ASSESSMENT OF THE IMPACT OF WATER WASH-DOWN FOR MITIGATION OF RADIOLOGICAL DISPERsal DEVICE (RDD) CONTAMINATION

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Radiological Dispersal Devices (RDD)

• “Dirty bombs” are type of RDD that combine conventional explosives with radioactive material*

• Radioactive material from RDD could contaminate an area from a few blocks to several kilometers in diameter*

• Resulting level of radioactivity estimated at 5-50 µCi/m² with hot spots of 100-500 µCi/m² (DHS Scenario 11)

• Contaminant could be one or more radioactive isotopes

* Source: U.S. NRC Factsheet on Dirty Bombs
Examples of RDD Contaminants

- **Cesium** ($^{137}$Cs)
  - $t_{1/2} \sim 30$ years
  - $^{137}$Cs $\rightarrow^{137}$Ba + $\beta^{-} + \gamma$
  - substitutes for K in natural systems

- **Strontium** ($^{90}$Sr)
  - $t_{1/2} \sim 29$ years
  - $^{90}$Sr $\rightarrow^{90}$Y + $\beta^{-}$
  - substitutes for Ca in natural systems

- **Cobalt** ($^{60}$Co)
  - $t_{1/2} \sim 5$ years
  - $^{60}$Co $\rightarrow^{60}$Ni + $\beta^{-} + \gamma$

Beta decay of $^{137}$Cs to $^{137}$Ba

- Commonly used in medicine and industry (e.g. imaging, sterilization, tracers)
- Can persist in environment for hundreds of years
- Difficult to decontaminate from surfaces

1: [http://www.moltensalt.org/references/static/home.earthlink.net/bhoglund/radiation_Facts.html](http://www.moltensalt.org/references/static/home.earthlink.net/bhoglund/radiation_Facts.html)
Typical Urban Building Surfaces

- Concrete
- Brick
- Limestone
- Asphalt
- Non-porous surfaces
Washington, D.C. Examples

- Indiana limestone
- Milford Pink granite
- Colorado Yule marble
- Greene County granite
- Lambert Cedar marble
Impact of RDD

- Depends on
  - amount and type of RDD material
  - means of dispersal
  - weather conditions
  - geometry of local environment
  - interaction with surface materials
  - building infiltration
  - water pathway

NYC in rain³

NYC on sunny day⁴

http://flickr.com/photos/24871167@N00/720076236

http://www.flickr.com/photos/nicestuff2104/128823255/
Requirements for RDD Decontamination Processes and Technologies

Requirements include:

- applicable to large urban setting
- non-destructive
- cost efficient
- minimizes social and economic damage

http://www.redoveryellow.com/trips/chicago/index.html
Water Wash Down as a Gross Decontamination Procedure

- Water wash down of urban surfaces using fire hoses or pressure washers is an all hazards approach to decontamination

- Effects of water wash down for decontamination of urban surfaces covered with Radiological Dispersal Device (RDD) contamination are unknown

- Water wash down may reduce the RDD contamination levels on the surface being decontaminated but it may also create a large secondary waste stream, spread contamination to uncontaminated areas, and compromise later decontamination efforts.

- In addition, fire hoses and/or pressure washers could re-aerosolize the radioactive particles, creating an additional health hazard.

- All of these impacts must be assessed in controlled studies to determine if water wash down is an appropriate approach for RDD decontamination.
Cesium-137

- Cesium chosen for study
  - Used in medicine and industry
  - CsCl is deliquescent
  - Adsorptive to various mineral surfaces
- Relative humidity (RH) affects fate of CsCl particles

Cs is used in nuclear medicine

Radioactive waste is generated

CsCl crystal structure
CsCl as RDD material

- Hygroscopicity-Deliquescence
  - CsCl is a salt like NaCl.
  - At relative humidity of 68%, CsCl particles become aqueous.
  - Aqueous form of CsCl can be transported through water channels on porous urban surfaces.

20 RH%

80 RH%
Project Overview

• This project is comprised of three parts:
  
  (1) Initial experiments using non-radioactive cesium to determine
      (a) the effectiveness of water wash-down, and
      (b) the fate of cesium in the environment

  (2) Discussion of experimental results and relevant literature with a
      team of experts in the field to evaluate the usage of water wash-down
      for radionuclide decontamination

  (3) Preparation of guidance when, if ever, water wash-down is effective
      as a tool to decontaminate and mitigate radionuclide contamination
Water Wash Down Experiments

Objectives
1. Evaluate the decontamination efficacies of fire hose and pressure washer techniques
2. Assess the fate of RDD contaminants in the environment after water wash down

Method
These objectives will be achieved by replicating the decontamination processes on a smaller scale in the laboratory.

Experimental results will be used to:
• Determine the amount of cesium removed from the surface through analysis of the waste water;
• Examine the subsurface penetration of cesium into the concrete, brick, and limestone
• Characterize the aerosol cesium particles created during the water wash down
Replication of water wash-down on the smaller scale
Simulating fire hose pressure on the laboratory scale
Measuring of fire hose pressure at Durham Highway Fire Station

Setup used to measure firehose pressure

Plain tip nozzle (15/16” ID) attached to Ball Shutoff Valve (Akron Brass Company)
Replication of water wash-down on the smaller scale
Simulating firehose pressure on the laboratory scale - Results

![Graph showing pressure on surface (psi) vs. distance fire hose nozzle to target (ft)]

- Pressure on surface (psi)
  - 3
  - 2
  - 1
  - 0

- Distance fire hose nozzle to target (ft)
  - 20
  - 30
Test Parameters

- Cesium deposition conditions:
  - Wet deposition using cesium solution in water
  - Dry deposition using cesium solution in methanol
  - Dry deposition using cesium solution in methanol on coupons that have been equilibrated in an 83% relative humidity chamber

- Urban Surface types:
  - Sand aggregate concrete
  - Clay brick
  - Indiana limestone
Experimental Conditions

- Firehose simulation
  - A water pressure (1.6 psi) on a 30’ distance target surface and a jet diameter (6.5”) was determined from the preliminary simulation test using actual firehose equipment

- Bench scale waste water collected
  - Wash-down conducted for 10 seconds to yield 0.9 gallons per coupon
Test Conditions Continued

- Coupon size: 3 x 3 x 3 cm

- Cs particle surface concentration: 10 µL of a 200 ppm $^{133}$CsCl solution.
Cs Particle Contamination

~3 LPM $N_2$

- Swagelok Tee
- Septum
- Spray nozzle
- 1” ID ring
- Clamp holder
- Filter holder
Experimental Setup: decontamination chamber
Analysis

• Rinsates are analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to determine the concentration of cesium in each sample using EPA method 6020 A.

• The fates of cesium on coupon surfaces are assessed by analyzing the cesium penetration profile using laser ablation coupled with ICP-MS (LA-ICP-MS).

• Filters (37 mm PTF) are used to collect the aerosolized particles during wash down and are extracted and analyzed using ICP-MS.
Preliminary Efficacy Results:

Deposition method

- Wet (Cs in water)
- Dry made wet (Cs in methanol, high RH)
- Dry (Cs in methanol)

Removal efficiency

- Brick
- Concrete
- Limestone
Preliminary test conclusions

- Dry deposition of cesium on coupons has a higher removal efficiency than cesium deposited by other methods.

- The initial use of the fire hose may suppress subsequent decontamination of residual cesium from surfaces because of deliquescence of the Cs salt (based on dry-made-wet experiments).

- Filter analysis results show that the potential for cesium contamination of the fire hose operator may be minimal.
Cesium Penetration Profile Under Typical Environmental Conditions

- Outdoor RDD simulation test results
  - Indiana limestone and sand aggregate concrete
  - Coupons were positioned within 50 ft from the detonation for Cs particle deposition
  - Two RH conditions (33 and 84 %) at varied exposure time
  - LA-ICP-MS for Cs penetration profile analysis
Cs Penetration through Limestone (2 weeks at 84 RH%)
Cs Penetration through Limestone (Non Weathered Surfaces 20 ft vertical, 2 weeks)
Cs penetration through limestone
20 ft Vertical, 4 months
Dry $\rightarrow$ Wet

Cs penetration through limestone, 20 ft Vertical, 4 months
Wet $\rightarrow$ Wet

21 mm
Cs Penetration through Concrete (20 ft vertical, 1 day, Wet → Wet)
Cs Penetration through Concrete (20 ft Vertical, 28 days, Wet → Wet)

Top Surface (exposed edge)
**Future work**

- Complete cesium penetration analysis via Laser Ablation ICP-MS
- Assemble a panel of experts to discuss the results and draft a white paper on the use of fire hose wash-down in an urban environment
- Study the effects of pressure washing and determine its ability to decontaminate urban surfaces and mitigate exposure to the contamination
Future work

- Pressure washing experiments will be completed in the new room-size chamber located at EPA National Homeland Security Research Center’s Research Triangle Park Facility