Radiological Risk Assessment (Wednesday, February 12, 2014 14:00)

Protecting National Critical Infrastructure against Radiological Threat

I. Yaar[1,2], I. Halevy[2], Z. Berenstein[2] and A. Sharon[2]

1) *Ministry of National Infrastructures, Energy and Water Resources, Chief Scientist Office, 14, Hartum St. POB 36148, Jerusalem 9136002, Israel*
2) *Nuclear Research Center Negev (NRCN), P.O. Box 9001, Beer-Sheva 84190, Israel*

INTRODUCTION

National Critical Infrastructure (NCI) such as transportation, water, energy etc., are essential elements in a developed country's economy. As learned after the 9/11 attack[xx], a terror attack on these complex system may cause thousands of casualties and significant economic damage. The attack can be a conventional one; like the train bombing in Spain[xxi] or the bus bombing in London[xxii], or a non-conventional one; like the Sarin attack on the underground train in Tokyo, Japan[xxiii]. A radiological attack on a NCI is also feasible[xxiv]. This type of attack must be taken into consideration due to the vulnerability of ani infrastructure to such an attack, and the severe economic outcome of it[xxv]. The radioactive materials that might be used by terrorists were recently identified and categorized in one of the IAEA Nuclear Security Series publication[xxvi,xxvii]. The most common and therefore reachable radio nuclides are the gamma emitters ^{60}Co, ^{137}Cs and ^{192}Ir, the beta emitter ^{90}Sr and the alpha emitters ^{241}Pu, ^{238}Pu and ^{241}Am.

A radiological event can be any of two principle scenarios. In the first scenario, a radiological dispersion device (RDD) or “dirty” bomb is used. This device consists of a radiation source which is detonated using conventional or improvised explosives[xxviii]. Most of the casualties in this event will be from the explosion blast wave. However, some people might become contaminated with different levels of radiation[xxix], some might need to go through some type of medical screening process and the costs of the total actions might be significant[xxx].

The second scenario involves a silent dispersion of radioactive material in a public site. In this event, there are no immediate known casualties, and the fact that people were exposed to radioactive material will be discovered only in the uncommon event when symptoms of radiation sickness will be identified due to exposure to high radiation dose[xxxi], or if the radioactive material is discovered by a first responder equipped with a radiation detector or a dosimeter. The main impact of such a radiological attack is the contamination of a large area[xxxii]. The size of the contaminated area depends on the type and activity of the radioactive material, on the type and geometry of the dispersion device, on the micro-meteorology conditions and on the cross contamination caused by the movement of people inside the contaminated area[xxxiii].

Two experimental programs, "Green Field"[xxxiv] (GF) and "Red House"[xxxv] (RH) were recently conducted in Israel in order to increase the preparedness for a RDD event. The GF program aimed at evaluating the consequences of an outdoor and an indoor explosion of an RDD device; while the RH program aimed at evaluating the outcome of a silent dispersion of a radioactive material inside a building. Based on the results of these two experimental programs, the consequences of a possible RDD attack or a silent indoor dispersion of a radioactive material will be given and the necessary preventative steps that can be taken in order to secure NCI's against these threats will be specified.

EXPERIMENTAL SETUP AND RESULTS

2.1 Simulation of an outdoor RDD attack

An outdoor explosion of a RDD can be used by terrorists in the attempt to contaminate NCI's such as harbors docks, train stations, bus stations airports, water sources, power stations, etc., with radioactive materials. In the last part of the GF program, a set of experiments using the short lived radioisotope ^{99m}Tc were conducted in order to study the consequences of such an event[xxxvi]. Overall, fourteen tests were conducted using 5-7 Curies of ^{99m}Tc bottled in a 30 cc saline water and coupled to 0.25-2.5 kg of TNT, in each test. All of the experiments' results were recorded by three video cameras (taken from three different angles), by a high speed camera and some of them were also recorded by a thermal Infra-Red (IR) camera.

On site Gamma measurements were taken by several gamma detectors. A small personal detecting system based on a 1" by 1" cesium-iodide (CsI) crystal, a laboratory medium resolution detector based on a 1.5" by 1.5" lanthanum-bromide ($LaBr_3$) crystal and a spectral advanced radiological monitoring system (SPARCS) based on several sodium-iodide crystals. A high gamma resolution pure germanium (HPGe) detector was also used at the laboratory in order to count the radioactivity collected by the Petri dishes that were placed around the detonation point. The activity that was measured on the ground following one of the 2.5 kg tests, measured with the SPARCS system, is depicted in Figure 1 in units of $\mu Ci/m^2$.

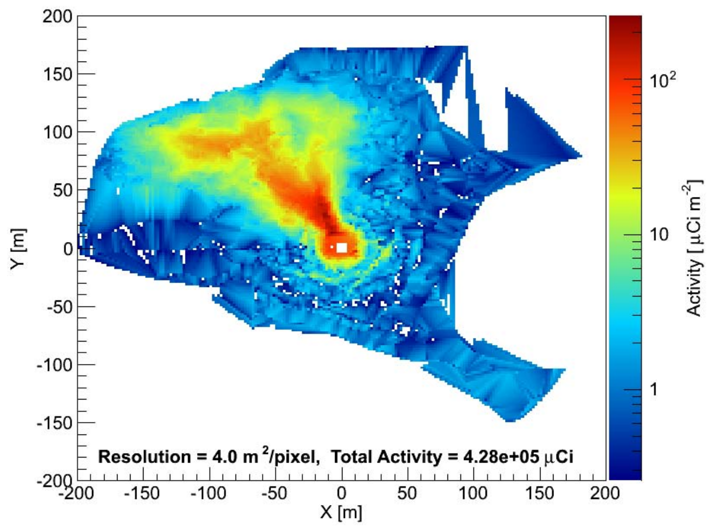

Figure 1. The activity on the ground after a 2.5 kg test, measured with the SPARKS system. The results are given in units of $\mu Ci/m^2$

The main findings concluded from these experiments, which can be relevant to a real RDD event inside a critical transportation system are that about 20 % of the total activity is found on the ground close to the detonation point and less than 1 % of the original activity is observed outside of this area. It should be mentioned, that this is true only for the cases where most of the particles created were fine aerosols due to the charge geometry and radioactive material type that enhanced the creation of such particles. In cases where most of the particles will be in the ballistic size range (>100 microns aerodynamic diameter), a reasonable assumption in the case of a RDD made of a metallic ^{60}Co or ^{192}Ir source, it is reasonable to assume that most of the particles will settle on the ground within the range of few hundred meters around the point of release.

2.2. Simulation of an indoor RDD attack

In this section, the results of a set of tests that were conducted in order to measure the consequences of an indoor RDD event are given[xxxv]. This scenario is relevant to a terrorist attempt to contaminate NCI's installed inside buildings, such as power stations, water pumping station, train stations or airport terminals, with a radioactive material. When an RDD is detonated inside a building with openings part of the radioactive material will contaminate the building and the rest will be emitted out from doors and windows. In all of the experiments conducted in this part of the program, two identical charges were simultaneously detonated. One charge was placed outdoor and the second one was hanged at the center of a small steel chamber, 3 by 3 by 2 m^3, with two 1 by 1 m^2 openings in the center of adjacent walls. Tests results were recorded by three video cameras, by a high speed camera and some of them were also recorded by a thermal IR camera. In addition to comparing between the heights of the clouds created inside and outside of the steel chamber, the amount and the size of the particles that were emitted from the openings after the blast and the distribution of the material inside the chamber were also measured.

In six of the indoor shots non-radioactive CsCl and $SrTiO_3$ powders, simulating radioactive sources, were used. After each of these shots, samples were taken from the walls, the ceiling and the floor, and from samplers that were hanged outside of each window. These samples were analyzed using an Inductively Coupled Plasma Mass Spectrometry (ICP-MS) laser ablation technique, and the average material (CsCl or $SrTiO_3$) concentration on these areas was calculated. The results show that within this amount of explosive and chamber size, the material was dispersed homogenously over the walls and windows area. Therefore, the ratio between the fraction of radioactive material that will be dispersed outside and inside the building in an indoor RDD event, will be proportional to the ratio between the total openings' area (doors, windows etc.) and the total area of the building (including walls, floor and ceiling).

2.3 Simulation of a silent indoor dispersion of radioactive material

A set of experiments, which included silent dispersion of liquid ^{99m}Tc, were conducted as a part of the "Red-House" (RH) experimental program[xxxv]. This part of the program was conducted in order to improve the preparedness and response to terrorism scenarios such as silence dispersion of radioactive material inside NCI's installed inside buildings. The tests were conducted (on July 2010) in the assigned Chemical, Biological, Radiological and Nuclear (CBRN) Israel Defense Force (IDF) home front command facility.

The CBRN training building is designed as a small size two-floor shopping mall. The main floor (ground floor) is about 24 by 24 m^2 size and includes an empty central part (18 by 18 m^2) surrounded by shops and offices. The radioactive concentration in the air inside the building was measured by ten low volume (2 liters per minute) air samplers and five high volume air samplers (20 m^3/10min). PDS and LnBr detectors were used for mapping the contamination level, both on the first and on the second floor. The dispersion was performed by an electric sprayer which can produce fine particles in an order of several microns. Each dispersion included 50 mCi of ^{99m}Tc mixed with 3.5 liters of water. The liquid drops size distribution was Gaussian-shaped with a mean value of 30 micron and a standard deviation of 10 microns. The time period for each release was 10 min. Upon spraying, the aerosol was dispersed by the building ventilation system. The aerosol was anticipated to dry in a short time period leaving a small micrometer size salt particle containing ^{99m}Tc. A typical spatial distributions of the floor surface deposition, depicted in µrem per hour (µrem/h), as measured in one of the tests is presented in Figure 2.

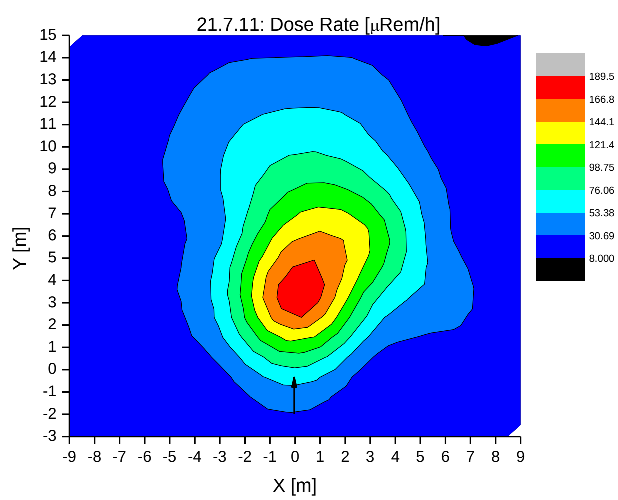

Figure 2. Spatial distribution of the floor surface deposition in µrem/h

DISCUSSION AND CONCLUSIONS

Based on the experimental results presented in this work and on other theoretical[xxix,xxxvii,xxxviii] and experimental[xxviii,xxx,xxxii,xxxiii,xxxix,xl,xli] work conducted in the past, some new insights regarding the security of NCI's can be obtained. As demonstrated in the Goiania accident[xlii], a detonation of an RDD or a silent dispersion of radioactive material inside an airport terminal, train station, bus central station, subway system or harbor[xliii], even when a category 1 radiation source is usedError! Bookmark not defined., will only cause minor injuries and few casualties from high radiation doses. On the other hand, this event will probably have a huge economic impact on the country involved[xliv], and therefore cannot be ignored.

A coordinated radiological terror attack on international airports, main harbors or power stations, will probably close these facilities for periods of months or more, resulting in a big economic and physiologic effect[xlv]. This long time period is needed for cleaning of the radioactive contamination to a point where these systems can be reopened according to IAEA guidelines for contaminated areas[xlvi]. Additional general conclusions about the physical outcome of such events can be drawn from the experimental work presented here. First, it is clear that in a silent radiological event or in an RDD event where only a small quantity of explosives is involved, most of the radioactive material will be found in a close vicinity to the point of detonation or dispersion, resulting with high levels of contamination. The rest of the material will be found inside the ventilation system, especially on the surface of the filters, and will be carried by people to other parts of the infrastructure involved, or outside. In an RDD event that involves a large quantity of explosives, the damaged and contaminated central area will be larger, the radioactive material concentration inside the affected area will be lower and the area that will be contaminated will be much larger and mostly downwind from the detonation point.

The big question that has yet to be answered is: **what has to be done in order to minimize the chances for such an event to occur in one of the NCI's around the world**?

The most promising answer to this question is based on the multilayer security system approach[xlvii,xlviii]. The first security layer is a personal screening process of people at the entrance to the main infrastructure transportation facility. This process is not simple to perform, in order to achieve a 100% screening coverage, all entrances must be secured by trained security teams having monitoring capabilities, which will allow them to hold everyone who enter the facility for a short screening procedure, after which the person is either allowed to enter into the facility or he has to go through a more comprehensive screening process. If an international airport will be taken as an example, all private vehicles entering the airport from any point of entry and all of the people coming via public transportation system (buses, trains, subway) have to be stopped for a short questioning process before they are allowed to enter into the main airport area.

The second security layer, which has to be integrated into the security system, is an explosive detection system[xlix]. These systems are usually based on well-known techniques and they can prevent conventional as well as RDD terror attacks, or at least stop them at the entrance to the secured area.

The third security layer is one that can cope directly with any radiological terror threat[l]. The most challenging ones are the alpha[li] and beta[lii] emitters. A detection system that will identify these radioisotopes will easily detect gamma emitters like ^{60}Co, ^{137}Cs and ^{192}Ir. The detection system can be a simple hand held radiation detector, operated by the security personnel posted at the first or second security layer; or a more complicated radiation detection portal suitable for the detection (and in some types identification) of radioactive material[liii]. The screening of public, vehicles and cargo for radioactive material will result in some level of false alarm rate coming from the presence of Naturally Occurring Radioactive Material (NORM) and from people that had been treated or examined with radioisotopes several days before they went through the radiation detection portal[liv].

These security systems are aimed at prevention from a terrorist to enter into any NCI caring a radioactive material. If this system fails to alert, a second line of radiation detectors, aimed at detecting and/or identification of radioactive material release, has to be installed inside the facility. According to the results obtained in the RH experimental program, the preferred place for the positioning of these detectors is inside the air-conditioning ducts, as close as possible to the filters of the air that is being sucked from the building and some other detectors have to be positioned outside the building in order to detect a release of radioactive material outside. The main purpose of this second line of radiation detectors is to raise an alert as soon as possible on the presence of radioactive material, in order to minimize the exposure of people involved and to prevent farther transportation of the contamination to other parts of the NCI that was attacked.

REFERENCES

1. G. Makinen, The Economic Effects of 9/11: A Retrospective Assessment, Report for Congress, RL31617 (2002).
2. F. Reinares, The Madrid Bombing and Global Jihadism, Survival: Global Politics and Strategy, 52 (2010) 83.
3. P. Murphy, Intelligence and Security Committee Report into the London Terrorist Attacks on 7 July 2005, ISC 105/2006, May 2006.
4. Natural and Selected Synthetic Toxins, A.T. Tu and W. Gaffield editors, ACS Symposium series, Vol. 745, Chapter 20, Overview of Sarin Terrorist Attacks in Japan, Natural and Selected Synthetic Toxins, pp 304–317 (1999).
5. The Terrorist Threat to the U.S. Commercial Passenger and Freight Rail System, Office of Intelligence and Analysis / Directorate for Preparedness, Homeland Infrastructure Threat & Risk Analysis Center (2006).
6. J.M. Acton, M.B. Rogers and P.D. Zimmerman, Beyond the Dirty Bomb: Re-thinking Radiological Terror, Survival: Global Politics and Strategy, 49 (2007) 151.
7. Code of Conduct on the Safety and Security of Radioactive Sources, International Atomic Energy Agency, Vienna, 2004.
8. Categorization of Radioactive Sources, IAEA Safety Standards for protecting people and the environment, Safety Guide No. RS-G-1.9, International Atomic Energy Agency, Vienna, 2005.
9. A. Sohier and F. Hardeman, Radiological Dispersion Devices: are we prepared? Journal of Environmental Radioactivity, 85 (2006) 171.
10. C.O. Slater, J.C. Gehin and R.T. Santoro, A Study of the Effects of a Radiation Dispersal Device, Oak Ridge National Laboratory, Nuclear Science and Technology Division (94), ORNL/TM-2003/128 (5/2003).
11. S.V. Musolino and F.T. Harper, Emergency Response Guidance for the First 48 Hours after the Outdoor Detonation of an Explosive Radiological Dispersal Device, Health Physics, 90 (2006) 377.
12. J.M. Acton, M.B. Rogers and P.D. Zimmerman, Beyond the Dirty Bomb: Re-thinking Radiological Terror,
Survival: Global Politics and Strategy, 49 (2007) 151.
13. V.P. Reshetin and J.L. Regens, Estimation of Radioactivity Levels Associated With a 90Sr Dirty Bomb Event, Atmospheric Environment, 39 (2005) 4471.
14. F.T. Harper, S.V. Musolino and W.B. Wente, Realistic Radiological Dispersal Device Hazard Boundaries and Ramifications for Early Consequence Management Decisions, Health Physics, 93 (2007) 1.
15. A. Sharon, I. Halevy, D. Sattinger and I. Yaar, Cloud rise model for radiological Dispersal device events, Atmospheric Environment, 54 (2012) 603.
16. Sharon, I. Halevy, Z. Bernstein, M. Levy, S. Tabibzada, A. Ashkenazi, I. Yaar, The "Red House" Project, An Experimental Study of Indoor Dispersion of Radioactive Material, NRCN privet communication (11/2011).
17. A. Sharon, I. Halevy, Z. Berenstien, P. Banaim and I. Yaar, "Green Fiels III" - November 2012 Campaign, preliminary summary, NRCN Report, N972/0113 (12/2012).
18. A. Elliott, Security of Radioactive Materials for Medical Use, S. Apikyan and D. Diamond (eds.), Countering Nuclear and Radiological Terrorism, Springer, 2006, 95.
19. M. Durante and L. Manti, Estimates of radiological risk from a terrorist attack using plutonium, Radiation Environment Biophysics, 41 (2002) 125.
20. Z. Prouza, V. Beckova, I. Cespirova, J. Helebrant, J. Hulka, P. Kuca, V. Michalek, P. Rulik, J. Skrkal and J. Hovorka, Field tests using radioactive matter, Radiation Protection Dosimetry, 139 (2010) 519.
21. Z. Prouza, J. Helebrant, V. Beckova, I. Cespirova, , J. Hulka, P. Kuca, V. Michalek, P. Rulik and J. Skrkal, Explosion Tests Using Radioactive Substances, in Proceedings of Third European IPRA Congress, Helsinki, Finland, 14-16 June 2010.
22. X. Cao, G. Roy, P. Brousseau, L. Erhardt and W. Andrews, A Cloud Rise Model for Dust and Soot from High Explosive Detonations, Propellants Explosives Pyrotechnics, 35 (2010) 1.
23. The radiological accident in Goiania, IAEA, VIENNA, 1988, STI/PUB/815, ISBN-92-0-129088-8.

24. M.K. Zaidi, Risk Assessment in Detection and Prevention of Terrorist Attacks in Harbors and Costal Areas, in I. Linkov et al. (eds.), Environmental Security in Harbors and Costal Areas, Springer 2007, 309.
25. A.P. Schmid, High Consequence Radiological Terrorism Scenarios - U.N., in W.D. Wood and D.M. Robinson (eds.), International Approaches to Securing Radioactive Sources against Terrorism, Springer 2009, 79.
26. E. Eraker, Cleanup After a Radiological Attack, U.S. Prepares Guidance, The Nonproliferation Review (2004) 167.
27. INTERNATIONAL ATOMIC ENERGY AGENCY, Remediation of Sites with, Dispersed Radioactive Contamination, Technical Reports Series No. 424, IAEA, Vienna (2004).
28. Protecting the Nation's Seaports: Balancing Security and Cost, Jon D. Haveman and Howard J. Shatz editors, PPIC Pub., San Francisco, Ca (2006).
29. J. Becker and L. Smit, Transport security, Annex XVIII of ASSESS Final Report, DG TREN, European Commission (2005).
30. C. Bruschini, Commercial Systems for the Direct Detection of Explosive for Explosive Ordnance Disposal Tasks, Subsurface Sensing Technologies and applications, 2 (2001) 299.
31. R.T. Kouzes, Challenges for interdiction of nuclear threats at borders, First International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA), Marseille (7-10 June 2009) 1.
32. I. Yaar, I. Peysakhov and E.M.A. Hussein, Passive detection and identification of a concealed 241Am source in transport, Packaging, Transport, Storage and Security of Radioactive Material, 19 (2008) 189.
33. I. Yaar and Esam M.A. Hussein, Passive Detection of Concealed 90Sr RTGs in Transport, Packaging, Transport, Storage and Security of Radioactive Material 15 (2004) 149.
34. I. Yaar and I. Peysakhov, A Multiple-Detector Radioactive Material Detection Spectroscopic (RMDS) Portal, Nuclear Instrumentation and Methods in Physics Research A, Vol. 712 (2013) 62.
35. R.T. Kouzes and E.R. Siciliano, "The response of radiation portal monitors to medical radio-nuclides at border crossings," Radiat. Meas., 41 (2006) 499.