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# Ground deposition pattern of an explosive radiological dispersal device (RDD)

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**ABSTRACT**
"Green Field" (GF) project conducting in Israel, between the years 2010-14, aimed at increasing the preparedness for possible terrorism events, where a radioactive (RA) material disperse via an explosive charge. About 20 atmospheric dispersion tests were conducted using 6-8 Ci of $^{99m}$Tc which were coupled to TNT charges within the range of 0.25-25 kg. Different typical urban ground surfaces were used below the charges, in order to study its effect on the activity ground deposition pattern. We have used efficient aerosolizing devices, means that most of the RA particles were initially in the size of fine aerosols. Ground activity measurements were performed both around the dispersion point and up to few hundred meters down wind. Micrometeorology parameters (wind intensity and direction, potential temperature, relative humidity, solar radiation and atmospheric stability) were measured allowing comparisons to atmospheric dispersion models' predictions[1]. Based on the experimental results, new model parameterizations were calculated. 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.

## 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.

GF 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 latter 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 length scale of fine aerosols. The HE amount used was up to 25 kg of TNT.

The main GF II, III 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.

## 1. Experimental setup

Phases II and III of the project included 20 tests where 6-8 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, grass, 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 SEM and EDS for the sake of size distribution, morphology and chemical composition. Agglomerates of dirt and RA material were detected.
All tests were documented and recorded by three video cameras, high speed camera, thermal camera (part of the shots), fast multispectral radiometer (part of the shots) 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. The test field area (GZ and far distance) and some of detecting devices can be seen in figures 1 and 2 respectively.

**Figure 1**: The GZ area (on concrete surface - right) and far field look (left) of the test site. Height reference balloon and a video camera are on the left.

**Figure 2:** Portable $LnBr_3$ detector with a lead shield plate and a PDS (right) and 25 kg of TNT cloud 4 s following the detonation (left).

## RESULTS AND DISCUSSIONS

A comparison between raw data (gross counts per second) and analyzed data (surface activity) for 0.25 kg of TNT shot is shown in figure 3.

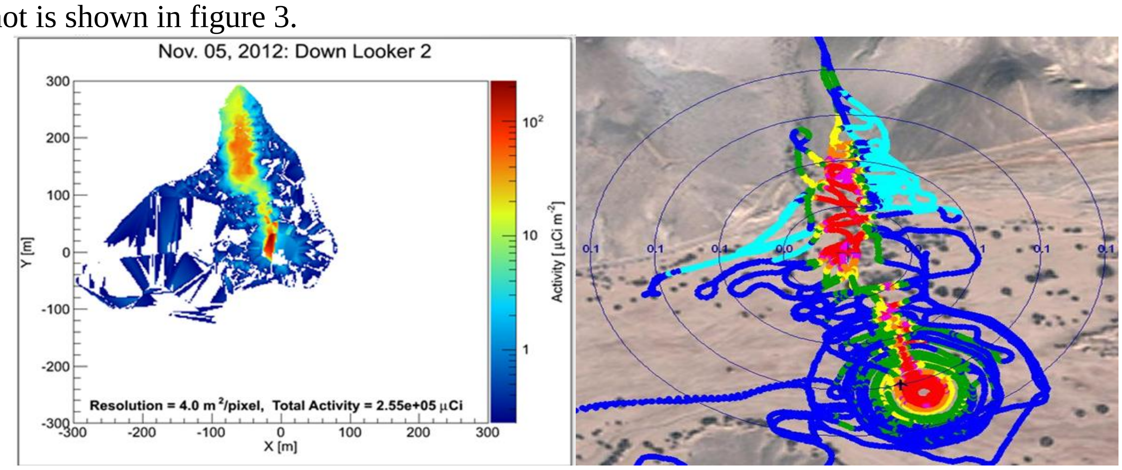


**Figure 3**: Raw (right) vs. analyzed (left) data of activity ground deposition following detonation of 0.25 kg of TNT combined to RA source of 6.6 Ci of $^{99m}$Tc.

Note that the 2D maps in figure 3 do not include the activity in the GZ "hot" area where most of it was deposited. Based on the analyses of GF experiments, it was found out that 3-25% of the total activity was deposited on the GZ area inside a circle of 3-4 fireball radii. Since most of the RA particles dispersed as fine, respirable, aerosols another 2% of the total activity was found on the ground up to 300 m downwind. This means that most of the activity, initially dispersed, was not recover. The GZ activity of the same test is shown in figure 4.

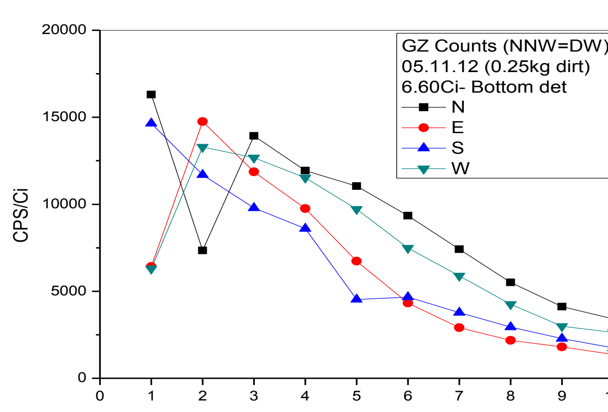

**Fig. 4**: GZ activity [cps/Ci] distribution along four directions from the detonation point (North, South, East and West). This area contains up to 25% of the total activity and its influence can be up to few hundreds of meters.


## SUMMARY

Activity deposition pattern of outdoor explosive RDD experiments were discussed and analyzed. In cases of fine, respirable size, aerosols dispersion, most of the activity deposited inside a circle of up to 4 fireball radii around the detonation point. About an order of magnitude less was deposited in the rest of the wide open area, in the downwind direction. The effects of different RA particles size distribution on the ground deposition pattern is still being studying under the framework of GF project.


## REFERENCES


**1**. Hotspot 2.07.2, Health physics and atmospheric dispersion code, LLNL-USA, Sep. 2011. See also in Hot Spot user guide Sharon et al.

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