High Explosive Radiological Dispersion Device: Time and Distance Multiscale Study

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A wide range of explosion tests imitates different explosive RDD scenarios were conducted and aimed at increasing the preparedness for possible terrorism events, where radioactive (RA) materials disperse via an explosive charge. About 20 atmospheric dispersion tests were conducted using6-8 Ci of ^{99m}Tc which were coupled to TNT charges within the range of 0.25-25 kg. Tests performed above different typical urban ground surfaces (in order to study the surface effect on the activity ground deposition pattern due to different in particles size distribution). We have used an efficient aerosolizing devices, means that most of the RA particles were initially created within the size of fine aerosols, mostly respirable. Ground activity measurements were performed both, around the dispersion point and up to few hundred meters downwind. Micrometeorology parameters (wind intensity and direction, potential temperature, relative humidity, solar radiation and atmospheric stability) were collected allowing comparisons topredictions of existing atmospheric dispersion models'[1]. Based on the experimental results, new model parameterizations were performed. Improvements in the models' predictions were achieved and a set of thumb rules for first responders was formulated. This paper describes the project objectives, some of the experimental setups and results obtained. Post detonation nuclear forensic considerations can be made based upon results achieved.

1. Introduction

Health and environmental consequences of an explosive RDD event depend on many parameters. Among them: type and amount of high explosive (HE), type of RA material, device geometry, surface type below the detonation and local meteorology conditions. A given set of these parameters will define the severity of the event by means of the total dose levels that people might be exposed to (both externally and internally) and the level (and size) of the contaminated area. The dispersion of fine respirable size (<10 micron)is mainly a risk via inhalation while the dispersion of large size particles and aerosols is a hazardous via external exposure. The final RA particle size distribution following such an event is the key question for a reliable risk assessment calculations and preparedness for explosive RDD events.

The project includes three phases (I, II and III) with different aims for each one. GFI included a wide set of detonation tests where simulant material were dispersed and the explosion cloud were detected up to the effective height, before its downwind motion. One of the important achievements of this phase is the formulation of a model[2] for the elevation of the explosion cloud up to the effective height as a function of: time elapsed, horizontal wind speed, atmospheric stability class and HE amount up to 100 kg (equivalent to TNT).

The other two phases included atmospheric dispersion of an explosive RDD devices using a short live RA material (^{99m}Tc with $T_{1/2}$=6.02 hr. and gamma photon on 141 kev). The device used was such that, initially, most of the RA particles created were within the range of fine aerosols. The HE amount used was up to 25 kg of TNT.

Data collecting done during and after the tests included different time and length scales. From micro-seconds (follow the detonation fireball evolution) to minutes (follow the downwind motion of the contaminated cloud)and from the immediate area around the detonation point to 100's m downwind direction.

The main project objectives were:

- Measuring the surface activity concentrations around ground zero(GZ), were meteorology is not yet influence, and up to a few hundred meters downwind. Existing models are weak in very near area predictions.
- Study the fireball–ground interaction by means of the amount of activity deposited on the ground in the close vicinity where the fireball "kisses" the ground.
- Measuring the aerial distribution of the activity around the detonation point.
- Measuring the effect of different HE amounts and different surfaces on the ground activity deposition pattern.
- Comparison between predictions of atmospheric and health physics dispersion codes (Hotspot, ERAD, LODI, RODOS, ARGOS) and field results.
- New models' parameterizations based on the experimental results and comprehensive calculations.

2. Experimental setup

Phases II and III of the project included 20 tests where6-8 Ci of ^{99m}Tc dispersed by 0.25-20 kg of TNT charges. Shots were done above clean or dirt surfaces in order to study the effect of the different amount of dirt entrained into the fireball. While clean (steel) surface do not involve much of dirt entrainment into the fireball, dirtier surfaces (packed sand soil, concrete, asphalt) involve dirt in the fireball and hence reduce the amount of fine RA particles, due to agglomeration-condensation processes.
We study the effect of different heights of detonation above ground level and compare it to ground detonation.
High resolution radiation detection (about 40 points collected) was done in order to get an accurate 2D radiation fields. Special attention was given to few meters circle around the detonation point, called "Ground Zero" (GZ).
RA concentrations in the air were measured by high volume air samplers around the detonation point.
Particles were collected by stubs from the GZ area and were analyzed by SEMand EDS for the sake of size distribution, morphology and chemical composition. Agglomerates of dirt and RA material were detected.
Tests were documented and recorded by three video cameras (from 3 different locations), high speed camera, thermal camera (part of the shots), fast multispectral radiometer (in some of the tests) and stills camera.
Radiation detection was done by $LnBr_3$, personal detection system PDS (CsI crystal), HPGE, NaI (different volumes) and beta surface detectors. Each point were measured shielded (by Lead plates) and unshielded for local and integrated (including the GZ "hot zone") radiation levels, respectively.

3. Results and discussions

A comparison between the 2D ground contamination raw data (cps) and analyzed data (real surface activity) for 0.25 kg of TNT shot is shown in figure 1.

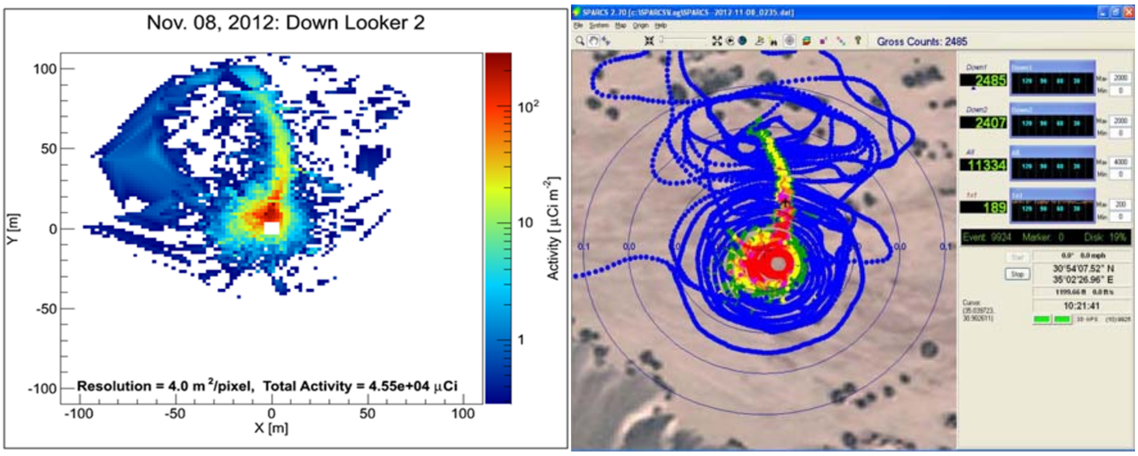

Figure1: Raw (right)vs. analyzed (left) data of activity ground deposition following detonation of 0.25 kg of TNT combined to RA source of 6.6 Ci of ^{99m}Tc.

Note that the 2D maps in figure 1 do not include the contribution of the "hot" area, few meters around the detonation point, where most the activity was deposited. It was found out that 3-20% of the total activity was deposited in area radios of 3-4 fireball radii. Since most of the RA particles dispersed were fine, respirable size, just 2% of the total activity was found on the ground up to 300 m downwind. That means that most of the activity, initially dispersed, was not found. The "hot zone" activity is shown in figure 2.

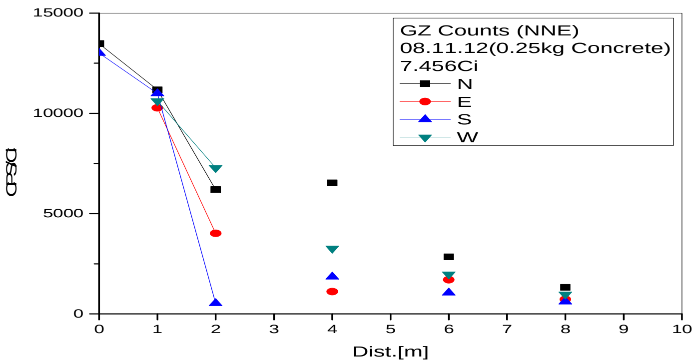

Fig. 2: The "hot zone" activity [cps/Ci] distribution along four directions away from the detonation point (North, South, East and West).

3. Summary

The final activity ground deposition pattern following the detonation of an RDD involves time and distance multiscale phenomena. The initial radiactive particle's size defined at 10's-100's micro-seconds time scale while agglomeration to ambient dirt occur 10's-100's ms after the detonation.

The area few meters around the detonation point contains much more activity then the wide area of few hundreds of meters downwind. We have shown an example of results from a real RA material atmospheric dispersion test performed during this study.

References

1. Hotspot 2.07.2, Health physics and atmospheric dispersion code, LLNL-USA, Sep. 2011.

2. A. Sharon, I. Halevy, D. Sattinger, I. Yaar, Cloud rise model for RDD events, Atmospheric Environment 54 (2012) 603-610.