U.S. Nuclear Regulatory Commission Initial Consequence Assessment
for a Postulated U.S. Government Accountability Office
Radiological Dispersal Device Event
June 18, 2007

Background

On May 29, 2007, the U.S. Government Accountability Office's (GAO's) Forensic Audits and Special Investigations (FSI) team informed the Nuclear Regulatory Commission (NRC) staff that it was able to fraudulently obtain a license from the NRC on March 5, 2007, then alter the license quantities (total authorized amount) to obtain quotes for the purchase of a total of 45 moisture density gauges from two vendors. Each moisture density gauge could contain a maximum of 1.85 GBq (50 mCi) of Am-241 and 0.37 GBq (10 mCi) of Cs-137, which is an International Atomic Energy Agency (IAEA) Category 4 quantity[1]. The aggregated amount of radioactive material in the 45 devices is 83.3 GBq (2.25 Ci) Am-241 and 16.7 GBq (0.45 Ci) Cs-137 which constitutes an IAEA Category 3 quantity for Am-241 and an IAEA Category 5 quantity for Cs-137.

In further discussion with NRC staff on June 1, 2007, GAO indicated that individuals seeking to do harm could have completed the purchases, obtained the material, and constructed device(s) to disperse the materials in aerosol form in a high population area. GAO observed that such an event would require significant clean-up efforts.

The IAEA defines risk in the event that the radioactive material in a Category 3 source is dispersed by fire or explosion as:

> "This amount of radioactive material, if dispersed, could possibly - although it would be extremely unlikely - permanently injure or be life threatening to persons in the immediate vicinity. There would be little or no risk of immediate health effects to persons beyond a few metres away, but contaminated areas would

[1] International Atomic Energy Agency, Safety Standards, "Categorization of Radioactive Sources," Safety Guide No. RS-G-1.9, August 2006. The IAEA describes the risk of a Category 4 source as:

> "Unlikely to be dangerous to the person: It is very unlikely that anyone would be permanently injured by this source. However, this amount of unshielded radioactive material, if not safely managed or securely protected, could possibly - although it would be unlikely - temporarily injure someone who handled it or who was otherwise in contact with it for many hours, or who was close to it for a period of many weeks. This amount of radioactive material, if dispersed, could not permanently injure persons."

The IAEA describes the risk of a Category 3 source as:

> "Dangerous to the person: This source, if not safely managed or securely protected, could cause permanent injury to a person who handled it or who was otherwise in contact with it for some hours. It could possibly - although it would be unlikely - be fatal to be close to this amount of unshielded radioactive material for a period of days to weeks."

The NRC and Agreement States have , since July 2006, increased the security for IAEA Code of Conduct Category 1 and 2 quantities of radioactive material.

need to be cleaned up in accordance with international standards. The area to be cleaned up would probably not exceed a small fraction of a square kilometre.[2]"

Discussion

The consequences of a malevolent release of 83.3 GBq (2.25 Ci) Am-241 and 16.7 GBq (0.45 Ci) of Cs-137 (IAEA Category 3 quantities) obtained from 45 portable moisture density gauges are highly dependent on the scenario and a number of variables, including the dose calculation methodology. It should be noted that because of the many variables and uncertainties about actual conditions, doses to individuals within a few hundred meters from radiological dispersal are difficult to accurately estimate.

Based on dose modeling using Hotspot 2.0[3] for an explosive dispersal scenario, it would be unlikely that anyone more than 75 meters (69 yds) away from the release would get a dose exceeding the Department of Homeland Security (DHS) Protective Action Guides (PAGs) for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents[4] of 0.01 Sv (1 rem) projected Total Effective Dose Equivalent (TEDE) for the early phase on an event. The contaminated area [exceeding the Federal Radiological Monitoring and Assessment Center (FRMAC) derived response levels for the intermediate phase PAGs, 0.02 Sv/yr (2 rem/yr)], that would be considered for relocation of personnel could extend out to about 60 meters (55 yds) in the downwind direction. The area that would be considered for decontamination may extend out to about 130 meters (119 yds) in the downwind direction. To put these dose consequences in perspective, the NRC's regulation, Title 10 Code of Federal Regulations Part 20, Section 1201, allows a radiation worker to receive up to 0.05 Sv/yr (5 rem/yr) total effective dose equivalent.

While GAO mentioned only a general event to disperse the materials in aerosol form, the NRC staff postulated a liquid aerosol release (sprayer) scenario as a hypothetical event that could have the potential for more significant radiological doses. Based on calculations using both

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[2] The size of the area to be cleaned up would depend on many factors, including the activity, the radionuclide, how it was dispersed, and the weather.

[3] http://www.llnl.gov/nhi/hotspot The Hotspot Health Physics codes, developed by Lawrence Livermore National Laboratory, were created to provide emergency response personnel and emergency planners with a fast, field-portable set of software tools for evaluating incidents involving radioactive material. Hotspot codes estimate the downwind radiological impact following the release of radioactive material resulting from a continuous or puff release, explosive release, fuel fire, or an area contamination event using a hybrid of the well-established Gaussian plume model.

[4] The Department of Homeland Security Protective Action Guides for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents; Published in the Federal Register on January 3, 2006, for interim use and comment. (71 FR 174)

RASCAL 3.0[5] and Hotspot 2.0 dose modeling tools, it may be possible for persons directly in the plume to receive doses via the inhalation pathway that exceed the DHS IND/RDD Early Phase PAGs of 0.01-0.05 Sv (1-5 rem). For this case, inhalation doses exceeding the annual dose for a radiation worker, 0.05 Sv (5 rem), are not likely to be exceeded beyond about 800 meters (0.5 mi). However, it may be possible for persons, exposed during the entire passage of the plume, to receive a dose exceeding the DHS IND/RDD Early Phase PAG of 0.01 Sv (1 rem) TEDE at distances as far out as about 4.8 km (3 mi) in the downwind direction. The extent of the contaminated area that would be considered for decontamination may extend out to about 160 meters (0.1 mi) in the downwind direction. It should be noted that these dose estimates are highly dependent on the liquid aerosol generated by the sprayer. A larger aerosol particle size distribution than assumed in the calculation, would drastically reduce the estimated inhalation doses.

Finally, a dose assessment for exposure in a contaminated urban area using RESRAD,[6] version 6.1, July 7, 2001, in deterministic mode was performed. Two scenarios were analyzed for 83.3 GBq (2.25 Ci) Am-241 and 16.7 GBq (0.45 Ci) of Cs-137 (the aggregate amount of radioactive material in the 45 devices GAO could have purchased) uniformly distributed as an aerosolized solution. Both scenarios assume that an individual does not live in the contaminated area.

- In the first scenario, an individual spends 2 hours/day (0.05 years) outdoors in the contaminated area (going to/from work and lunch). (Table 1.)

- In the second scenario, an individual spends 2 hours/day (0.05 years) outdoors in the contaminated area (going to/from work and lunch) and works inside in the contaminated area, on the first floor of a building (which provides some shielding), 40 hours/week (0.24 years). (Table 2.)

The RESRAD model calculations indicate that the inhalation pathway is not an important contributor to dose for material deposited outdoors. The majority of the dose is external dose due to Cs-137 (approximately 2000 times that for the Am-241 dose). The contribution from internal dose is negligible. For both scenarios, the area of contamination that could result in a 0.02 Sv (2 rem) annual dose (DHS IND/RDD Intermediate Phase PAGs) is less than the 0.5

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[5] NUREG-1741, "RASCAL 3.0: Description of Models and Methods," February 2001. The Radiologic Assessment System for Consequence AnaLysis (RASCAL) 3.0 is the latest version of the RASCAL series of codes. RASCAL was developed for use by U.S. Nuclear Regulatory Commission personnel who conduct an independent assessment of radiological accidents to prepare dose projections. Agency wide Documents Access and Management System (ADAMS) Number ML010940218

[6] NUREG/CR-6692, "Probabilistic Modules for the RESRAD and RESRAD-BUILD Computer Codes, User Guide," October 2000. RESRAD and RESRAD-BUILD codes are part of the RESRAD family of codes developed by the U.S. Department of Energy. For many years these deterministic codes have been used as dose assessment tools for cleanup efforts at sites contaminated with radioactive materials. The RESRAD code applies to the cleanup of soil, and the RESRAD-BUILD code applies to the cleanup of buildings and structures. Agency wide Documents Access and Management System (ADAMS) Number ML003774030

km^2 (0.2 mi^2) criterion used in the DOE and NRC RDD report,[7] which was later used to support the technical basis for the IAEA Code of Conduct[8] and NRC's enhanced security measures.

Table 1. Uniform Dispersal Using RESRAD		
Scenario 1 - Continuously Exposed for .05 year		
Dispersal Area (km^2)	Area Radius (m)	Annual Dose (mrem/yr)
0.5	400	2
0.4	360	3
0.3	310	4
0.2	250	6
0.1	180	12
0.01	56	100
0.001	18	726

[7] "Radiological Dispersal Devices: an Initial Study to Identify Radioactive Materials of Greatest Concern and Approaches to Their Tracking, Tagging, and Disposition, Report to the Nuclear Regulatory Commission and the Secretary of Energy," May 2003. Agency wide Documents Access and Management System (ADAMS) Number ML070380440

[8] International Atomic Energy Agency, "Code of Conduct on the Safety and Security of Radioactive Sources," January 2004.

Table 2. Uniform Dispersal Using RESRAD		
Scenario 2 - Continuously Exposed for 0.05 year outdoors and 0.24 year inside a building in the contaminated zone		
Dispersal Area (km^2)	Area Radius (m)	Annual Dose (mrem/yr)
0.5	400	7
0.4	360	13
0.3	310	18
0.2	250	26
0.1	180	52
0.01	56	437
0.001	18	3162

Conclusion

If the objective of the malevolent action is to achieve high radiation doses to individuals via the inhalation pathway, then the dispersal of a given amount of radioactive material must be kept in relatively high concentrations. Thus, the area of significant contamination requiring cleanup will be relatively small. Alternatively, if the objective of the malevolent action is to achieve widespread contamination, then the given amount of radioactive material would be highly dispersed into relatively low concentrations. Thus, the radiological dose to individuals will also be relatively small. What Tables 1 and 2 illustrate is that the more radioactive material is dispersed, the smaller the radiological dose will be to individuals. Hence, the more the radioactive material is dispersed, the more likely that it will be of little or of no risk of immediate health effects and only small areas may be required to be cleaned up.

This assessment does not speculate about the likelihood of occurrence or achieving success of any of the postulated scenarios. As with any speculative assessment, there is a range of unknown factors on which a value is based. This assessment is intended to capture a range of realistic yet conservative assumptions, but does not bound every factor or condition for the hypothetical scenarios.

For a hypothetical malevolent dispersal of 83.3 GBq (2.25 Ci) Am-241 and 16.7 GBq (0.45 Ci) of Cs-137 (IAEA Category 3 quantities), there would be little or no risk of immediate health effects to persons beyond a few meters away from the release point. Contaminated areas would need to be cleaned up in accordance with the Department of Homeland Security Protective Action Guides. The area to be cleaned up would probably not exceed a small fraction of a square kilometer.

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Approval (DSP) Date

Adams Accession No. ML071690552