RESEARCH REPORT

Radioactive Materials Security

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INTRODUCTION

The focus of much of international terrorism in the last decade or so has been on causing mass casualties – trying to kill as many people as possible in as spectacular a manner as possible. This focus on deaths may be one reason that there have been no incidents of radiological terrorism in spite of evidence that such attacks have been contemplated. The fact that radiological terrorism has been repeatedly referred to as a "weapon of mass disruption" and that the science behind radiation health effects is so well-disseminated (and those health effects so easily calculated) may well have convinced terrorist groups that it simply is not an effective way of causing mass numbers of casualties, absent very high-activity sources and a plausible way to obtain and "weaponize" them. Through programs such as the National Nuclear Security Administration's (NNSA) Global Threat Reduction Initiative (GTRI) the United States is well on its way to securing the most dangerous radioactive sources, making them a much less attractive target for prospective terrorists or criminal organizations – even when they are held at so-called "soft targets" such as hospitals and universities.

There still remains the possibility that terrorist or criminal organizations might try to obtain radioactive materials to spread about as an agent of fear – using a style of attack that, while non-lethal, carries with it the ability to terrify the population. Attacks such as these might make radioactive terrorism more attractive because of the fear that radiation induces among members of the public. It may be appropriate, then, to characterize radioactive materials not only by the health threat they pose but to include the overall risk posed to society by the use of radioactive materials to deny access to important areas, to cause economic damage, or to sow fear in society.

Obviously, regardless of the "endpoint" aimed for by terrorist or criminal organizations, not all radioactive materials should be treated the same. Smoke detectors, for example, contain very low levels of radioactivity and the risk they pose – even considering their potential use in a terrorist attack – is dwarfed by their benefit to society. Similarly, the small quantities of radionuclides used in biological and medical research make for poor weapons while producing a tremendous positive value to society. Such materials should not be subjected to the same level of scrutiny as, say, radioactive sources used in well logging (radioactive sources are often lowered into boreholes to help locate water or hydrocarbon deposits and to determine the characteristics or the rock through which the hole was drilled). Along these same lines the low-activity radioactive sources that are locked within pieces of equipment (gas chromatographs or soil density gauges, for example) may not require the same level of security as sources used to calibrate some kinds of radiation detectors.

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On November 14, 2005 the Nuclear Regulatory Commission published an Order Imposing Increased Controls that specified security precautions aimed at reducing the risk that a dangerously radioactive source might be stolen and used for malicious purposes. These controls, however, do not address the large number of radioactive sources that can be used to frighten or to deny access to territory as opposed to causing physical harm. For these, the regulatory guidance is given in the Code of Federal Regulations, Title 10, Part 20:

10 CFR 20.1801 Security of stored material.
The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas.

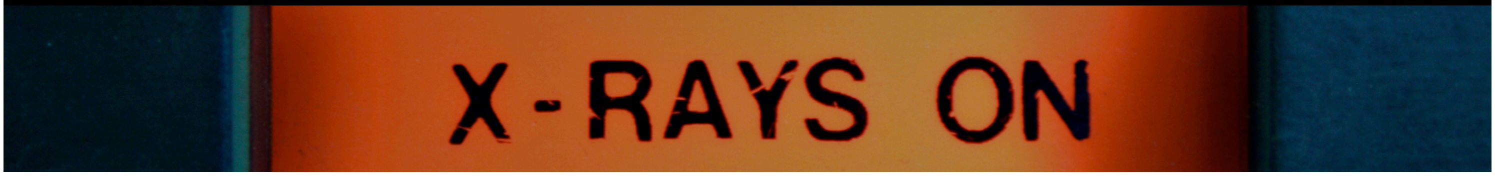
This regulatory requirement is admirably brief and non-prescriptive. Unfortunately it is also open to widely variable interpretation. For example, as an academic/ medical Radiation Safety Officer my stance was that minor quantities of radioactive materials – quantities used in most research laboratories – needed to be kept in locked rooms or locked freezers as long as they were concentrated in small "stock vials" but that radioactive waste containers only needed to be stored in marked containers. My rationale was that the paper towels, latex gloves, test tubes, and other miscellanea that comprised the bulk of laboratory radioactive waste posed virtually no threat because it was so diffuse a source of radioactivity and because the containers were too bulky to easily smuggle out of the building. My regulators concurred with this assessment, but those of some of my RSO colleagues did not – there were some inspectors who felt that "every regulated atom" needed to be kept secured under lock and key. There was a similar difference of opinion when it came to low-activity radioactive sources contained within laboratory equipment such as gas chromatographs. This lack of consistency stems in part from the absence of agreement on what levels of radioactivity – and what form that radioactivity is in – pose a threat to the public health and welfare.

There are a number of factors that make a radioactive source more or less attractive to a malicious organization; which of these factors are most relevant depends on the use to which the source is to be put. For example, a group determined to cause radiation-related death and illness among many people would likely place more of an emphasis on the total amount of radioactivity in a source and on the type of radioactivity emitted; a group interested in denying use of an area might place more of an emphasis on dispersibility and ease of concealment. Some of these characteristics are described below and are summarized in the accompanying table. It may be prudent to consider these characteristics when developing more nuanced source security guidelines.

- **Source activity** – high-activity sources can cause more harm and can contaminate larger areas; but are more dangerous to work with and are more difficult to conceal
  - **High activity** – sources contain enough radioactivity to cause harm or death to those exposed under normal conditions such as taking a bus (e.g. 100 Ci Co-60 radiography source)
  - **Moderate activity** – sources contain enough radioactivity to cause lethal exposure under extraordinary circumstances or to cause injury (e.g. the Po-210 used to murder Alexander Litvenenko)
  - **Low activity** – sources are unable to cause injury (e.g. 1 mCi vial of tritium used for research)

- **Innate dispersibility** – sources that are powdered and soluble are more easily dispersible without processing; solid and insoluble radioactive materials are often easier to handle without spreading contamination
  - **High innate dispersibility** – source material is powdered or liquid and is easily accessible without specialized equipment (e.g. syringes filled with I-131 intended for nuclear medicine)
  - **Moderate innate dispersibility** – dispersing the source material requires specialized equipment or skills (e.g. Cs-137 in ceramic form inside a welded source capsule)
  - **Low innate dispersibility** – source material is in solid form (ceramic or metal alloy) that cannot be dispersed without substantial processing (e.g. a metal alloy Ir-192 radiography source)

- **Type of radiation emitted**
  - **Alpha radiation –** least penetrating and easiest to conceal, most damaging when in contact with living cells, lowest cleanup limits
  - **Beta radiation –** moderately penetrating (but still easily shielded), less damaging to living organisms, often has the highest cleanup limits
  - **Gamma radiation –** highly penetrating, difficult to conceal, cleanup limits similar to beta-emitting radionuclides



- **Ease of cleanup** – radionuclides with lower cleanup limits require a higher remediation effort and higher cost
    - **Easy cleanup** – cleanup limits are relatively high, typical physical and chemical form are amenable to remediation (e.g. spilled Tc-99m in a medical center, which can be easily wiped up or allowed to decay)
    - **Moderately easy cleanup** – cleanup limits are moderate, typical physical and chemical forms can be remediated, albeit with some difficulty (e.g. spilled I-131, which can seep into cracks or pores and chemically bonds to surfaces)
    - **Difficult cleanup** – cleanup limits are low, radionuclide adheres tenaciously to surfaces or saturates the volume of contaminated materials (e.g. Am-241, which has very low cleanup levels and is often in a physical form that is difficult to remediate)

- **Ease of concealment** – radionuclides that are easy to conceal can be smuggled more easily, but typically are more difficult to administer in a manner that will cause harm
    - **Easy to conceal** – radiation emitted is easy to shield, physical size of sources plus shielding is relatively small and innocuous (e.g. the Po-210 that was used to murder Alexander Litvenenko and could be concealed in a pharmaceutical capsule)
    - **Moderately easy to conceal** – radiation emitted is more penetrating and requires more extensive shielding (e.g. Sr-90, which requires at least 1 cm of plastic shielding)
    - **Difficult to conceal** – radiation emitted is very penetrating, requiring bulky or heavy shielding (e.g. Cs-137, which might require several hundred pounds of lead to reduce gamma radiation to undetectable levels)

- **Availability** – an isotope cannot be used unless it can be obtained; in general, the more readily available an isotope is, the less harm it can inflict (e.g. smoke detectors are readily available but are difficult to weaponize); sources that are in common use or that do not require a radioactive materials license to obtain are more available than those that must be licensed or stolen from secure facilities
    - **Easily available** – source is in common use (possibly at locations with minimal security), source is relatively easy to steal, can be obtained without a radioactive materials license (e.g. 1 μCi Am-241 smoke detector source)
    - **Moderately easily available** – source requires a radioactive materials license to purchase legally, is typically found in secured locations, but is not normally found in quantities requiring Increased Controls (e.g. 10 Ci Cs-137 well logging source)
    - **Available with difficulty** – source requires a radioactive materials license to purchase and falls under Increased Controls regulations, including need for background check and enhanced security precautions (e.g. 1000 Ci Cs-137 blood irradiator)

- **Potential lethality** – some sources are more likely to be lethal than others due to the type of radiation emitted, source activity, ability to become lost, etc. – for example, radiography sources have caused a number of deaths around the world while process control gauges typically have too little radioactivity to cause harm
    - **Highly lethal** – sources that, if dispersed maliciously, can cause hundreds of deaths (or more) and that likely have caused deaths in the past (e.g. high-activity sources of Cs-137 or of most alpha-emitting radionuclides)
    - **Moderately lethal** – sources that, if dispersed maliciously, can cause up to tens of deaths (e.g. moderate-activity sources of Cs-137, high-activity sources of Co-60)
    - **Low lethality** – sources that are unlikely to cause deaths (e.g. smoke detector sources, soil density gauges)

The following table gives some qualitative examples of a variety of types of radioactive materials and how they compare using the characteristics noted above. It must be noted that this table is qualitative in nature, primarily because there is tremendous variability within each category of sources. This table can help to compare categories of sources but a more detailed analysis is required to develop a quantitative assessment of the risk in each source category.

Source	**Activity**	**Innate Dispersibility**	**Type of Radiation**	**Ease of cleanup**
Smoke detector	Very low	Very low	Alpha	Moderate
Research stock vial	Low	High	Beta	Very easy
Lab equip.	Very low	Low	Beta, gamma	Moderate
Blood irradiator	Very High	Moderate – high	Gamma	Difficult
Industrial radiography	high	Moderate - high	Gamma	Difficult
Soil density gauge	Low	Low	Alpha, gamma, neutron	Moderate
Process control gauge	Low	Low	Beta, gamma	Easy
Well logging	Moderate	Moderate	Alpha, gamma	Difficult
Radiopharmaceuticals	Low – moderate	Very high	Beta, gamma	Easy
Radiation oncology	Moderate to very high	Low to high	Gamma	Difficult to very difficult

Ease of concealment	Availability	Potential lethality	Overall Threat
Very easy	High	Very low	Very low
Very easy	Moderate	Very low	Very low
Easy	Moderate	Very low	Very low
Difficult	Moderate	Very high	Very high
Easy	Moderate	High	Very high
Easy	Moderate	Low	Low
Very easy	Moderate	Low	Low
Easy	Moderate	Moderate to high	Moderate
Easy	High	Low	Moderate
Easy to moderate	High	High	High

Summary and conclusions

It makes sense to require the highest level of controls over the sources most likely to be targets for theft and that can do the most harm (or cause the greatest societal and financial impact) if stolen and used maliciously. Thus, a process control gauge, having a low level of radioactivity, low potential lethality, low innate dispersibility, etc. poses little threat and may not require the same level of security as a radiopharmaceutical delivery vehicle that is filled with highly dispersible radionuclides (albeit with shorter half-lives). Similarly, radioactive waste containers at most research institutions contain little radioactivity and the bulk of that is not highly dispersible – such containers may be aesthetically displeasing but do not pose a threat to the public health or welfare.

While there is general agreement among radiation safety professionals regarding the relative risks posed by various radioactive materials (including sources) those who are responsible for managing radiation safety programs do not typically report to supervisors who are as knowledgeable. In addition, the current regulations – as written – do not provide unambiguous guidance that can be used to help radiation safety professionals work with their management to provide appropriate security for an organization's radioactive materials. This same unambiguous guidance will also help to ensure a common set of standards among inspectors from regulatory agencies. Accordingly, it seems reasonable to suggest that clear and unambiguous guidance – perhaps in the form of a "Best Practices Manual" on this topic – be provided to radioactive materials licensees that provides advice on appropriate security measures for a variety of radioactive materials types and threat levels.

Terminology

Alpha radiation – heavy particles emitted from unstable atoms; alpha particles are a high threat if ingested or inhaled and are a low risk if they remain outside the body
Beta radiation – light particles emitted from unstable atoms; beta particles are a moderate risk if ingested or inhaled and can cause skin burns (but no internal injury) if they remain outside the body
Contamination – the presence of radioactivity in a place where it is neither expected nor desired; contamination can be cleaned up
Curie – a measure of the rate at which radiation is emitted from radioactive materials; 1 Ci of radioactivity will undergo 37 billion radioactive decays per second
Dose (radiation) – a measure of the amount of energy deposited in the body from being exposed to radiation; this energy can go on to cause radiation sickness or cancer
Gamma radiation – high-energy photons emitted by unstable atoms; gamma rays are highly penetrating and cause low to moderate damage to cells
Half-life – the amount of time required for 50% of radioactive atoms to decay; after 10 half-lives the remaining radioactivity is about 0.1% of the original radioactivity
Increased Controls – regulatory requirement for higher levels of security for radioactive sources felt to pose a greater risk of theft or use by terrorists
Rad – a measure of the amount of energy deposited in an object from radiation
Radiation – the transfer of energy from one place to another; in the case of radiation safety the energy is transferred from an unstable atom or a radiation-emitting device (e.g. x-ray machine) via the emission of particles (alpha or beta) or photons (x-ray or gamma ray)
Radioactivity – the presence of unstable atoms that achieve stability by emitting radiation; radioactivity is an inherent property of some atoms
Rem – a measure of the biological damage caused by radiation, accounting for the fact that some forms of radiation (e.g. alpha) are more damaging to the body than are others

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