Emergency Fast Facts – Health Physics

1 Summary of Incident Types

Incident Type	Radiation Involved
Threat of an incident	None
Misplaced, Lost, or Stolen Source	Source(s); sealed or unsealed
Transportation Accident or Spill	Source(s); sealed or unsealed
Workplace Injury	Isotopes depend on work processes
Reactor Accident	Fission Products
Radiation Exposure Device	Sealed gamma source
Radiological Dispersal Device (RDD or "dirty bomb"	Radioactive materials dispersed by conventional explosive or other means
Improvised Nuclear Device (IND)	Special nuclear materials, fission and activation products

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2 Significance of Dose Rate Meter Readings

Reading		Significance
20 μGy h^{-1}	(2 mR h^{-1})	• Limit for radiation dose rate in an uncontrolled area
50 μGy h^{-1}	(5 mR h^{-1})	• Controlled entry as a radiation area
1 mGy h^{-1}	(100 mR h^{-1})	• 10 mSv (1 rem) in 10 hours
100 mGy h^{-1}	(10 R h^{-1})	• 50 mSv (5 rem) in 30 minutes
1 Gy h^{-1}	(100 R h^{-1})	• May develop radiation sickness with 1 hour exposure
10 Gy h^{-1}	(1,000 R h^{-1})	• May develop radiation sickness with 5-6 minutes exposure • Will reach LD50 in 30 minutes • Will receive lethal dose (10 Gy) in 1 hour

3 Significance of Contamination Survey Meter Readings

Reading (per 100 cm^2)		Significance
(Bq)	(dpm)	
0.33 (α) 16 (β/γ)	20 (α) 1,000 (β/γ)	• Limit for contamination in an uncontrolled area
32 (α) 1,670 (β/γ)	2,000 (α) 100,000 (β/γ)	• Resuspended contamination may lead to inhalation or ingestion risk
16,700 (α/β/γ)	1,000,000 (α/β/γ)	• Likely to lead to inhalation of significant amounts of activity

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4 Sealed Source Activities

Activity		Significance	Actions
10s of kBq	µCi	Not a significant health risk	• Control as radioactive material
10s of MBq	mCi	May be a minor health risk	• Do not handle directly • Use tongs
10s of GBq	Ci	May be a health risk	• Do not handle directly • Use tongs
100s of GBq	A few Ci	May be a health risk	• Do not approach closely • Do not handle source
TBq	10s of Ci	May be a severe health risk	• Do not approach without radiation dose and dose-rate monitoring equipment

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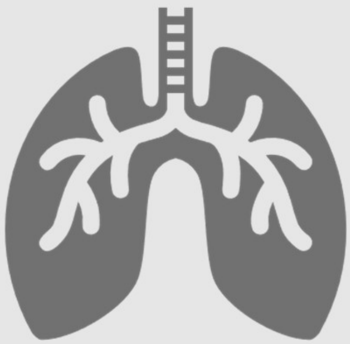
5 Assessment of Intakes

Estimates of the amount of material inhaled can be estimated from the concentration of material in air.



Intake (Bq)= BR (m^3 h^{-1}) × Time (h) × Concentration (Bq m^{-3})

Breathing Rate (m^3 h^{-1})	Condition
2.31×10^{-4} m^3 s^{-1}	Rest
3.48×10^{-4} m^3 s^{-1}	Moderate Activity
5.0×10^{-4} m^3 s^{-1}	Strenuous Activity

Estimates of the amount of material inhaled can also be estimated from nasal swabs.

Swabs taken from the anterior nares can be measured with a contamination meter. Activity detected is assumed to represent 10% of the material inhaled.

Intake (Bq)= Count Rate (cps) × Efficiency (dps cps^{-1}) × 10

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6 Indications That a Stochastic CDG Has Been Reached

Clinical Decision Guide (CDG) levels are the once in a lifetime intake that represents a stochastic risk (0.25 Sv). Separate levels are given for avoidance of deterministic effects.

CDGs were introduced in NCRP Report 161 to assist physicians in making treatment decisions. They are NOT intended to be the only factor considered in making treatment decisions.

Nuclide	1st 24-Hour Urine Sample – Gross Count (dpm)	Nasal Swab (dpm)
^{90}Sr	3.4×10^7	2.5×10^7
^{137}Cs	7.7×10^7	1.7×10^8
^{192}Ir	1.1×10^7	1.8×10^8
^{226}Ra	1.1×10^4	3.4×10^5
^{235}U	1.5×10^3	1.1×10^5
^{238}Pu	1.0×10^2	2.4×10^4
^{239}Pu	9.6×10^1	2.3×10^4
^{241}Am	1.0×10^3	2.8×10^4

7 Air Concentrations Required to Reach a CDG

Clinical Decision Guide (CDG) levels are the once in a lifetime intake that represents a stochastic risk (0.25 Sv). Separate levels are given for avoidance of deterministic effects.

CDGs were introduced in NCRP Report 161 to assist physicians in making treatment decisions. They are NOT intended to be the only factor considered in making treatment decisions.

Nuclide	Deterministic Effect	Concentration		Concentration to Reach Stochastic Limit	
		MBq m^{-3}	µCi m^{-3}	MBq m^{-3}	µCi m^{-3}
$^{90}SrCl$	Bone Marrow Depression	2,600	70,000	51	1,400
^{131}I	Hypothyroidism	30	800	76	2,100
$^{137}CsCl$	Bone Marrow Depression	8,000	220,000	350	9,500
$^{144}CeO_2$	Pneumonitis	3,700	100,000	52	1,400
$^{210}PoCl_2$	Bone Marrow Depression	1,900	51,000	0.67	18
$^{210}PoCl_4$	Bone Marrow Depression	1,900	51,000	0.67	18
$^{238}PuO_2$	Pneumonitis	40	1,100	0.049	1.3
$^{239}PuO_2$	Pneumonitis	40	1,100	0.18	4.9
$^{241}AmO_2$	Pneumonitis	40	1,100	0.57	1.5

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8 Comparison of Internal Monitoring Techniques

Technique	Advantages	Disadvantages
Fixed *in-vivo* counter	Low detection limit	Limited availability
	No uncertainty from chemical form or biokinetics	Generally calibrated for operational nuclides of interest
Mobile *in-vivo* counter	On-site measurement	Requires event-specific calibration
Handheld detector	Readily available	High detection limits
	Useful for rapid screening of large numbers of people	
Urine Bioassay	Low detection limits	Delayed result from collection time and analysis time
	Discrimination of external contamination	Management of excreta samples
Fecal Bioassay	Low detection limits	Delayed result from collection time and analysis time
	Appropriate for insoluble compounds	Management of excreta samples

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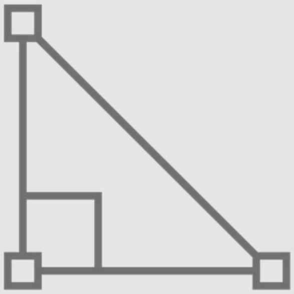
Uncontrolled Sealed Source

Sealed Sources

Dose Rate at a Distance

Dose rates can be estimated based on the source activity (A) and distance between the detector and the source (d).

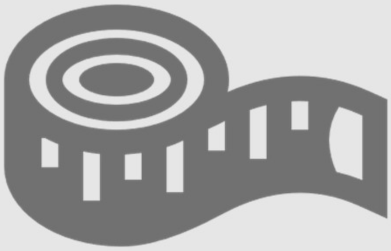
$$\dot{D}=\frac{A\times\Gamma}{d^2}$$



If the radionuclide of the sealed source is unknown, reference the tables on the following pages for nuclides commonly used in different scenarios.

Estimating Distance

Distance (d) from a source can be roughly estimated by taking measurements (D_1 and D_2) at two different distances (x_1 and x_2) - along the same line of sight.



$$d=\frac{x_2-x_1}{1-\sqrt{\frac{D_1}{D_2}}}$$

Sealed Sources

INDUSTRIAL

Industrial Radiography

Source	Typical Activity	Dose Rate at 1 m (mSv/h)	Time to exceed 1 mSv at 1 m
Co-60	2.2 TBq	8.15×10^2	4 sec
Se-75	3.0 TBq	6.97×10^2	5 sec
Yb-169	190 GBq	1.68×10^1	4 min
Tm-170	5.6 TBq	9.37×10^0	6 min
Ir-192	5.5 TBq	8.79×10^2	4 sec

Food/Product Irradiators

Source	Typical Activity	Dose Rate at 1 m (mSv/h)	Time to exceed 1 mSv at 1 m
Co-60	4.0×10^6 TBq	1.48×10^9	2.4×10^{-6} s
Cs-137	1.1×10^5 TBq	8.57×10^6	4.2×10^{-4} s

Sealed Sources

HIGH DOSE MEDICAL / RESEARCH SOURCES

Blood Irradiators

Source	Typical Activity	Dose Rate at 1 m (mSv/h)	Time to exceed 1 mSv at 1 m
Co-60	89 TBq	3.30×10^4	0.1 s
Cs-137	260 TBq	2.03×10^4	0.2 s

Gamma Knife

Source	Typical Activity	Dose Rate at 1 m (mSv/h)	Time to exceed 1 mSv at 1 m
Co-60	260 TBq	9.63×10^4	0.03 s

Teletherapy

Source	Typical Activity	Dose Rate at 1 m (mSv/h)	Time to exceed 1 mSv at 1 m
Co-60	150 TBq	5.55×10^4	0.07 s
Cs-137	19 TBq	1.48×10^3	2 s

Self-Shielded Irradiators

Source	Typical Activity	Dose Rate at 1 m (mSv/h)	Time to exceed 1 mSv at 1 m
Co-60	930 TBq	3.44×10^5	0.01 s
Cs-137	560 TBq	4.36×10^4	0.08 s

RADIOISOTOPE THERMAL GENERATORS

Not commonly encountered, radioisotope thermal (or thermionic) generators are used for the generation of electricity in remote locations where electricity cannot be provided by normal generation. They work by using heat energy created by the absorption of radiation from the radioactive source to generate electricity using a thermocouple device.

	With Shielding	Without Shielding
Surface Dose Rate	0.002 Sv/h	10 Sv/h
Dose Rate at 1 m	0.0001 Sv/h	> 0.010 Sv/h
Time to exceed 1 mSv at surface	30 min	0.36 sec
Time to exceed 1 mSv at 1 m	10 h	6 min

Terrestrial RTGs typically use 90Sr as their heat source. Although is a beta emitter, the dose rate from an unshielded RTG can be substantial due to the bremsstrahlung X-rays produced in metallic components.

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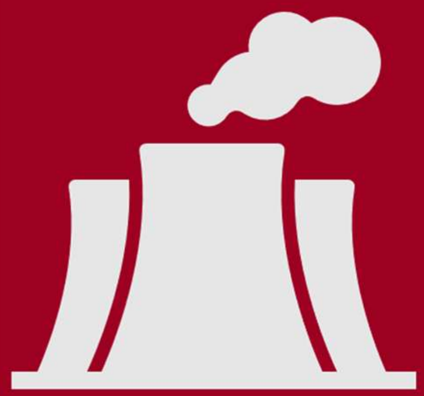
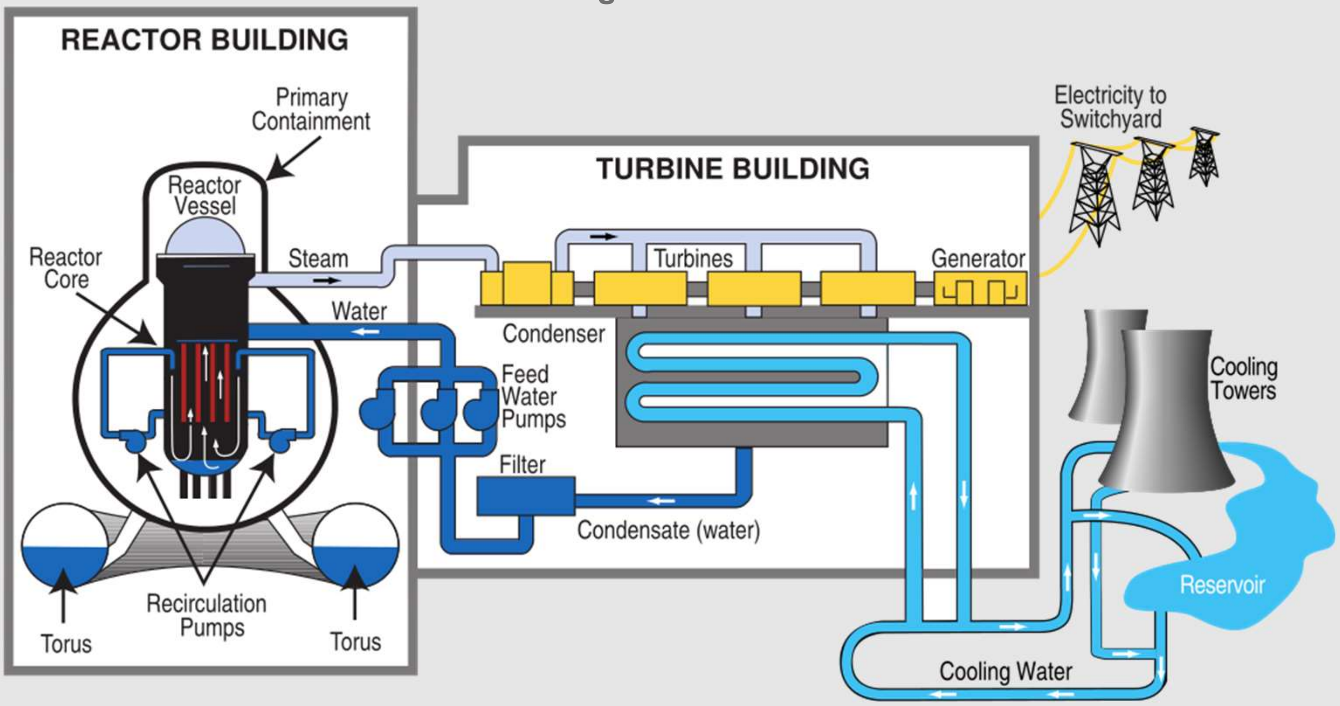
Reactor Emergencies



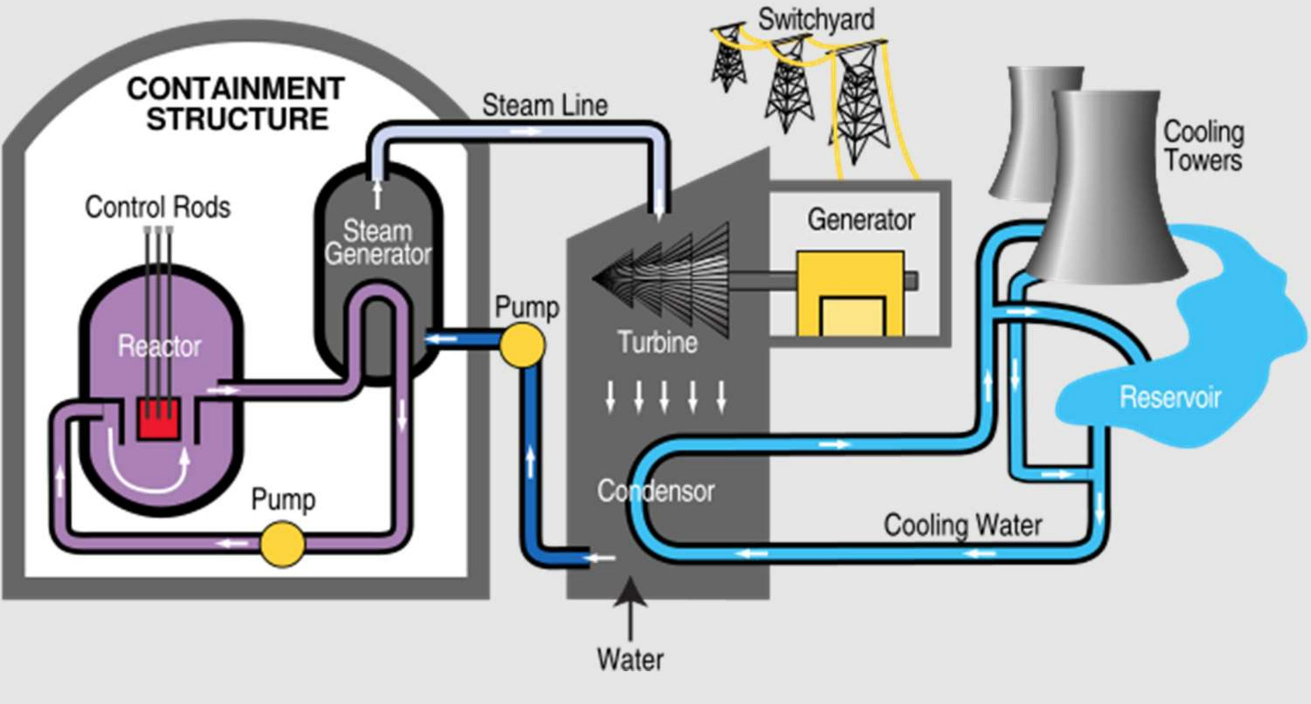
Reactor Accidents

Fuel element rupture releases gaseous and volatile fission products first

In a BWR accident, these can be released from the reactor building, turbine building, or cooling tower.



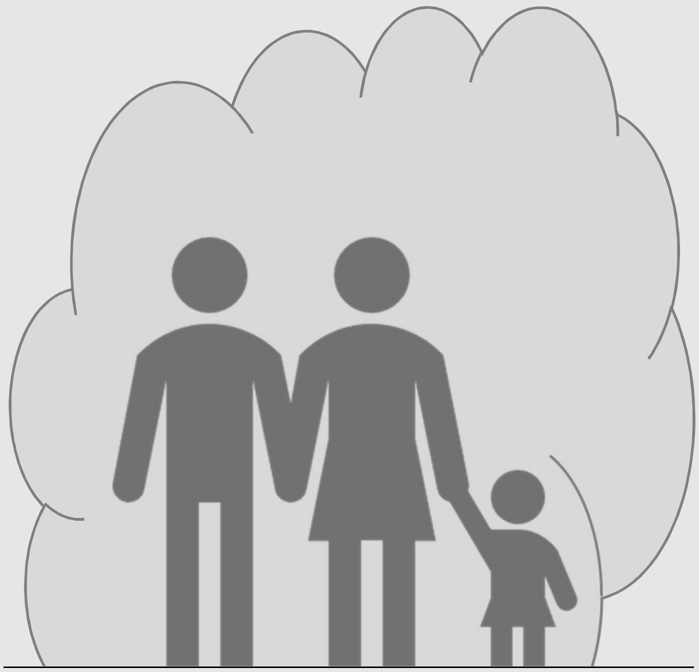
In a PWR accident, fission products are most likely to be released from the containment building itself.



Reactor Accidents

Isotopes of Concern – External Dose from Plume

Radionuclides expected to deliver >90% of the dose resulting from a severe core-damage accident. Listed in order of importance.



Isotope	Conversion Factor for External γ from Immersion (mSv/h)/(kBq/m³)
I-132	4.4×10^{-5}
I-135	3.5×10^{-4}
I-133	1.3×10^{-4}
Kr-88	4.8×10^{-4}
Te-132	4.4×10^{-5}
I-131	8.1×10^{-5}
Sb-129	3.2×10^{-4}
Xe-135	5.2×10^{-5}
Te-131m	3.1×10^{-4}
I-134	5.9×10^{-4}
Xe-133	7.4×10^{-6}

Ambient dose rates can be determined with a β/γ survey meter held at waist level. The window of the probe should be pointed upwards to avoid including radiation contributions from ground deposited material.

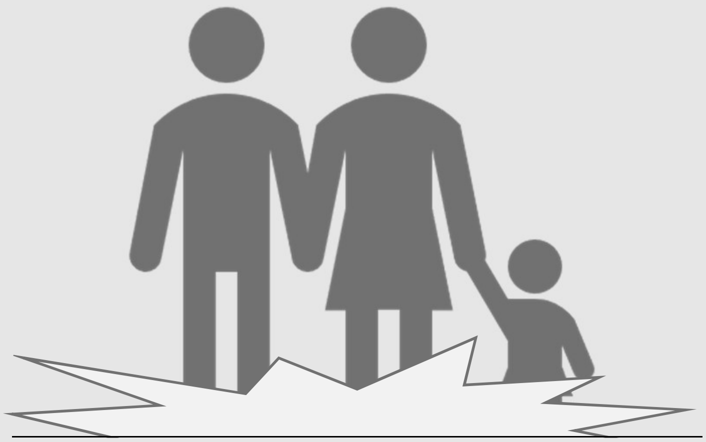
>95% of the iodine released is expected to be in the form of cesium-iodide. The remainder is a combination of elemental iodine and HI.

Reactor Accidents

Isotopes of Concern – External Dose from Ground Deposition

Radionuclides expected to deliver >90% of the dose resulting from a severe core-damage accident. Listed in order of importance.

Isotope	Ambient Dose Rate from Deposition (mSv/h)/(kBq/m^2)
Te-132	8.0×10^{-7}
I-133	2.1×10^{-6}
I-135	5.4×10^{-6}
I-132	7.8×10^{-6}
I-131	1.3×10^{-6}
Te-131m	4.8×10^{-6}
Ba-140	6.4×10^{-7}
La-140	7.6×10^{-6}
Sb-129	4.9×10^{-6}
Np-239	5.8×10^{-7}

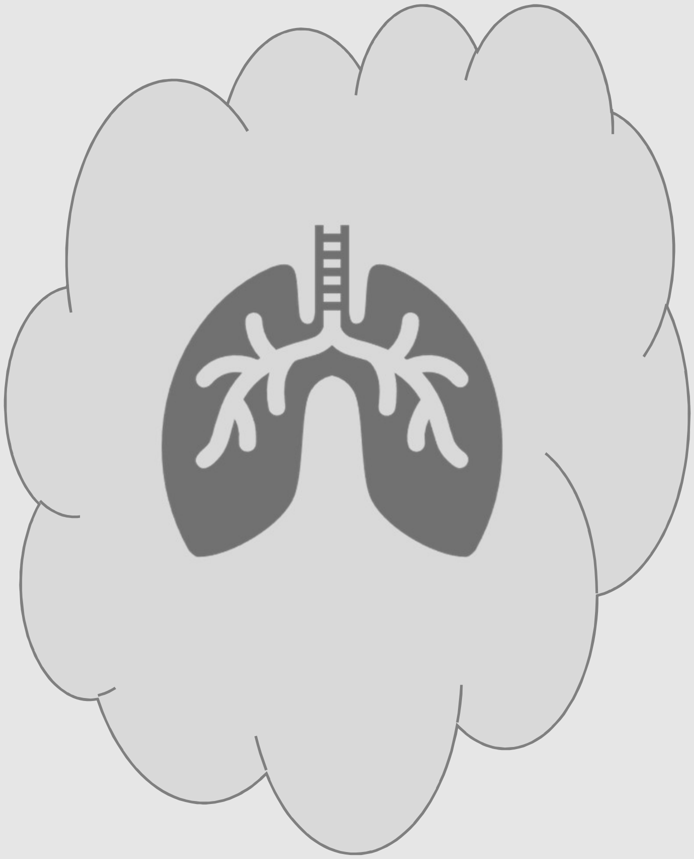


>95% of the iodine released is expected to be in the form of cesium-iodide. The remainder is a combination of elemental iodine and HI.

Reactor Accidents

Isotopes of Concern – Dose from Inhalation of Plume

Radionuclides expected to deliver >90% of the dose resulting from a severe core-damage accident. Listed in order of importance.



Isotope	Committed Effective Dose Conversion Factor for Inhalation (mSv/h)/(kBq/m^3)
Te-132	3.0×10^{-3}
Sr-89	1.2×10^{-2}
Ba-140	8.7×10^{-3}
Cs-134	3.0×10^{-2}
I-131	1.1×10^{-2}
I-133	2.3×10^{-3}
Cs-137	5.9×10^{-2}
I-135	4.8×10^{-4}
Cs-136	4.2×10^{-3}
I-132	1.7×10^{-4}
Ru-103	4.5×10^{-3}
Sr-90	2.4×10^{-1}
Te-131m	1.4×10^{-3}
Y-91	1.3×10^{-2}
Te-129m	1.2×10^{-2}

>95% of the iodine released is expected to be in the form of cesium-iodide. The remainder is a combination of elemental iodine and HI.

Emergency Fast Facts – Health Physics

Skin Contamination

Skin Contamination

Action Levels for Contaminated Skin

If the Isotope and Efficiency are Known

Alpha (dpm/cm²)	Beta/Gamma (dpm/cm²)	Beta/Gamma (µR/hr)	Actions
< 600	< 6,000	Non-detectable	• None required
600 – 6,000	6,000 – 60,000	Non-detectable	**INTERVENTION OPTIONAL** • Decontaminate or advise to shower and wash clothing • No significant health risk
6,000 – 60,000	60,000 – 600,000	20 – 30	**INTERVENTION ADVISABLE** • Prevent inadvertent ingestion and inhalation • Limit spread of contamination from contaminated person • Decontaminate
> 60,000	> 600,000	200 - 300	**INTERVENTION REQUIRED** • Prevent inadvertent ingestion and inhalation • Limit spread of contamination from contaminated person • Decontaminate

Skin Contamination

Action Levels for Contaminated Skin

If the Isotope and Efficiency are Unknown

Uncorrected Count Rate (cpm)	Actions
< 1,000	• Release to home
< 10,000	• Advise to shower and change clothing, or; • Decontaminate and release to home
10,000 – 100,000	• Decontaminate and release to home
> 100,000	• Decontaminate • Evaluate for internal contamination • Consider medical countermeasures or further follow-up

Skin Doses

The equivalent beta dose (H_T) to skin is dose calculated to the basal layer of the skin (70 µm in depth). The contamination is assumed to be uniformly and thinly spread over the skin.

The gamma contribution to the dose rate is generally a few percent.

$$H_{T(skin)} = C_{skin} \times CF_{Beta-skin} \times t$$

C(skin) is the concentration of the material on the skin in Bq cm^{-1}

CF(beta-skin) is a conversion factor in (µGy hr^{-1})x(Bq cm^{-2})$^{-1}$

t is how long the contaminant was present on the skin in hours

Skin Contamination

Skin Dose Conversion Factors for Some Common Isotopes

Isotope	Dose Conversion Factor for Skin Contamination (μGy/h)/(Bq/cm^2)
F-18	1.9
Na-22	1.7
Na-24	2.2
P-32	1.9
S-35	0.35
K-40	1.5
Ca-45	0.84
Mn-56	2.4
Co-56	0.55
Co-60	0.78
Ni-65	2.2
Cu-67	1.3
Ga-66	1.6
Ga-68	1.8
Rb-87	1.9
Sr-89	1.8

Isotope	Dose Conversion Factor for Skin Contamination (μGy/h)/(Bq/cm^2)
Sr-90/Y-90	3.5
Y-90	2.0
Mo-99/Tc-99m	1.9
Ru-106/Rh-106	2.2
Ag-111	1.8
I-123	0.38
I-125	0.021
Cs-137	1.6
Ba-140/La-140	3.8
La-140	2.1
Ce-141	1.8
Ce-143	2.0
Ir-192	1.9
Tl-201	0.27
Tl-204	1.6
U-235	0.18

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Radiological Dispersal Device

Radiological Dispersal

METHODS OF DISPERSION

Radioactive materials may be dispersed over a large area via aerosol generation, physical spreading across a surface, or the more commonly-imagined explosion.

The primary concern with an explosive RDD will be the injuries caused by the blast and flying debris.

Summary of Isotopes of Concern

Source	Emission	Form	Size of Source	Likely Source Origin
Co-60	γ β	Metal	9.3×10^{2} TBq	Sample Irradiator
Sr-90	β	Ceramic	7.4×10^{2} TBq	RTG
Cs-137	γ β	Salt	2.6×10^{2} TBq	Blood Irradiator
Ir-192	γ β	Metal	3.7×10^{0} TBq	Industrial Radiography
Ra-226	α	Salt	4.0×10^{-1} TBq	Disused Medical Sources
Am-241	α	Ceramic	7.4×10^{-1} TBq	Well Logger

DOSE RATES FROM A DISPERSED SOURCE

Dose rates at one meter above a source uniformly distributed over an area

Area (m^2)	Cobalt-60 9.3×10^{2} TBq	Cesium-137 2.6×10^{2} TBq	Iridium-192 3.7×10^{0} TBq	Radium-226 4.0×10^{-1} TBq
1.0×10^{0}	2.39×10^{4}	1.40×10^{3}	4.10×10^{1}	8.32×10^{-2}
1.0×10^{1}	1.59×10^{3}	9.35×10^{1}	2.73×10^{0}	5.54×10^{-3}
1.0×10^{2}	3.17×10^{1}	1.87×10^{0}	5.45×10^{-2}	1.11×10^{-4}
1.0×10^{3}	4.76×10^{-1}	2.80×10^{-2}	8.17×10^{-4}	1.66×10^{-6}
1.0×10^{4}	6.34×10^{-3}	3.73×10^{-4}	1.09×10^{-5}	2.21×10^{-8}
1.0×10^{5}	7.93×10^{-5}	4.66×10^{-6}	1.36×10^{-7}	2.76×10^{-10}

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