Radiological Dispersal Device (RDD)

Radiological Dispersal Device:

Any method used to deliberately disperse radioactive material to create terror or harm. A dirty bomb is an example of an RDD. It is made by packaging explosives (like dynamite) with radioactive material to be dispersed when the bomb goes off.

What Is an RDD? A *radiological dispersal device (RDD)* is an unconventional weapon that a terrorist might use to destabilize a community, as described at right. Although often used to represent a dirty bomb, the radioactivity in an RDD could also be distributed passively (nonexplosively), such as through spraying or spreading by hand. Alternately, a *radiological exposure device (RED)* might be used, which would simply involve placing a radioactive source in a public area to expose people passing by.

Where Would the Radioactive Material Come From? Radionuclides are used in a variety of industry, medicine, and scientific research applications, as illustrated by the examples below. Many of these are in sealed sources, used in civil engineering (in flow gauges and to test soil moisture and material thickness/integrity for construction), in petroleum engineering (in well logging for oil exploration), in the airline industry (in fuel gauges and to check welds and structural integrity), in medicine (cancer treatment, pacemakers, and diagnostics), in homes (smoke detectors), and to make electricity (in radiothermal generators or RTGs, that generate power in remote areas ranging from lighthouses to outer space).

Examples of Radionuclides in Common Use

Medicine		Industry/Commerce				Science
Diagnosis	***Treatment***	***Energy, Defense***	***Testing, Production***	***Food, Agriculture***	***Home***	***Research***
Tracer, flow *(Tc-99m, I-131)*	Gamma knife, blood/tissue sterilization *(Cs-137, Co-60)*	Commercial electricity *(U, Pu)*	Nondestructive test of structural integrity, radiographic imaging *(Co-60, Ir-192)*	Food product sterilization *(Co-60)*	Smoke detector *(Am-241)*	High-energy physics *(Cf-252, U-235)*
Tissue scan for clot, mass *(Ga-67)*	Needle, seed implants *(Cs-137, Ir-192, Ra-226)*	Remote power *(Sr-90)*	Density, moisture gauges *(Am-241, Cs-137)*	Pest (fruit fly) sterilization *(Cs-137, Co-60)*	Luminescent watch/clock dial *(H-3)*	Biokinetics *(Pu, Sr-90, others)*
X-ray *(Cs-137, Co-60)*	Pacemaker *(Pu-238)*	Defense/weapons *(Pu, H-3, U and depleted U)*	Material thickness, flow, conveyor, level gauges *(Am-241, Cs-137, Co-60, Kr-85)*	Seed, spice sterilization *(Cs-137, Co-60)*	Gas camping lantern *(Th-232)*	Biological tracer, protein/synthesis *(C-14, H-3, N-15 P-32, S-35)*
Am-americium, C-carbon, Cf-californium, Co-cobalt, Cs-cesium, Ga-gallium, H-3-tritium, I-iodine, Ir-iridium, K-potassium, Kr-krypton, N-nitrogen, P-phosphorous, Pu-plutonium, Ra-radium, S- sulfur, Sr-strontium, Tc- technetium, Th- thorium, U-uranium.						

Radioactive sources can be portable or fixed, and most are quite small, ranging from tiny brachytherapy needles or seeds (implanted for localized cancer treatment) to thimble-sized plugs sealed within secure capsules for industrial gauges. Even the larger sources are fairly small; for example, the radioactive component of an RTG can range from the size of a roll of duct tape to a small wastebasket, although the outer housing can more than double the overall size. Most sources are encapsulated or sealed in housings of stainless steel, titanium, platinum, or other metal, and gamma emitters are encased in dense shielding (such as lead) to attenuate external gamma irradiation.

Only some of the materials identified above are considered likely RDD candidates, based on portability coupled with relatively high levels of radioactivity. Not of concern are those with minute amounts of radioactivity, e.g., smoke detectors, camping lanterns, or brachytherapy needles; these would not constitute a dispersal or exposure issue even if thousands were collected to extract their radioactive material. (Key radionuclides of concern for RDDs are described in the next section.) Radioactive waste from the nuclear power industry or legacy weapons facilities is also considered a possible source, with its attractiveness depending on the specific radionuclides in that waste, their physical and chemical forms, and levels of radioactivity. High-activity wastes (e.g., from nuclear energy reactors) are well controlled, and the largest volumes of radioactive waste typically contain relatively low concentrations, so these materials are generally considered a secondary concern for RDDs.

Which Radionuclides Are of Most Concern? Although dozens of radionuclides are used across various sealed sources (selected devices and associated sources are shown at right), only a small number are in concentrated amounts or are widely available. Nine isotopes of interest for RDDs are:

Source for medical teletherapy machine (1-in.diameter, within stainless steel housing) *(Cs-137, Co-69)*

Teletherapy machine

Source for industrial radiography device (like for medical unit) *(Co-60, Ir-192)*

Industrial radiography device

Source inside capsule at end of flexible cable *(Co-60, Ir-192; well logs also use Am-241, Cs-137)*

Well logging devices with source at tip

Russian radiothermal generators (RTGs) *(Sr-90)*

- Americium-241 *(Am-241)*
- Californium-252 *(Cf-252)*
- Cesium-137 *(Cs-137)*
- Cobalt-60 *(Co-60)*
- Iridium-192 *(Ir-192)*
- Plutonium-238 *(Pu-238)*
- Polonium-210 *(Po-210)*
- Radium-226 *(Ra-226)*
- Strontium-90 *(Sr-90)*

Basic radiological properties for these nine isotopes are summarized below. (Note: radium-226 exists in nature, as does a small amount of polonium-210; the rest are man made.)

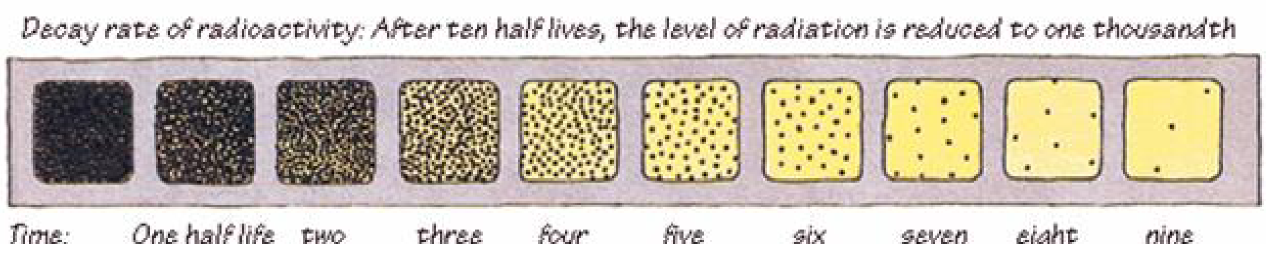
The specific activity of a radionuclide is inversely proportional to its half-life, as curies per gram (Ci/g). Unique to each isotope, it provides an indication of the rate at which that given radionuclide decays. Note that although iridium-192 has the highest specific activity among the nine, it decays to a stable isotope much more quickly than the others because its half-life is only 2.5 months. As a general rule of thumb, 7 to 10 half-lives can indicate how long an isotope could be expected to remain radioactive. (Less than 1% of the original amount remains after seven half-lives.) For example, if iridium-192 were dispersed, it would probably be gone within 2 years, while levels of cobalt-60 would drop to 1 percent within 40 years, but it would take cesium-137 more than 200 years to be reduced to the same level.

Basic Radiological Properties of Nine Key Radionuclides for RDDs

Isotope	***Half-Life*** *(years)*	***Specific Activity*** *(Ci/g)*	***Decay Mode***	***Radiation Energy*** *(MeV)*		
				Alpha (α)	***Beta*** (β)	***Gamma*** (γ)
Americium-241	430	3.5	α	5.5	0.052	0.033
Californium-252	2.6	540	α (SF, EC)	5.9	0.0056	0.0012
Cesium-137	30	88	β, IT	-	0.19, 0.065	0.60
Cobalt-60	5.3	1,100	β	-	0.097	2.5
Iridium-192	0.2 *(74 d)*	9,200	β, EC	-	0.22	0.82
Plutonium-238	88	17	α	5.5	0.011	0.0018
Polonium-210	0.4 *(140 d)*	4,500	α	5.3	-	-
Radium-226	1,600	1.0	α	4.8	0.0036	0.0067
Strontium-90	29	140	β	-	0.20, 0.94	-

SF = spontaneous fission; IT = isomeric transition; EC = electron capture. A hyphen means not applicable. The radiation energies for cesium-137 include the contributions of barium-137 metastable (Ba-137m), and those for strontium-90 include the contributions of yttrium-90.

This concept of half life is illustrated below (from the Uranium Information Center, Melbourne, Australia, www.uic.com.au/ral.htm):



Three of the nine isotopes considered candidates for an RDD are strong gamma-ray emitters: Cs-137 (from Ba-137m), Co-60, and Ir-192. These three could pose an external hazard to individuals who handle them (e.g., potential terrorists) if their protective shielding was removed or not used. In fact, it is precisely their gamma radiation that makes these three isotopes valuable for commercial and medical applications. Gamma emitters are used to sterilize food and equipment, irradiate tumors, nondestructively evaluate high-integrity welds and castings (industrial radiography), and in industrial gauges.

A fourth, Sr-90, emits beta particles and has limited but notable commercial uses. Like alpha emitters, beta emitters primarily represent an internal health hazard if ingested or inhaled. The major use of Sr-90 is in RTGs, and many of these were produced by the former Soviet Union to generate electricity in remote locations for applications such as lighthouses. The poor accountability for Soviet-era RTGs has been widely publicized, and they pose a considerable threat because they may contain tens of thousands of curies of Sr-90. Radioactive decay has substantially reduced initial levels of older RTGs, but levels in newer units could be much higher than 10,000 Ci. Summary information for these four isotopes in typical sealed sources is highlighted at left.

Selected Highlights for Typical Commercial Sources

Radionuclide	***Typical Form***	***Initial Activity** (Ci)*	
		Medical	***Industrial***
Cesium-137	Cesium chloride	0.01-10	10-1,000
Cobalt-60	Metallic cobalt or alloy	0.01-10	10-1,000
Iridium-192	Metallic iridium	0.01-10	10-1,000
Strontium-90	Strontium chloride, fluoride, titanate	1-10	1-10,000

The remaining isotopes are primarily alpha emitters: Am-241, Cf-252, Po-210, Pu-238, and Ra-226. Alpha particles are easily shielded with only minimal amounts of material, so they do not pose a significant external health hazard. Rather, their significance relates to health concerns if ingested or inhaled. In addition, Am-241 is commonly mixed with beryllium to produce a neutron-emitting source. Similarly, Cf-252 emits neutrons through spontaneous fission. Neutron emitters represent both an external and internal health hazard. Among other applications, alpha or neutron emitters have been used in soil moisture/density gauges, medical pacemakers, and well logging gauges used in the petroleum industry.

How Dispersible Would these Radionuclides Be? Dispersibility will depend on the physical and chemical properties of the radioactive material used in an RDD. Metallic forms would be difficult to disperse while a powder could be dispersed fairly readily. Common forms of radionuclides in sealed sources are shown on the next page. Cobalt, iridium, and polonium generally exist as solid metals and would not be readily dispersible. Several of the others, including americium, californium, and plutonium, are typically oxides that could exist as a powder. Cesium is typically found as cesium chloride, which is also a powder and is quite soluble in water. Radium and strontium are used in various forms; strontium fluoride in certain sealed sources is sintered such that it is essentially insoluble and nondispersible. Even considering the forms in current sources, the specific physical and chemical characteristics of radioactive materials that could be in an RDD is uncertain because the original material could be chemically or physically altered (weaponized) to enhance dispersal. If the dispersal method is explosion via a dirty bomb, that would also likely physically and chemically alter the materials to produce a mixture that could include oxides as well as nitrates (from the explosives) over a range of particle sizes.

Chemical Forms of Radioactive Materials Often Found in Sealed Sources	
Radionuclide	***Form***
Americium-241	Americium oxide; americium-beryllium (AmBe) neutron sources are typically compressed powders
Californium-252	Californium oxide
Cesium-137	Cesium chloride
Cobalt-60	Metallic cobalt, or cobalt-nickel alloy
Iridium-192	Metallic iridium
Plutonium-238	Plutonium dioxide, generally pressed into a ceramic-like material
Polonium-210	Metallic foil
Radium-226	Radium bromide or radium chloride
Strontium-90	Metallic strontium, strontium chloride, strontium-fluoride, strontium-titanate

What Would the Response to an RDD Involve? The response to an RDD event would consist of several phases. The first phase would involve immediate life-saving measures, such as treating blast victims and evacuating areas as indicated (e.g., based on radioactivity levels). The second phase would involve evaluating the extent of contamination and taking measures to control further contamination and minimize human exposures. The last phase would involve recovery and cleanup efforts, including decontamination and remediation of contaminated property.

As background on potential health effects, evidence linking radiation exposure to observable biological effects has only been found at relatively high doses, i.e., acute doses exceeding 25 rads (see below). (For context, natural background radiation translates to an average annual dose of about 0.3 rem, which is far below the threshold for acute effects and corresponds to a lifetime risk of about 1 in 100.) On average, about half of all cancers that can be induced by radiation are fatal; this ranges from about 10% for thyroid cancer to essentially 100% for liver cancer. An RDD would most likely result in relatively small radiation exposures, which overall might not substantially differ from an annual background dose. But in the unlikely event someone was highly exposed, chelation therapy (to enhance excretion) and other medical interventions could be pursued, including to limit internal deposition.

Threshold Doses for Prodromal Effects	
***Dose** (rads)*	***Indicator Effects***
50	Blood count changes
100	Nausea, vomiting, appetite loss, malaise, and fatigue
200	Diarrhea or bloody diarrhea
300	Epilation (hair loss)
500	Erythema (skin reddening)

The degree of decontamination for a given area would depend on conditions specific to that setting. Federal, state and local officials are developing emergency response plans, but a common set of numerical standards for RDD cleanup has not been established. Although various radiation regulations would be used as guides, none are directly applicable to RDD scenarios. More than 10 years ago, in its manual of protective actions guides (PAGs), EPA identified nonbinding recommendations for responses in the early and intermediate stages of a radiological emergency. However, these PAGs were developed for accidents at nuclear power plants and not for incidents of radiological terrorism. Specifically the PAGs do not contain guidance for the long-term phase, final cleanup.

The Department of Homeland Security has formed an interagency working group that includes representatives from eight Federal departments and agencies to develop new guidance for cleaning up after any RDD attack. Recommendations are expected to include use of the EPA PAG values for radiation exposure in the early and intermediate stages of a radiological terrorist attack. For the cleanup of areas contaminated by an RDD, rather than using a single numeric guideline that would not be able to account for all settings, it is expected that local stakeholders and decision makers would follow a process to develop cleanup plans tailored to the specific characteristics of the given situation, considering optimization approaches. Thus, residual radionuclide concentrations would be expected to vary from case to case, and there will not likely be a uniform, generic cleanup level.

Illustrative Case Study: 1987 Radiological Accident in Goiania, Brazil

In September 1987, a hospital in Goiania, Brazil, moved to a new location and left its radiation cancer therapy unit behind. Found by scrap metal hunters, it was dismantled and the cesium chloride source containing 1,400 Ci of cesium-137 was removed. Pieces were distributed to family and friends, and several who were intrigued by the glow spread it across their skin. Eleven days later, alert hospital staff recognized symptoms of acute radiation syndrome in a number of victims.

The ensuing panic caused more than 112,000 people – 10% of the population – to request radiation surveys to determine whether they had been exposed. At a makeshift facility in the city's Olympic Stadium, 250 people were found to be contaminated. 28 had sustained radiation-induced skin injuries (burns), while 50 had ingested cesium, so for them the internal deposition translated to an increased risk of cancer over their lifetime. Tragically, 2 men, 1 woman, and 1 child died from acute radiation exposure to the very high levels of gamma radiation from the breached source.

In addition to the human toll, contamination had been tracked over roughly 40 city blocks. Of the 85 homes found to be significantly contaminated, 41 were evacuated and 7 were demolished. It was also discovered that through routine travels, within that short time people had cross-contaminated houses nearly 100 miles away. Cleanup generated 3,500 m^3 radioactive waste at a cost of $20 million.

The impacts of this incident continued beyond the health and physical damage to profound psychological effects including fear and depression for a large fraction of the city's inhabitants. Further, frightened by the specter of radioactive contamination, neighboring provinces isolated Goiania and boycotted its products. The price of their manufactured goods dropped 40% and stayed low for more than a month. Tourism, a primary industry, collapsed and recent population gains were reversed by business regression. Total economic losses were estimated at hundreds of millions of dollars. A key lesson learned from this incident is the importance of enhancing the broader understanding of radiation. This fact sheet is intended to help support that objective.

(For additional information see: International Atomic Energy Agency (IAEA), 1988, *The Radiological Accident in Goiania*, Vienna, Austria.)




Where Can I Find More Information about RDDs? In the last several years, a number of reports, studies, articles, and books have been published that discuss issues related to RDDs. An introduction to selected resources follows; this list is not intended to be comprehensive.

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