^{i212}	1E-7	8E-9	3E2
Pb^{212}	1E-8	5E-9	2E2
Bi^{214}	3E-7	1E-8	4E2
Pb^{214}	3E-7	4E-8	1E3
Rn^{220}	9E-9	1E-8	6E2
Rn^{222}	3E-8	8E-8	3E3
Ra^{223}	3E-10	9E-11	3
Ra^{224}	7E-10	2E-10	8
Ra^{225}	3E-10	1E-10	4
Ra^{226}	3E-10	2E-10	9
Ac^{227}	2E-13	2E-13	1E-2
Th^{227}	1E-10	7E-11	2
Ac^{228}	4E-9	6E-9	2E2

DAC Factors

	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
Ra^{228}	5E-10	1E-10	5
Th^{228}	4E-12	2E-11	0.7
Th^{229}	4E-13	2E-12	7E-2
Th^{230}	3E-12	3E-12	0.1
U^{230}	1E-10	4E-11	1
Pa^{231}	6E-13	1E-12	4E-2
Th^{232}	5E-13	3E-12	0.1
U^{232}	3E-12	4E-11	0.7
U^{233}	2E-11	7E-11	2
U^{234}	2E-11	7E-11	2
Pa^{234}	3E-6	7E-7	2E4
Th^{234}	6E-8	9E-8	3E3
U^{235}	2E-11	8E-11	3
Pu^{236}	8E-12	1E-11	0.6
Np^{237}	2E-12	8E-12	0.3
U^{238}	2E-11	8E-11	3
Pu^{238}	3E-12	6E-12	0.2
Pu^{239}	3E-12	5E-12	0.2
Np^{239}	9E-7	5E-7	4E3
Pu^{240}	3E-12	5E-12	0.2
Pu^{241}	1E-10	2E-10	10
Am^{241}	3E-12	5E-12	0.1
Pu^{242}	3E-12	5E-12	0.2
Cm^{242}	1E-10	1E-10	5

DAC Factors

	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
I^{134}	2E-5	3E-6	1E5
I^{135}	7E-7	3E-7	1E4
Cs^{137}	6E-8	8E-8	3E3
Ba^{140}	6E-7	3E-7	1E4
La^{140}	5E-7	3E-7	1E4
Gd^{148}	3E-12	5E-12	0.2
Ir^{192}	9E-8	1E-7	4E3
Tl^{204}	9E-7	9E-7	3E4
Pb^{210}	1E-10	1E-10	5
Po^{210}	3E-10	2E-10	9
Bi^{210}	1E-8	9E-9	3E2
B^{i212}	1E-7	8E-9	3E2
Pb^{212}	1E-8	5E-9	2E2
Bi^{214}	3E-7	1E-8	4E2
Pb^{214}	3E-7	4E-8	1E3
Rn^{220}	9E-9	1E-8	6E2
Rn^{222}	3E-8	8E-8	3E3
Ra^{223}	3E-10	9E-11	3
Ra^{224}	7E-10	2E-10	8
Ra^{225}	3E-10	1E-10	4
Ra^{226}	3E-10	2E-10	9
Ac^{227}	2E-13	2E-13	1E-2
Th^{227}	1E-10	7E-11	2
Ac^{228}	4E-9	6E-9	2E2

DAC Factors

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Ra^{228}	5E-10	1E-10	5
Th^{228}	4E-12	2E-11	0.7
Th^{229}	4E-13	2E-12	7E-2
Th^{230}	3E-12	3E-12	0.1
U^{230}	1E-10	4E-11	1
Pa^{231}	6E-13	1E-12	4E-2
Th^{232}	5E-13	3E-12	0.1
U^{232}	3E-12	4E-11	0.7
U^{233}	2E-11	7E-11	2
U^{234}	2E-11	7E-11	2
Pa^{234}	3E-6	7E-7	2E4
Th^{234}	6E-8	9E-8	3E3
U^{235}	2E-11	8E-11	3
Pu^{236}	8E-12	1E-11	0.6
Np^{237}	2E-12	8E-12	0.3
U^{238}	2E-11	8E-11	3
Pu^{238}	3E-12	6E-12	0.2
Pu^{239}	3E-12	5E-12	0.2
Np^{239}	9E-7	5E-7	4E3
Pu^{240}	3E-12	5E-12	0.2
Pu^{241}	1E-10	2E-10	10
Am^{241}	3E-12	5E-12	0.1
Pu^{242}	3E-12	5E-12	0.2
Cm^{242}	1E-10	1E-10	5

DAC Factors

	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^3
I^{134}	2E-5	3E-6	1E5
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Ba^{140}	6E-7	3E-7	1E4
La^{140}	5E-7	3E-7	1E4
Gd^{148}	3E-12	5E-12	0.2
Ir^{192}	9E-8	1E-7	4E3
Tl^{204}	9E-7	9E-7	3E4
Pb^{210}	1E-10	1E-10	5
Po^{210}	3E-10	2E-10	9
Bi^{210}	1E-8	9E-9	3E2
B^{i212}	1E-7	8E-9	3E2
Pb^{212}	1E-8	5E-9	2E2
Bi^{214}	3E-7	1E-8	4E2
Pb^{214}	3E-7	4E-8	1E3
Rn^{220}	9E-9	1E-8	6E2
Rn^{222}	3E-8	8E-8	3E3
Ra^{223}	3E-10	9E-11	3
Ra^{224}	7E-10	2E-10	8
Ra^{225}	3E-10	1E-10	4
Ra^{226}	3E-10	2E-10	9
Ac^{227}	2E-13	2E-13	1E-2
Th^{227}	1E-10	7E-11	2
Ac^{228}	4E-9	6E-9	2E2

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U^{230}	1E-10	4E-11	1
Pa^{231}	6E-13	1E-12	4E-2
Th^{232}	5E-13	3E-12	0.1
U^{232}	3E-12	4E-11	0.7
U^{233}	2E-11	7E-11	2
U^{234}	2E-11	7E-11	2
Pa^{234}	3E-6	7E-7	2E4
Th^{234}	6E-8	9E-8	3E3
U^{235}	2E-11	8E-11	3
Pu^{236}	8E-12	1E-11	0.6
Np^{237}	2E-12	8E-12	0.3
U^{238}	2E-11	8E-11	3
Pu^{238}	3E-12	6E-12	0.2
Pu^{239}	3E-12	5E-12	0.2
Np^{239}	9E-7	5E-7	4E3
Pu^{240}	3E-12	5E-12	0.2
Pu^{241}	1E-10	2E-10	10
Am^{241}	3E-12	5E-12	0.1
Pu^{242}	3E-12	5E-12	0.2
Cm^{242}	1E-10	1E-10	5

DAC Factors

	10CFR20	10CFR835	
	uCi/mL	uCi/mL	Bq/M^{3}
Am^{243}	3E-12	5E-12	0.1
Cm^{244}	5E-12	9E-12	0.3
Cf^{249}	2E-12	3E-12	0.1
Bk^{249}	7E-10	1E-9	50
Cf^{252}	8E-12	1E-11	0.6
Es^{253}	6E-10	2E-10	9

The values stated for Rn^{220} and Rn^{222} include their progeny; Tl^{206}, Tl^{208}, Tl^{210}, Po^{212}, Po^{214}, Po^{216}, Po^{218}, and At^{218}.

These inhalation values are taken from 10CFR20 and 10CFR835 and are the most restrictive values for the selected radioisotopes. A more complete listing of DAC Factors and ALIs for both Inhalation and Ingestion can be found in the handbook of Air Monitoring.

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Definitions

10CFR20 § 20.1003 Definitions.
Absorbed dose means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy). Accelerator-produced radioactive material means any material made radioactive by a particle accelerator.

Activity is the rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci) and the Becquerel (Bq).

Airborne radioactive material means radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne radioactivity area means a room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations—
(1) In excess of the derived air concentrations (DACs) specified in appendix B, to §§ 20.1001–20.2401, or
(2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

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(2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

Air-purifying respirator means a respirator with an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air-purifying element.

ALARA (acronym for ‘‘as low as is reasonably achievable’’) means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Annual limit on intake (ALI) means the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue (ALI values for intake by ingestion and by inhalation of selected radionuclides are given in table 1, columns 1 and 2, of appendix B to §§ 20.1001–20.2401).

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Assigned protection factor (APF) means the expected workplace level of respiratory protection that would be provided by a properly functioning respirator or a class of respirators to properly fitted and trained users. Operationally, the inhaled concentration can be estimated by dividing the ambient airborne concentration by the APF.

Atmosphere-supplying respirator means a respirator that supplies the respirator user with breathing air from a source independent of the ambient atmosphere, and includes supplied-air respirators (SARs) and self-contained breathing apparatus (SCBA) units.

Background radiation means radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the licensee. ‘‘Background radiation’’ does not include radiation from source, byproduct, or special nuclear materials regulated by the Commission.

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Bioassay (radiobioassay) means the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Byproduct material means—
(1) Any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or using special nuclear material;
(2) The tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by these solution extraction operations do not constitute ‘‘byproduct material’’ within this definition;
(3)(i) Any discrete source of radium-226 that is produced, extracted, or converted after etraction, before, on, or after August 8, 2005, for use for a commercial, medical, or research activity;
or
(ii) Any material that—
(A) Has been made radioactive by use of a particle accelerator; and

Bioassay (radiobioassay) means the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Byproduct material means—
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(ii) Any material that—
(A) Has been made radioactive by use of a particle accelerator; and

(B) Is produced, extracted, or converted after extraction, before, on, or after August 8, 2005, for use for a commercial, medical, or research activity;
and
(4) Any discrete source of naturally occurring radioactive material, other than source material, that—
(i) The Commission, in consultation with the Administrator of the Environmental Protection Agency, the Secretary of Energy, the Secretary of Homeland Security, and the head of any other appropriate Federal agency, determines would pose a threat similar to the threat posed by a discrete source of radium-226 to the public health and safety or the common defense and security;
and
(ii) Before, on, or after August 8, 2005, is extracted or converted after extraction for use in a commercial, medical, or research activity.

Class (or lung class or inhalation class) means a classification scheme for inhaled material according to its rate of clearance from the pulmonary region of the lung. Materials are classified as D, W, or Y, which applies to a range of clearance half-times: for Class D (Days) of less than 10 days, for Class W (Weeks) from 10 to 100 days, and for Class Y (Years) of greater than 100 days.

(B) Is produced, extracted, or converted after extraction, before, on, or after August 8, 2005, for use for a commercial, medical, or research activity;
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(i) The Commission, in consultation with the Administrator of the Environmental Protection Agency, the Secretary of Energy, the Secretary of Homeland Security, and the head of any other appropriate Federal agency, determines would pose a threat similar to the threat posed by a discrete source of radium-226 to the public health and safety or the common defense and security;
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Collective dose is the sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation.

Committed dose equivalent (HT,50) means the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed effective dose equivalent (HE,50) is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose (HE,50 = S wT HT,50).

Constraint (dose constraint) means a value above which specified licensee actions are required.

Controlled area means an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

Critical Group means the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.

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Declared pregnant woman means a woman who has voluntarily informed the licensee, in writing, of her pregnancy and the estimated date of conception. The declaration remains in effect until the declared pregnant woman withdraws the declaration in writing or is no longer pregnant.

Decommission means to remove a facility or site safely from service and reduce residual radioactivity to a level that permits—
(1) Release of the property for unrestricted use and termination of the license;
or
(2) Release of the property under restricted conditions and the termination of the license.

Deep-dose equivalent (Hd), which applies to external whole-body exposure, is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm2).

Demand respirator means an atmosphere- supplying respirator that admits breathing air to the facepiece only when a negative pressure is created inside the facepiece by inhalation.

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Derived air concentration (DAC) means the concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI. DAC values are given in table 1, column 3, of appendix B to §§ 20.1001– 20.2401.

Derived air concentration-hour (DAChour) is the product of the concentration of radioactive material in air (expressed as a fraction or multiple of the derived air concentration for each radionuclide) and the time of exposure to that radionuclide, in hours. A licensee may take 2,000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 5 rems (0.05 Sv).

Discrete source means a radionuclide that has been processed so that its concentration within a material has been purposely increased for use for commercial, medical, or research activities.

Disposable respirator means a respirator for which maintenance is not intended and that is designed to be discarded after excessive breathing resistance, sorbent exhaustion, physical damage, or end-of-service-life renders it unsuitable for use. Examples of this type of respirator are a disposable halfmask respirator or a

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disposable escape-only self-contained breathing apparatus (SCBA).

Distinguishable from background means that the detectable concentration of a radionuclide is statistically different from the background concentration of that radionuclide in the vicinity of the site or, in the case of structures, in similar materials using adequate measurement technology, survey, and statistical techniques.

Dose or radiation dose is a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose equivalent (HT) means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).

Effective dose equivalent (HE) is the sum of the products of the dose equivalent to the organ or tissue (HT) and the weighting factors (wT) applicable to each of the body organs or tissues that are irradiated (HE = S wT HT).

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Embryo/fetus means the developing human organism from conception until the time of birth.

Entrance or access point means any location through which an individual could gain access to radiation areas or to radioactive materials. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.

Exposure means being exposed to ionizing radiation or to radioactive material.

External dose means that portion of the dose equivalent received from radiation sources outside the body.

Extremity means hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Filtering facepiece (dust mask) means a negative pressure particulate respirator with a filter as an integral part of the facepiece or with the entire facepiece composed of the filtering medium, not equipped with elastomeric sealing surfaces and adjustable straps.

Fit factor means a quantitative estimate of the fit of a particular respirator to a specific individual, and typically estimates the ratio of the concentration of a substance in ambient air to its concentration inside the respirator when worn.

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Fit test means the use of a protocol to qualitatively or quantitatively evaluate the fit of a respirator on an individual.

Generally applicable environmental radiation standards means standards issued by the Environmental Protection Agency (EPA) under the authority of the Atomic Energy Act of 1954, as amended, that impose limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.

Gray [See § 20.1004].

Helmet means a rigid respiratory inlet covering that also provides head protection against impact and penetration.

High radiation area means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or 30 centimeters from any surface that the radiation penetrates.

Fit test means the use of a protocol to qualitatively or quantitatively evaluate the fit of a respirator on an individual.

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Hood means a respiratory inlet covering that completely covers the head and neck and may also cover portions of the shoulders and torso.

Individual monitoring means—
(1) The assessment of dose equivalent by the use of devices designed to be worn by an individual;
(2) The assessment of committed effective dose equivalent by bioassay (see Bioassay) or by determination of the time-weighted air concentrations to which an individual has been exposed, i.e., DAC-hours; or
(3) The assessment of dose equivalent by the use of survey data.

Individual monitoring devices (individual monitoring equipment) means devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescence dosimeters (TLDs), pocket ionization chambers, and personal (‘‘lapel’’) air sampling devices.

Internal dose means that portion of the dose equivalent received from radioactive material taken into the body.

Lens dose equivalent (LDE) applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm^2).

Hood means a respiratory inlet covering that completely covers the head and neck and may also cover portions of the shoulders and torso.

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(3) The assessment of dose equivalent by the use of survey data.

Individual monitoring devices (individual monitoring equipment) means devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescence dosimeters (TLDs), pocket ionization chambers, and personal (‘‘lapel’’) air sampling devices.

Internal dose means that portion of the dose equivalent received from radioactive material taken into the body.

Lens dose equivalent (LDE) applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm^2).

License means a license issued under the regulations in parts 30 through 36, 39, 40, 50, 60, 61, 63, 70, or 72 of this chapter.

Licensed material means source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Commission.

Licensee means the holder of a license.

Limits (dose limits) means the permissible upper bounds of radiation doses.

Loose-fitting facepiece means a respiratory inlet covering that is designed to form a partial seal with the face.

Lost or missing licensed material means licensed material whose location is unknown. It includes material that has been shipped but has not reached its destination and whose location cannot be readily traced in the transportation system.

Member of the public means any individual except when that individual is receiving an occupational dose.

License means a license issued under the regulations in parts 30 through 36, 39, 40, 50, 60, 61, 63, 70, or 72 of this chapter.

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Member of the public means any individual except when that individual is receiving an occupational dose.

Monitoring (radiation monitoring, radiation protection monitoring) means the measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Nationally tracked source is a sealed source containing a quantity equal to or greater than Category 1 or Category 2 levels of any radioactive material listed in Appendix E of this part. In this context a sealed source is defined as radioactive material that is sealed in a capsule or closely bonded, in a solid form and which is not exempt from regulatory control. It does not mean material encapsulated solely for disposal, or nuclear material contained in any fuel assembly, subassembly, fuel rod, or fuel pellet. Category 1 nationally tracked sources are those containing radioactive material at a quantity equal to or greater than the Category 1 threshold. Category 2 nationally tracked sources are those containing radioactive material at a quantity equal to or greater than the Category 2 threshold but less than the Category 1 threshold.

Negative pressure respirator (tight fitting) means a respirator in which the air pressure inside the facepiece is negative during inhalation with respect to the ambient air pressure outside the respirator.

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Negative pressure respirator (tight fitting) means a respirator in which the air pressure inside the facepiece is negative during inhalation with respect to the ambient air pressure outside the respirator.

Nonstochastic effect means health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect).

NRC means the Nuclear Regulatory Commission or its duly authorized representatives.

Occupational dose means the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation or to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include doses received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released under § 35.75, from voluntary participation in medical research programs, or as a member of the public.

Particle accelerator means any machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 MeV. For purposes of this definition, ''accelerator'' is an equivalent term.

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Person means—
(1) Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Department of Energy (except that the Department shall be considered a person within the meaning of the regulations in 10 CFR chapter I to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission under section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244), the Uranium Mill Tailings Radiation Control Act of 1978 (92 Stat. 3021), the Nuclear Waste Policy Act of 1982 (96 Stat. 2201), and section 3(b)(2) of the Low-Level Radioactive Waste Policy Amendments Act of 1985 (99 Stat. 1842)), any State or any political subdivision of or any political entity within a State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and
(2) Any legal successor, representative, agent, or agency of the foregoing.

Planned special exposure means an infrequent exposure to radiation, separate from and in addition to the annual dose limits.

Positive pressure respirator means a respirator in which the pressure inside the respiratory inlet covering exceeds the ambient air pressure outside the respirator.

Person means—
(1) Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Department of Energy (except that the Department shall be considered a person within the meaning of the regulations in 10 CFR chapter I to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission under section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244), the Uranium Mill Tailings Radiation Control Act of 1978 (92 Stat. 3021), the Nuclear Waste Policy Act of 1982 (96 Stat. 2201), and section 3(b)(2) of the Low-Level Radioactive Waste Policy Amendments Act of 1985 (99 Stat. 1842)), any State or any political subdivision of or any political entity within a State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and
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Positive pressure respirator means a respirator in which the pressure inside the respiratory inlet covering exceeds the ambient air pressure outside the respirator.

Powered air-purifying respirator (PAPR) means an air-purifying respirator that uses a blower to force the ambient air through air-purifying elements to the inlet covering.

Pressure demand respirator means a positive pressure atmosphere-supplying respirator that admits breathing air to the facepiece when the positive pressure is reduced inside the facepiece by inhalation.

Public dose means the dose received by a member of the public from exposure to radiation or to radioactive material released by a licensee, or to any other source of radiation under the control of a licensee. Public dose does not include occupational dose or doses received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released under § 35.75, or from voluntary participation in medical research programs.

Qualitative fit test (QLFT) means a pass/fail fit test to assess the adequacy of respirator fit that relies on the individual's response to the test agent.

Quality Factor (Q) means the modifying factor (listed in tables 1004(b).1) derive dose equivalent from absorbed dose.

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Quality Factor (Q) means the modifying factor (listed in tables 1004(b).1) derive dose equivalent from absorbed dose.

Quantitative fit test (QNFT) means an assessment of the adequacy of respirator fit by numerically measuring the amount of leakage into the respirator.

Rad (See § 20.1004).

Radiation (ionizing radiation) means alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in this part, does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light.

Radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Reference man means a hypothetical aggregation of human physical and physiological characteristics arrived at by international consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base.

Rem (See § 20.1004).

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Rem (See § 20.1004).

Residual radioactivity means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from activities under the licensee's control. This includes radioactivity from all licensed and unlicensed sources used by the licensee, but excludes background radiation. It also includes radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR part 20.

Respiratory protective device means an apparatus, such as a respirator, used to reduce the individual's intake of airborne radioactive materials.

Restricted area means an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

Sanitary sewerage means a system of public sewers for carrying off waste water and refuse, but excluding sewage treatment facilities, septic tanks, and leach fields owned or operated by the licensee.

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Sanitary sewerage means a system of public sewers for carrying off waste water and refuse, but excluding sewage treatment facilities, septic tanks, and leach fields owned or operated by the licensee.

Self-contained breathing apparatus (SCBA) means an atmosphere-supplying respirator for which the breathing air source is designed to be carried by the user.

Shallow-dose equivalent (Hs), which applies to the external exposure of the skin of the whole body or the skin of an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2).

Site boundary means that line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Source material means—
(1) Uranium or thorium or any combination of uranium and thorium in any physical or chemical form; or
(2) Ores that contain, by weight, one twentieth of 1 percent (0.05 percent), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

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Special nuclear material means—
(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material, but does not include source material;
or
(2) Any material artificially enriched by any of the foregoing but does not include source material.

Stochastic effects means health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Supplied-air respirator (SAR) or airline respirator means an atmosphere-supplying respirator for which the source of breathing air is not designed to be carried by the user.

Survey means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material

Special nuclear material means—
(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material, but does not include source material;
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(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material, but does not include source material;
or
(2) Any material artificially enriched by any of the foregoing but does not include source material.

Stochastic effects means health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Supplied-air respirator (SAR) or airline respirator means an atmosphere-supplying respirator for which the source of breathing air is not designed to be carried by the user.

Survey means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material

Special nuclear material means—
(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material, but does not include source material;
or
(2) Any material artificially enriched by any of the foregoing but does not include source material.

Stochastic effects means health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

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Survey means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material

and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Tight-fitting facepiece means a respiratory inlet covering that forms a complete seal with the face.

Total Effective Dose Equivalent (TEDE) means the sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Unrestricted area means an area, access to which is neither limited nor controlled by the licensee.

Uranium fuel cycle means the operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, and reprocessing of spent uranium fuel to the extent that these activities directly support the production of electrical power for public use. Uranium fuel cycle does not include mining operations, operations at waste disposal sites, transportation of radioactive material in support of these operations, and the reuse of recovered non-uranium special nuclear and byproduct materials from the cycle.

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User seal check (fit check) means an action conducted by the respirator user to determine if the respirator is properly seated to the face. Examples include negative pressure check, positive pressure check, irritant smoke check, or isoamyl acetate check.

Very high radiation area means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 1 meter from a radiation source or 1 meter from any surface that the radiation penetrates. NOTE: At very high doses received at high dose rates, units of absorbed dose (e.g., rads and grays) are appropriate, rather than units of dose equivalent (e.g., rems and sieverts)).

Waste means those low-level radioactive wastes containing source, special nuclear, or byproduct material that are acceptable for disposal in a land disposal facility. For the purposes of this definition, low-level radioactive waste means radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in paragraphs (2), (3), and (4) of the definition of Byproduct material set forth in this section.

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Weighting factor W_T, for an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly.

For calculating the effective dose equivalent, the values of W_T are:

ORGAN DOSE WEIGHTING FACTORS

Organ or tissue	W_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	[1] 0.30
Whole Body	[2] 1.00

[1] 0.30 results from 0.06 for each of 5 "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

[2] For the purpose of weighting the external whole body dose (for adding it to the internal dose), a single weighting factor, W_T=1.0, has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specific guidance is issued.

Weighting factor W_T, for an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly.

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Whole body means, for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Working level (WL) is any combination of short-lived radon daughters (for radon-222: polonium-218, lead-214, bismuth-214, and polonium-214; and for radon-220: polonium-216, lead-212, bismuth-212, and polonium-212) in 1 liter of air that will result in the ultimate emission of 1.3E5 MeV of potential alpha particle energy.

Working level month (WLM) means an exposure to 1 working level for 170 hours (2,000 working hours per year/12 months per year = approximately 170 hours per month).

Total Effective Dose Equivalent (TEDE) means the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

* * * * *

§ 20.1004 Units of radiation dose.

Gray (Gy) is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads).

Whole body means, for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Working level (WL) is any combination of short-lived radon daughters (for radon-222: polonium-218, lead-214, bismuth-214, and polonium-214; and for radon-220: polonium-216, lead-212, bismuth-212, and polonium-212) in 1 liter of air that will result in the ultimate emission of 1.3E5 MeV of potential alpha particle energy.

Working level month (WLM) means an exposure to 1 working level for 170 hours (2,000 working hours per year/12 months per year = approximately 170 hours per month).

Total Effective Dose Equivalent (TEDE) means the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

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* * * * *

§ 20.1004 Units of radiation dose.

Gray (Gy) is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads).

Rad is the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram gray).

Rem is the special unit of any of the quantities expressed as dose equivalent.
The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem=0.01 sievert).

Sievert is the SI unit of any of the quantities expressed as dose equivalent.
The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).
(b) As used in this part, the quality factors for converting absorbed dose to dose equivalent are shown in table 1004(b).1.

Rad is the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram gray).

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Sievert is the SI unit of any of the quantities expressed as dose equivalent.
The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).
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The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).
(b) As used in this part, the quality factors for converting absorbed dose to dose equivalent are shown in table 1004(b).1.

Table 1004(B). 1 - QUALITY FACTORS AND ABSORBED DOSE EQUIVALENCIES

Type of radiation	Quality factor (Q)	Absorbed dose equal to a unit dose equivalent*
X-, gamma, or beta radiation	1	1
Alpha particles, multiple-charged particles, fission fragments, and heavy particles of unknown charge	20	0.05
Neutrons of unknown energy	10	0.1
High-energy protons	10	0.1

*Absorbed dose in rad equal to 1 rem or the absorbed dose in gray equal to 1 sievert.

(c) If it is more convenient to measure the neutron fluence rate than to determine the neutron dose equivalent rate in rems per hour or sieverts per hour, as provided in paragraph (b) of this section, 1 rem (0.01 Sv) of neutron radiation of unknown energies may, for purposes of the regulations in this part, be assumed to

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result from a total fluence of 25 million neutrons per square centimeter incident upon the body. If sufficient information exists to estimate the approximate energy distribution of the neutrons, the licensee may use the fluence rate per unit dose equivalent or the appropriate Q value from table 1004(b).2 to convert a measured tissue dose in rads to dose equivalent in rems.

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Table 1004(B).2 - MEAN QUALITY FACTORS, Q, AND FLUENCE PER UNIT DOSE EQUIVALENT FOR MONOENERGETIC NEUTRONS

Neutron energy (MeV)	Quality factor[a] Q	Fluence per unit dose equivalent[b] (neutrons cm^{-2} rem^{-1})
2.5E-8 (thermal)	2	980E6
1E-7	2	980E6
1E-6	2	810E6
1E-5	2	810E6
1E-4	2	840E6
1E-3	2	980E6
1E-2	2.5	1010E6
1E-1	7.5	170E6
5E-1	11	39E6
1	11	27E6
2.5	9	29E6
5	8	23E6
7	7	24E6
10	6.5	24E6
14	7.5	17E6
20	8	16E6
40	7	14E6
60	5.5	16E6
1E2	4	20E6
2E2	3.5	19E6
3E2	3.5	16E6
4E2	3.5	14E6

Table 1004(B).2 - MEAN QUALITY FACTORS, Q, AND FLUENCE PER UNIT DOSE EQUIVALENT FOR MONOENERGETIC NEUTRONS

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1E-4	2	840E6
1E-3	2	980E6
1E-2	2.5	1010E6
1E-1	7.5	170E6
5E-1	11	39E6
1	11	27E6
2.5	9	29E6
5	8	23E6
7	7	24E6
10	6.5	24E6
14	7.5	17E6
20	8	16E6
40	7	14E6
60	5.5	16E6
1E2	4	20E6
2E2	3.5	19E6
3E2	3.5	16E6
4E2	3.5	14E6

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5E-1	11	39E6
1	11	27E6
2.5	9	29E6
5	8	23E6
7	7	24E6
10	6.5	24E6
14	7.5	17E6
20	8	16E6
40	7	14E6
60	5.5	16E6
1E2	4	20E6
2E2	3.5	19E6
3E2	3.5	16E6
4E2	3.5	14E6

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1E-3	2	980E6
1E-2	2.5	1010E6
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5E-1	11	39E6
1	11	27E6
2.5	9	29E6
5	8	23E6
7	7	24E6
10	6.5	24E6
14	7.5	17E6
20	8	16E6
40	7	14E6
60	5.5	16E6
1E2	4	20E6
2E2	3.5	19E6
3E2	3.5	16E6
4E2	3.5	14E6

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[a] Value of quality factor (Q) at the point where the dose equivalent is maximum in a 30-cm diameter cylinder tissue-equivalent phantom.

[b] Monoenergetic neutrons incident normally on a 30-cm diameter cylinder tissue-equivalent phantom.

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[b] Monoenergetic neutrons incident normally on a 30-cm diameter cylinder tissue-equivalent phantom.

10CFR835 Definitions

§ 835.2 Definitions.
Accountable sealed radioactive source means a sealed radioactive source having a half-life equal to or greater than 30 days and an isotopic activity equal to or greater than the corresponding value provided in appendix E of this part.

Activity Median Aerodynamic Diameter (AMAD) means a particle size in an aerosol where fifty percent of the activity in the aerosol is associated with particles of aerodynamic diameter greater than the AMAD.

Airborne radioactive material or airborne radioactivity means radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne radioactivity area (ARA) means any area, accessible to individuals, where:
(1) The concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in appendix A or appendix C of this part; or
(2) An individual present in the area without respiratory protection could receive an intake exceeding 12 DAChours in a week.

10CFR835 Definitions

§ 835.2 Definitions.
Accountable sealed radioactive source means a sealed radioactive source having a half-life equal to or greater than 30 days and an isotopic activity equal to or greater than the corresponding value provided in appendix E of this part.

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(2) An individual present in the area without respiratory protection could receive an intake exceeding 12 DAChours in a week.

ALARA means ''As Low As is Reasonably Achievable,'' which is the approach to radiation protection to manage and control exposures (both individual and collective) to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. As used in this part, ALARA is not a dose limit but a process which has the objective of attaining doses as far below the applicable limits of this part as is reasonably achievable.

Annual limit on intake (ALI) means the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man (ICRP Publication 23) that would result in a committed effective dose of 5 rems (0.05 sieverts (Sv)) (1 rem = 0.01 Sv) or a committed equivalent dose of 50 rems (0.5 Sv) to any individual organ or tissue. ALI values for intake by ingestion and inhalation of selected radionuclides are based on International Commission on Radiological Protection Publication 68, Dose Coefficients for Intakes of Radionuclides by Workers, published July, 1994 (ISBN 0 08 042651 4). This document is available from Elsevier Science Inc., Tarrytown, NY.

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Authorized limit means a limit on the concentration of residual radioactive material on the surfaces or within the property that has been derived consistent with DOE directives including the as low as is reasonably achievable (ALARA) process requirements, given the anticipated use of the property and has been authorized by DOE to permit the release of the property from DOE radiological control.

Background means radiation from:
(1) Naturally occurring radioactive materials which have not been technologically enhanced;
(2) Cosmic sources;
(3) Global fallout as it exists in the environment (such as from the testing of nuclear explosive devices);
(4) Radon and its progeny in concentrations or levels existing in buildings or the environment which have not been elevated as a result of current or prior activities; and
(5) Consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation.

Bioassay means the determination of kinds, quantities, or concentrations, and, in some cases, locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of radioactive materials excreted or removed from.

Authorized limit means a limit on the concentration of residual radioactive material on the surfaces or within the property that has been derived consistent with DOE directives including the as low as is reasonably achievable (ALARA) process requirements, given the anticipated use of the property and has been authorized by DOE to permit the release of the property from DOE radiological control.

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Bioassay means the determination of kinds, quantities, or concentrations, and, in some cases, locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of radioactive materials excreted or removed from.

Calibration means to adjust and/or determine either:
(1) The response or reading of an instrument relative to a standard (e.g., primary, secondary, or tertiary) or to a series of conventionally true values; or
(2) The strength of a radiation source relative to a standard (e.g., primary, secondary, or tertiary) or conventionally true value.

Contamination area (CA) means any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in appendix D of this part, but do not exceed 100 times those values.

Controlled area means any area to which access is managed by or for DOE to protect individuals from exposure to radiation and/or radioactive material.

Declared pregnant worker means a woman who has voluntarily declared to for the purpose of being subject to the occupational dose limits to the embryo/fetus as provided in § 835.206. This declaration may be revoked, in writing, at any time by the declared pregnant worker.

Calibration means to adjust and/or determine either:
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Derived air concentration (DAC) means, for the radionuclides listed in appendix A of this part, the airborne concentration that equals the ALI divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m^3). For the radionuclides listed in appendix C of this part, the air immersion DACs were calculated for a continuous, non-shielded exposure via immersion in a semi-infinite cloud of radioactive material. Except as noted in the footnotes to appendix A of this part, the values are based on dose coefficients from ICRP Publication 68, Dose Coefficients for Intakes of Radionuclides by Workers, published July, 1994 (ISBN 0 08 042651 4) and the associated ICRP computer program, The ICRP Database of Dose Coefficients: Workers and Members of the Public, (ISBN 0 08 043 8768). These materials are available from Elsevier Science Inc., Tarrytown, NY.

Derived air concentration-hour (DAChour) means the product of the concentration of radioactive material in air (expressed as a fraction or multiple of the DAC for each radionuclide) and the time of exposure to that radionuclide, in hours.

Deterministic effects means effects due to radiation exposure for which the severity varies with the dose and for which a threshold normally exists (e.g., radiation-induced opacities within the lens of the eye).

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DOE means the United States Department of Energy.

DOE activity means an activity taken for or by DOE in a DOE operation or facility that has the potential to result in the occupational exposure of an individual to radiation or radioactive material. The activity may be, but is not limited to, design, construction, operation, or decommissioning. To the extent appropriate, the activity may involve a single DOE facility or operation or a combination of facilities and operations, possibly including an entire site or multiple DOE sites.

Entrance or access point means any location through which an individual could gain access to areas controlled for the purpose of radiation protection. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.

General employee means an individual who is either a DOE or DOE contractor employee; an employee of a subcontractor to a DOE contractor; or an individual who performs work for or in conjunction with DOE or utilizes DOE facilities.

High contamination area (HCA) means any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in appendix D of this part.

DOE means the United States Department of Energy.

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High contamination area (HCA) means any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in appendix D of this part.

High radiation area (HRA) means any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.1 rems (0.001 Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Member of the public means an individual who is not a general employee. An individual is not a ‘‘member of the public’’ during any period in which the individual receives an occupational dose.

Monitoring means the measurement of radiation levels, airborne radioactivity concentrations, radioactive contamination levels, quantities of radioactive material, or individual doses and the use of the results of these measurements to evaluate radiological hazards or potential and actual doses resulting from exposures to ionizing radiation.

Occupational dose means an individual’s ionizing radiation dose (external and internal) as a result of that individual’s work assignment. Occupational dose does not include doses received as a medical patient or doses resulting from background radiation or participation as a subject in medical research programs.

High radiation area (HRA) means any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.1 rems (0.001 Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

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Person means any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency, any State or political subdivision of, or any political entity within a State, any foreign government or nation or other entity, and any legal successor, representative, agent or agency of the foregoing; provided that person does not include DOE or the United States Nuclear Regulatory Commission.

Radiation means ionizing radiation: alpha particles, beta particles, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions.

Radiation, as used in this part, does not include non-ionizing radiation, such as radio waves or microwaves, or visible, infrared, or ultraviolet light.

Radiation area (RA) means any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the source or from any surface that the radiation penetrates.

Person means any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency, any State or political subdivision of, or any political entity within a State, any foreign government or nation or other entity, and any legal successor, representative, agent or agency of the foregoing; provided that person does not include DOE or the United States Nuclear Regulatory Commission.

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Radiation area (RA) means any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the source or from any surface that the radiation penetrates.

Radioactive material area means any area within a controlled area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in appendix E of this part.

Radioactive material transportation means the movement of radioactive material by aircraft, rail, vessel, or highway vehicle. Radioactive material transportation does not include preparation of material or packagings for transportation, storage of material awaiting transportation, or application of markings and labels required for transportation.

Radiological area (RA) means any area within a controlled area defined in this section as a ‘‘radiation area,’’ ‘‘high radiation area,’’ ‘‘very high radiation area,’’ ‘‘contamination area,’’ ‘‘high contamination area,’’ or ‘‘airborne radioactivity area.’’

Radiological worker means a general employee whose job assignment involves operation of radiation producing devices or working with radioactive materials, or who is likely to be routinely occupationally exposed above 0.1 rem (0.001 Sv) per year total effective dose.

Radioactive material area means any area within a controlled area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in appendix E of this part.

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Real property means land and anything permanently affixed to the land such as buildings, fences and those things attached to the buildings, such as light fixtures, plumbing and heating fixtures.

Real-time air monitoring means measurement of the concentrations or quantities of airborne radioactive materials on a continuous basis.

Respiratory protective device means an apparatus, such as a respirator, worn by an individual for the purpose of reducing the individual's intake of airborne radioactive materials.

Sealed radioactive source means a radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material. Sealed radioactive sources do not include reactor fuel elements, nuclear explosive devices, and radioisotope thermoelectric generators.

Source leak test means a test to determine if a sealed radioactive source is leaking radioactive material.

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Source leak test means a test to determine if a sealed radioactive source is leaking radioactive material.

Special tritium compound (STC) means any compound, except for H_2O, that contains tritium, either intentionally (e.g., by synthesis) or inadvertently (e.g., by contamination mechanisms).

Stochastic effects means malignant and hereditary diseases for which the probability of an effect occurring, rather than its severity, is regarded as a function of dose without a threshold, for radiation protection purposes.

Very high radiation area (VHRA) means any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

As used in this part to describe various aspects of radiation dose:

Absorbed dose (D) means the average energy imparted by ionizing radiation to the matter in a volume element. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 grays).

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Absorbed dose (D) means the average energy imparted by ionizing radiation to the matter in a volume element. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 grays).

Committed effective dose (E_{50}) means the sum of the committed equivalent doses to various tissues or organs in the body ($H_{T,50}$), each multiplied by the appropriate tissue weighting factor (W_T)—that is, $E50 = \Sigma W_T H_{T,50} + W_{Remainder} H_{Remainder,50}$. Where $W_{Remainder}$ is the tissue weighting factor assigned to the remainder organs and tissues and $H_{Remainder,50}$ is the committed equivalent dose to the remainder organs and tissues. Committed effective dose is expressed in units of rem (or Sv).

Committed equivalent dose ($H_{T,50}$) means the equivalent dose calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed equivalent dose is expressed in units of rem (or Sv).

Cumulative total effective dose means the sum of all total effective dose values recorded for an individual plus, for occupational exposures received before the implementation date of this amendment, the cumulative total effective dose equivalent (as defined in the November 4, 1998 amendment to this rule) values recorded for an individual, where available, for each year occupational dose was received, beginning January 1, 1989.

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Dose is a general term for absorbed dose, equivalent dose, effective dose, committed equivalent dose, committed effective dose, or total effective dose as defined in this part.

Effective dose (E) means the summation of the products of the equivalent dose received by specified tissues or organs of the body (H_T) and the appropriate tissue weighting factor (W_T)— that is, $E = \Sigma W_T H_T$. It includes the dose from radiation sources internal and/or external to the body. For purposes of compliance with this part, equivalent dose to the whole body may be used as effective dose for external exposures. The effective dose is expressed in units of rem (or Sv).

Equivalent dose (H_T) means the product of average absorbed dose ($D_{T,R}$) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (W_R). For external dose, the equivalent dose to the whole body is assessed at a depth of 1 cm in tissue; the equivalent dose to the lens of the eye is assessed at a depth of 0.3 cm in tissue, and the equivalent dose to the extremity and skin is assessed at a depth of 0.007 cm in tissue. Equivalent dose is expressed in units of rem (or Sv).

External dose or exposure means that portion of the equivalent dose received from radiation sources outside the body (i.e., ‘‘external sources’’).

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External dose or exposure means that portion of the equivalent dose received from radiation sources outside the body (i.e., ‘‘external sources’’).

Extremity means hands and arms below the elbow or feet and legs below the knee.

Internal dose or exposure means that portion of the equivalent dose received from radioactive material taken into the body (i.e., ‘‘internal sources’’).

Radiation weighting factor (W_R) means the modifying factor used to calculate the equivalent dose from the average tissue or organ absorbed dose; the absorbed dose (expressed in rad or gray) is multiplied by the appropriate radiation weighting factor. The radiation weighting factors to be used for determining equivalent dose in rem are as follows:

Extremity means hands and arms below the elbow or feet and legs below the knee.

Internal dose or exposure means that portion of the equivalent dose received from radioactive material taken into the body (i.e., ‘‘internal sources’’).

Radiation weighting factor (W_R) means the modifying factor used to calculate the equivalent dose from the average tissue or organ absorbed dose; the absorbed dose (expressed in rad or gray) is multiplied by the appropriate radiation weighting factor. The radiation weighting factors to be used for determining equivalent dose in rem are as follows:

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RADIATION WEIGHTING FACTORS[1], W_R

Type and energy range	Radiation weighting factor
Photons, electrons, and muons, all energies	1
Neutrons < 10 keV[2,3]	5
Neutrons 10 keV to 100 keV[2,3]	10
Neutrons > 100 keV to 2 MeV[2,3]	20
Neutrons > 2 MeV to 20 MeV[2,3]	10
Neutrons > 20 MeV[2,3]	5
Protons, other than recoil protons, > 20 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

[1] All values relate to the radiation incident on the body or, for internal sources, emitted from the source.

[2] When spectral data are insufficient to identify the energy of the neutrons, a radiation weighting factor of 20 shall be used.

[3] When spectral data are sufficient to identify the energy of the neutrons, the following equation may be used to determine a neutron radiation weighting factor value:

$$W_R = 5 + 17 \exp \frac{-(\ln(2En))^2}{6}$$

Where E_n is the neutron energy in MeV.

RADIATION WEIGHTING FACTORS[1], W_R

Type and energy range	Radiation weighting factor
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Neutrons > 100 keV to 2 MeV[2,3]	20
Neutrons > 2 MeV to 20 MeV[2,3]	10
Neutrons > 20 MeV[2,3]	5
Protons, other than recoil protons, > 20 MeV	5
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$$W_R = 5 + 17 \exp \frac{-(\ln(2En))^2}{6}$$

Where E_n is the neutron energy in MeV.

Tissue weighting factor (W_T) means the fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The equivalent dose to tissue, (HT), is multiplied by the appropriate tissue weighting factor to obtain the effective dose (E) contribution from that tissue.
The tissue weighting factors are as follows:

TISSUE WEIGHTING FACTORS FOR VARIOUS ORGANS AND TISSUES

Organs or tissues, T	Tissue weighting factor, W_T
Gonads	0.20
Red bone marrow	0.12
Colon	0.12
Lungs	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surfaces	0.01
Remainder[1]	0.05
Whole body[2]	1.00

Tissue weighting factor (W_T) means the fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The equivalent dose to tissue, (HT), is multiplied by the appropriate tissue weighting factor to obtain the effective dose (E) contribution from that tissue.
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Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surfaces	0.01
Remainder[1]	0.05
Whole body[2]	1.00

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Remainder[1]	0.05
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Thyroid	0.05
Skin	0.01
Bone surfaces	0.01
Remainder[1]	0.05
Whole body[2]	1.00

[1] "Remainder" means the following additional tissues and organs and their masses, in grams, following parenthetically: adrenals (14), brain (1400), extrathoracic airways (15), small intestine (640), kidneys (310), muscle (28,000), pancreas (100), spleen (180), thymus (20), and uterus (80). The equivalent dose to the remainder tissues ($H_{remainder}$), is normally calculated as the mass-weighted mean dose to the preceeding ten organs and tissues. In those cases in which the most highly irradiated remainder tissue or organ receives the highest dose of all the organs, a weighting factor of 0.025 (half of remainder) is applied to that tissue or organ and 0.025 (half of remainder) to the mass-weighted equivalent dose in the rest of the remainder tissues and organs to give the remainder equivalent dose.

[2] For the case of uniform external irradiation of the whole body, a tissue weighting factor (W_T) equal to 1 may be used in determination of the effective dose.

Total effective dose (TED) means the sum of the effective dose (for external exposures) and the committed effective dose.

Whole body means, for the purposes of external exposure, head, trunk (including male gonads), arms above and including the elbow, or legs above and including the knee.

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[1] "Remainder" means the following additional tissues and organs and their masses, in grams, following parenthetically: adrenals (14), brain (1400), extrathoracic airways (15), small intestine (640), kidneys (310), muscle (28,000), pancreas (100), spleen (180), thymus (20), and uterus (80). The equivalent dose to the remainder tissues ($H_{remainder}$), is normally calculated as the mass-weighted mean dose to the preceeding ten organs and tissues. In those cases in which the most highly irradiated remainder tissue or organ receives the highest dose of all the organs, a weighting factor of 0.025 (half of remainder) is applied to that tissue or organ and 0.025 (half of remainder) to the mass-weighted equivalent dose in the rest of the remainder tissues and organs to give the remainder equivalent dose.

[2] For the case of uniform external irradiation of the whole body, a tissue weighting factor (W_T) equal to 1 may be used in determination of the effective dose.

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Unless otherwise specified, the quantities used in the records required by this part shall be clearly indicated in special units of curie, rad, roentgen, or rem, including multiples and subdivisions of these units, or other conventional units, such as, dpm, dpm/100 cm^2 or mass units. The SI units, Becquerel (Bq), gray (Gy), and sievert (Sv), may be provided parenthetically for reference with scientific standards.

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Government Agency Websites

www.cdc.gov
www.defenselink.mil
www.dot.gov
www.eh.doe.gov/nepa
www.epa.gov/radiation
www.fedworld.gov
www.lanl.gov
www.lib.lsu.edu/gov/alpha
www.nrc.gov
www.nrc.gov/about-nrc/regulatory/research/radiological-toolbox.html
www.osha.gov
www.cirms.tis.doe.gov
www.dnfsb.gov
www.edf.fr
www.energy.gov
www.fda.gov/cdrh
www.fema.gov
www.lbl.gov
www.llnl.gov
www.doe.gov
www.ornl.gov
www.srs.gov

Government Agency Websites

www.cdc.gov
www.defenselink.mil
www.dot.gov
www.eh.doe.gov/nepa
www.epa.gov/radiation
www.fedworld.gov
www.lanl.gov
www.lib.lsu.edu/gov/alpha
www.nrc.gov
www.nrc.gov/about-nrc/regulatory/research/radiological-toolbox.html
www.osha.gov
www.cirms.tis.doe.gov
www.dnfsb.gov
www.edf.fr
www.energy.gov
www.fda.gov/cdrh
www.fema.gov
www.lbl.gov
www.llnl.gov
www.doe.gov
www.ornl.gov
www.srs.gov

Government Agency Websites

www.cdc.gov
www.defenselink.mil
www.dot.gov
www.eh.doe.gov/nepa
www.epa.gov/radiation
www.fedworld.gov
www.lanl.gov
www.lib.lsu.edu/gov/alpha
www.nrc.gov
www.nrc.gov/about-nrc/regulatory/research/radiological-toolbox.html
www.osha.gov
www.cirms.tis.doe.gov
www.dnfsb.gov
www.edf.fr
www.energy.gov
www.fda.gov/cdrh
www.fema.gov
www.lbl.gov
www.llnl.gov
www.doe.gov
www.ornl.gov
www.srs.gov

Government Agency Websites

www.cdc.gov
www.defenselink.mil
www.dot.gov
www.eh.doe.gov/nepa
www.epa.gov/radiation
www.fedworld.gov
www.lanl.gov
www.lib.lsu.edu/gov/alpha
www.nrc.gov
www.nrc.gov/about-nrc/regulatory/research/radiological-toolbox.html
www.osha.gov
www.cirms.tis.doe.gov
www.dnfsb.gov
www.edf.fr
www.energy.gov
www.fda.gov/cdrh
www.fema.gov
www.lbl.gov
www.llnl.gov
www.doe.gov
www.ornl.gov
www.srs.gov

Professional Organizations Websites

www.aarst.org
www.acgih.org/home.htm
www.amug.us
www.ansi.org
www.edf.fr
www.hps.org/iarpe
www.icrp.org
www.iaea.org/worldatom
www.hps1.org/aahp/abhp/abhp.htm
www.i-i-s.net
www.ncrp.com
www.nea.fr
www.nrsb.org
www.nuclearsafety.gc.ca
www.rsna.org
www.abmpexam.com
www.aiha.org
www.ans.org
www.cea.fr
www.hps.org
www.hps1.org/aahp
www.irpa.net
www.ncrponline.org
www.nrrpt.org
www.nrsi.org
www.radres.org
www.sra.org

Professional Organizations Websites

www.aarst.org
www.acgih.org/home.htm
www.amug.us
www.ansi.org
www.edf.fr
www.hps.org/iarpe
www.icrp.org
www.iaea.org/worldatom
www.hps1.org/aahp/abhp/abhp.htm
www.i-i-s.net
www.ncrp.com
www.nea.fr
www.nrsb.org
www.nuclearsafety.gc.ca
www.rsna.org
www.abmpexam.com
www.aiha.org
www.ans.org
www.cea.fr
www.hps.org
www.hps1.org/aahp
www.irpa.net
www.ncrponline.org
www.nrrpt.org
www.nrsi.org
www.radres.org
www.sra.org

Professional Organizations Websites

www.aarst.org
www.acgih.org/home.htm
www.amug.us
www.ansi.org
www.edf.fr
www.hps.org/iarpe
www.icrp.org
www.iaea.org/worldatom
www.hps1.org/aahp/abhp/abhp.htm
www.i-i-s.net
www.ncrp.com
www.nea.fr
www.nrsb.org
www.nuclearsafety.gc.ca
www.rsna.org
www.abmpexam.com
www.aiha.org
www.ans.org
www.cea.fr
www.hps.org
www.hps1.org/aahp
www.irpa.net
www.ncrponline.org
www.nrrpt.org
www.nrsi.org
www.radres.org
www.sra.org

Professional Organizations Websites

www.aarst.org
www.acgih.org/home.htm
www.amug.us
www.ansi.org
www.edf.fr
www.hps.org/iarpe
www.icrp.org
www.iaea.org/worldatom
www.hps1.org/aahp/abhp/abhp.htm
www.i-i-s.net
www.ncrp.com
www.nea.fr
www.nrsb.org
www.nuclearsafety.gc.ca
www.rsna.org
www.abmpexam.com
www.aiha.org
www.ans.org
www.cea.fr
www.hps.org
www.hps1.org/aahp
www.irpa.net
www.ncrponline.org
www.nrrpt.org
www.nrsi.org
www.radres.org
www.sra.org

Author's notes

Over my career in health physics starting with a US Army CBR unit at Dugway Proving Grounds in 1965 I have needed to quickly find that elusive data point that I just couldn't remember, even though I knew the information was in one of my several hundred reference books.

So, here it is today, the product of my work to assemble useful field information from a wide range of sources.

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Fellow of the Health Physics Society
Northern New Mexico, 2011

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