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Consequence Assessment for Potential Scenarios of Radiological Terrorists Events

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1. Introduction

Radiological dispersal device (RDD) means any method used to deliberately disperse radioactive material to create terror or harm. Dirty bomb is an example of RDD, which usually consists of radioactive material and unconventional explosive [1].

Dirty bomb was a problem long before September 11, 2001. In 1987, the Iraqi government tested a one-ton radiological bomb. The Iraqi tests confirmed that a dirty bomb is not effective as weapons of mass destruction (WMD) and that its main value is as a psychological weapon. In 1995, Chechen rebels buried a dirty bomb in a park in Moscow threatening to detonate one in the future if their demands were not met. Another good example of potential dirty bomb effects was an incident in Goiania, Brazil on September 18, 1987, where an orphaned medical source containing 1,375 Ci of Cs-137 resulted the death of four people and extensive environmental contamination.

The purposes of radiological terrorists events are not to destroy or damage the target but to disperse radioactivity in the environment. They inflict panic on a public and economic damage by disruption of business. They also have influence on enormous clean-up costs by spreading radioactive contamination including secondary impacts on water supply reservoirs. Generally, two major long-term concerns following a RDD are human health and economic impacts.

In this study, we developed potential scenarios of radiological terrorists events and performed their radiological consequence assessments in terms of total effective dose equivalent (TEDE), projected cumulative external and internal dose, and ground deposition of radioactivity.

2. Methods and Results

Although dozens of radionuclides are available in the world, only a relatively small set of them is considered attractive or producing an RDD. Likely RDD candidates are selected based on portability, relatively low security (readily obtainable), relatively high levels of radioactivity, and physical and chemical forms. Nine key radionuclides selected are Am-241, Cf-252, Cs-137, Co-60, Ir-192, Pu-238, Po-210, Ra-226, and Sr-90 based on the relative hazard of each type of radioactive source [2]. Characteristics of nine key radionuclides are shown in Table 1.

The effectiveness of the terror attack depends on how effectively the radioactive materials are dispersed. A dirty bomb detonated upwind of the selected target area can be as effective as one placed in the immediate vicinity. Dispersibility of RDD depends on the physical and chemical properties of the radioactive material. Metallic forms would be difficult to disperse. For example, cobalt and iridium are generally used in solid metallic form and therefore are not readily dispersible. In contrast, powdered forms would be most effectively dispersed by an RDD, and soluble chemical forms would be most likely to impact water systems. Cs-137 is often found in an ideal form for dispersal. But any form such as a solid metal can be reduced to a powder by easily obtained mechanical or chemical methods. It should be assumed that maker of a dirty bomb has converted the material to an easily dispersed powder.

Table 1. Key radionuclides of concern for RDD events

Isotope	Half-Life (years)	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
				Alpha (α)	Beta (β)	Gamma (γ)
Am-241	430	3.5	α	5.5	0.052	0.033
Cf-252	2.6	540	A (SF, EC)	5.9	0.0056	0.0012
Cs-137	30	88	β, IT	N/A	0.19, 0.065	0.60
Co-60	5.3	1,100	β	N/A	0.097	2.5
Ir-192	0.2	9,200	β, EC	N/A	0.22	0.82
Pu-238	88	17	α	5.5	0.011	0.0018
Po-210	0.4	4,500	α	5.3	N/A	N/A
Ra-226	1,600	1.0	α	4.8	0.0036	0.0067
Sr-90	29	140	β	N/A	0.20, 0.94	N/A
SF=spontaneous fission; IT=isomeric transition; EC=electron capture						

The goal of emergency response training is to prepare the responders to effectively mitigate the consequences of the hazardous material released. Responders should be trained through a combination of tabletop exercises, field exercises, and classroom instruction. One of important objectives of developing realistic RDD scenarios is the development of drill and exercise data to be used in tabletop exercises of emergency response training. Because unrealistic scenarios would result in poor training and poor performance, dirty bomb scenarios must be based on the more probable source terms, not extremely unlikely cases, to provide effective training and risk communications.

The most likely sources to be used for a dirty bomb are those that are easily stolen such as density gauges, well logging sources, radiography sources, and medical sources. These have relatively low levels of security when compared to special nuclear material (SNM; U-

235, U-233, Pu-239, etc.). Likely explosives are TriNitroToluene (TNT), Ammonium Nitrate/Fuel Oil (ANFO), and plastic explosives such as Semtex, C-3, C-4, etc.

In developing realistic RDD scenarios, factors to be considered and to play a significant role in the extent of impacts are: 1) How radioactive contamination is released to the environment; spilled on the ground or fire by transportation accident or explosion by a few pounds of high explosive (HE), 2) Atmospheric condition; higher ground concentration, therefore a bigger long-term problem, would be due to stable weather, precipitation events, and larger particle sizes of the aerosolized material, 3) Physical and chemical form of materials released.

In order to perform consequence assessments of potential RDD scenarios, Hotspot code is selected [3]. Its unique advantages as a radiological emergency response code include some capabilities to model the dispersal of radioactive material due to an explosion, to display contamination levels in units that emergency responders are familiar with, and to provide a plot of the area contaminated and calculate the square area.

In this study, it is assumed that RDD events occur in Seoul metropolitan city. Two sources of Cs-137 and Am-214 are selected. The risk posed by Cs-137 is an external gamma radiation hazard, and Am-241 is an internal alpha radiation hazardous material. To simulate as such a case of Goiania, Brazil, 1,300 Ci of Cs-137 with 5 lbs of HE is used as a RDD scenario, which belongs to category 2 of IAEA scale [2]. 50 lbs of HE is used to investigate an effect of more explosives. Weather condition includes normal NW winds of 3 m/s at average daytime (D stability) and calm nighttime (F stability). Total 8 cases are run as shown in Table 2.

Table 2. RDD scenario cases

Event	Amount	HE	Stability class
RDD-1	1,300 Ci of Cs-137	5	D
RDD-2	1,300 Ci of Cs-137	5	F
RDD-3	1,300 Ci of Cs-137	50	D
RDD-4	1,300 Ci of Cs-137	50	F
RDD-5	2 Ci of Am-241	5	D
RDD-6	2 Ci of Am-241	5	F
RDD-7	2 Ci of Am-241	50	D
RDD-8	2 Ci of Am-241	50	F

Figure 1 shows TEDE contour plot for the case of RDD-1. Area of red color indicates that TEDE level is more than 1 rem (10 mSv) and covered area is 2,000 m^2. At this level, immediate sheltering in place should be done and evacuation can be considered depending on situations. Generally, conservative cancer probability is 5×10^{-4}/rem. Green-colored area of 9 km^2 indicates exposure dose equal to chest X-ray. Figure 2 shows ground deposition (μ Ci/m^2) along the distance from explosive spot. Regulatory limit of Cs-137 in drinking water by ICRP-96 [4] is 10 Bq/L (0.27 μ Ci/m^3) which is the most outer contour line in Figure 2.

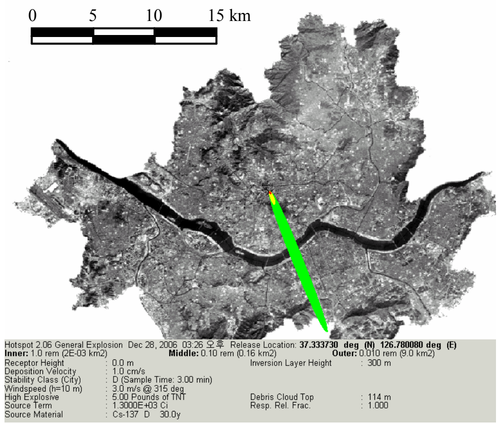

Figure 1. TEDE contour plot for RDD-1.

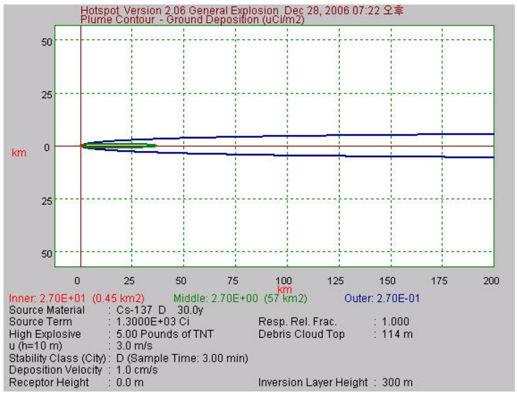

Figure 2. Ground deposition contour plot for RDD-1.

3. Conclusion

A numerical code is useful for assessing risks and estimating consequences of radiological dispersion from the dirty bomb threat in the urban area. It is also helpful for preventative actions and countermeasures of emergency preparedness and response system. It would provide quantitative model outputs which may guide the deployment of health physics survey teams and assist to make more specific emergency management decisions in case of any radiological accidental releases.

REFERENCES

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