

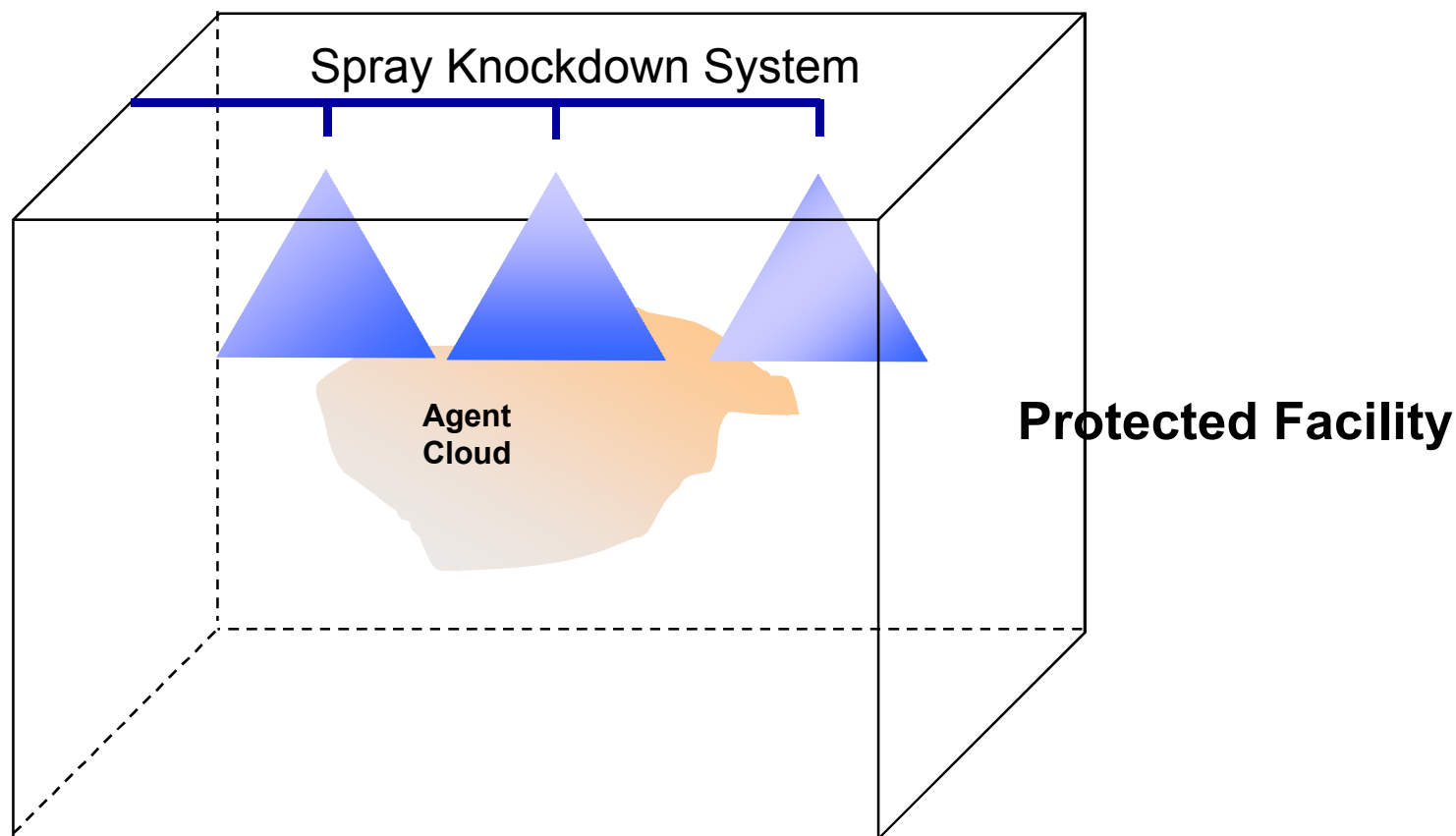


Spray Knockdown System for Rapid Containment and Neutralization of Airborne CBW Agents

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Spray Knockdown & Neutralization Concept

Interior Protection



Our objective is to investigate the use of small, charged liquid droplets to knockdown and neutralize clouds of CBW agents

Through a series of four projects, Sandia has developed and demonstrated a fundamental spray knockdown process

2001-2002

DARPA Immune Building Project

- Knockdown and neutralization of CBW agents in an interior facility
- Small (~30-50 μ m), uncharged droplets of modified DF-200
- Prototype system developed for Anniston, AL test facility

2004-2005

Laboratory Directed Research and Development (LDRD)

- Knockdown and neutralization of CBW agents in an outdoor setting
- Small (~30-50 μ m), charged droplets of modified DF-200
- Feasibility study

2008-2009

Chemical Materials Agency (Chem Demil)

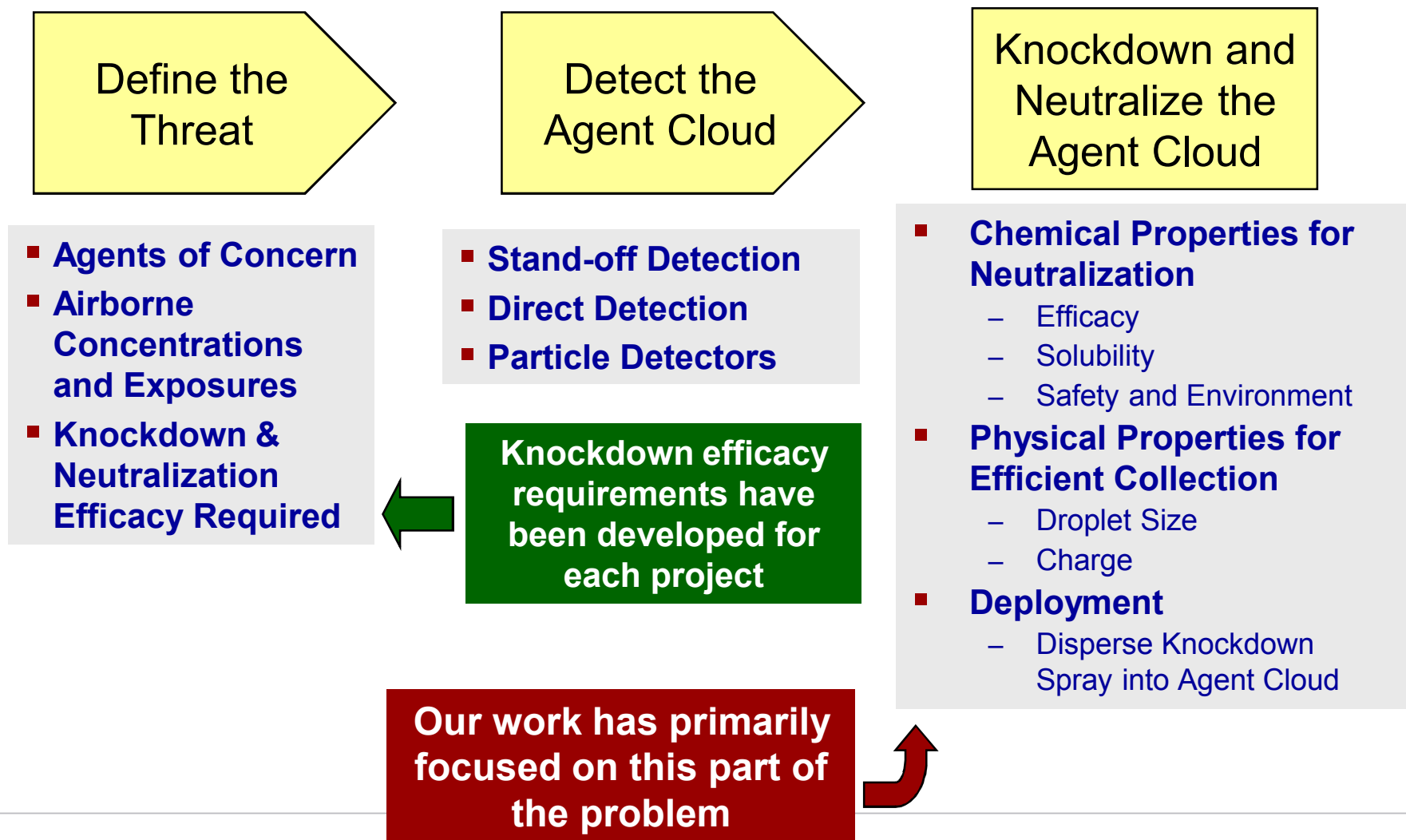
- Knockdown and neutralization of CBW agents in an interior or temporary demil facility
- Small (~30-50 μ m), charged droplets of modified DF-200
- Prototype system installed

2014-2017

Underground Transport Restoration Project

- Knockdown and neutralization of CBW agents in a subway system
- Small (~30-50 μ m), charged droplets of modified DF-200
- Demonstration in mock subway tunnel

Fundamental Requirements for Spray Knockdown & Neutralization System



Example calculations for knockdown efficacy requirements

| Toxic Material | Initial Airborne Concentration (mg/m ³) | Exposure at Initial Airborne Concentration (mg-min/m ³) ¹ | LC ₅₀ (mg-min/m ³) ³ | Log reduction required to reach LC ₅₀ | No significant effects dosage (mg-min/m ³) ⁵ | Log reduction required to reach no significant effects |
|----------------|---|--|--|--|---|--|
| VX | 560 | 300 | 15 | 1.3 | 0.09 | 3.5 |
| GB | 560 ⁶ | 300 | 35 | 0.9 | 0.5 | 2.8 |
| HD | 5600 ⁷ | 3000 | 900 | 0.5 | 2.0 | 3.2 |
| Anthrax Spores | 0.009 ³ | 0.0054 | 0.00015 ⁴ | 1.6 | 0.0000094 | 3.0 |
| Chlorine gas | 681,000 ² | 408,600 | 52,740 | 0.9 | 150 | 3.4 |

1: Estimated from scenarios in open literature

2: From estimated maximum concentration following Graniteville, SC release

3: Data from "Immune Building Systems Technology", Kowalski, WJ, 2003

4: Assumes 10¹¹ spores/g

5: Data for VX, GB, and HD from "Compilation of Existing Chemical Agent Guidelines Table as of September 1997", ORNL/TM-13649

6: Sarin attack by truck with sprayer from Davis et al. (2003, ISBN 0-8300-3473-1) 100 kg Sarin sprayed into 6 mph wind, 1 km down wind

7: Used same conditions as Davis but with 100 kg for VX and 1000 kg for HD

Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat

Detect the Agent Cloud

Knockdown and Neutralize the Agent Cloud

- Agents of Concern
- Airborne Concentration and Exposure
- Knockdown & Neutralization Efficacy Required

Modified Sandia DF-200 chemistry is being utilized for the knockdown and neutralization spray formulation

- **Chemical Properties for Neutralization**
 - Efficacy
 - Solubility
 - Safety and Environment
- **Physical Properties for Efficient Collection**
 - Droplet Size
 - Charge
- **Deployment**
 - Disperse Knockdown Spray into Agent Cloud

Sandia Decon Formulation (DF-200)

How Does it Work?

Components

**Foam Component
(Surfactants, mild
solvents, buffers)**

**Peroxide (7.9%
Solution)**

Novel Activator

Mix

Formulation

**Synergistic
formulation
(multiple
reactive
species)**

**Spray,
Foam,
Mist, or
Gel**

Multiple Uses

Kill of BW Agents

Kill of Bio Pathogens

**Neutralization of
CW Agents**

Neutralization of TICs



Final peroxide concentration is ~3.6%



Efficacy of Sandia DF-200 Formulation against CW Agents (US DoD Testing)

| Decontaminant | GD | | VX | | HD | |
|---------------|---------|---------|---------|---------|---------|---------|
| | 10 Min. | 60 Min. | 10 Min. | 60 Min. | 10 Min. | 60 Min. |
| DS2 | >99.9 | >99.9 | >99.9 | >99.9 | >99.9 | >99.9 |
| DF-200 | >99.9 | >99.9 | 97.8 | >99.9 | 84.8 | 99.9 |

Percent decontamination from kinetic tests against CW agents (US DoD stirred reactor tests using EasyDECON™-200 Lot 3829 at 25°C).

Efficacy of Sandia DF-200 Formulation against BW Agents (US DoD Testing)

| | <i>B. atrophaeus</i> | | <i>B. anthracis</i> Ames | | <i>B. anthracis</i> Vollum | | <i>B. anthracis</i> Vollum 1B | |
|-----------|----------------------|-------------------|--------------------------|---------------|----------------------------|----------|-------------------------------|----------|
| | MREF | Dahlgren | MREF | Dahlgren | MREF | Dahlgren | MREF | Dahlgren |
| | CFU | CFU | CFU | CFU | CFU | CFU | CFU | CFU |
| HTH (2%) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STB | 0 | 5158 (SD=7837) | 33 (SD=58) | 28 (SD=48) | 0 | 0 | 0 | 0 |
| MDF-200 | 0 | 4 | 0 | 0 | 0 | 0 | 6 (SD=10) | 0 |
| EasyDECON | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Residual spores following decontamination of CARC coupons (Initial surface loading: 1×10^7 spores; Contact time: 30 minutes; coupons rinsed in sterile de-ionized water following testing)

Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat

- Agents of Concern
- Airborne Concentrations and Exposures
- Knockdown & Neutralization Efficacy Required

Detect the Agent Cloud

- Stand-off Detection
- Direct Detection
- Particle Detectors

We have utilized fundamental physics and experimental work to determine the required physical properties

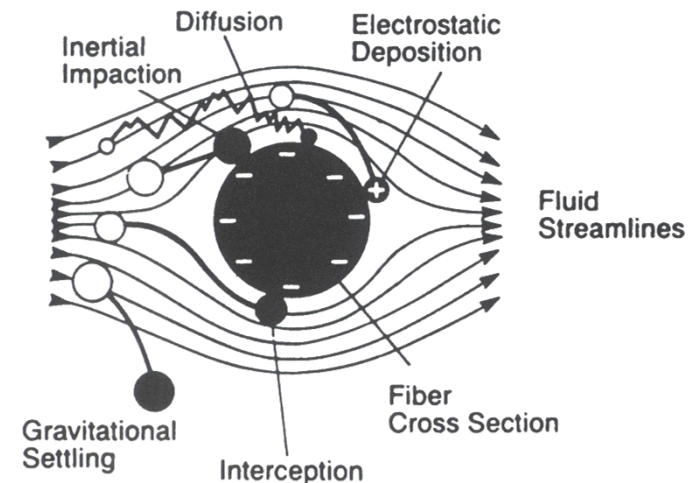
Knockdown and Neutralize the Agent Cloud

- **Chemical Properties for Neutralization**
 - Efficacy
 - Solubility
 - Safety and Environment
- **Physical Properties for Efficient Collection**
 - Droplet Size
 - Charge
- **Deployment**
 - Disperse Knockdown Spray into Agent Cloud

Physical properties of the knockdown spray droplets are important for optimal collection of agent vapors, liquid aerosols, and particles

- Particles may be collected by falling droplets with various mechanisms
 - Diffusion
 - Interception
 - Impaction
 - Thermal effects
 - Electrostatic effects

- Collection efficiency may be enhanced by certain physical properties of the droplets
 - Droplet size
 - Charge on the droplet
 - Concentration of the droplets
 - Surface tension (wettability)



From Spurney, "Advances in Aerosol Filtration"

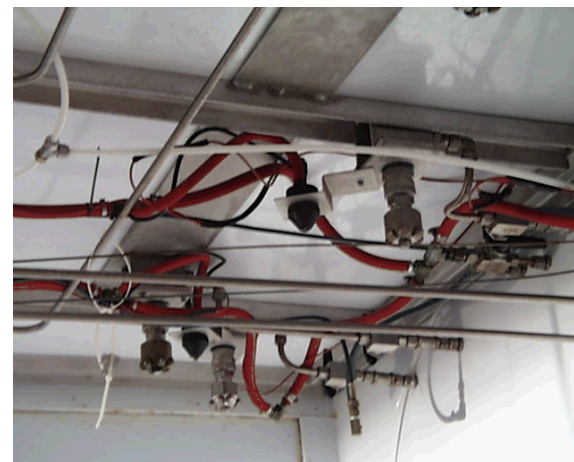
The optimal properties of the knockdown spray droplet properties have been determined through modeling and experimental work

Aerosol Test Chamber for Spray Knockdown Tests

- 8-ft wide by 16-ft long by 8-ft high chamber divided into two 8-foot cubes separated by an intervening wall (512 cu. ft.)
- The chamber was fitted with an array of nine electrostatic spray (ESS) nozzles (Maxcharge™ Spray Nozzle - Agricultural Manufacturing Company, Inc.) located at the top of the test chamber
- Spray droplet sizes from the nozzles are 30-40 microns in diameter
- Required air pressure for each nozzle is 20-90 psi
- Air consumption is 2.9–10 CFM
- The liquid flow rate is 50–200 ml/min for each nozzle



Aerosol Test Chamber at Sandia National Laboratories



ESS nozzles in the chamber

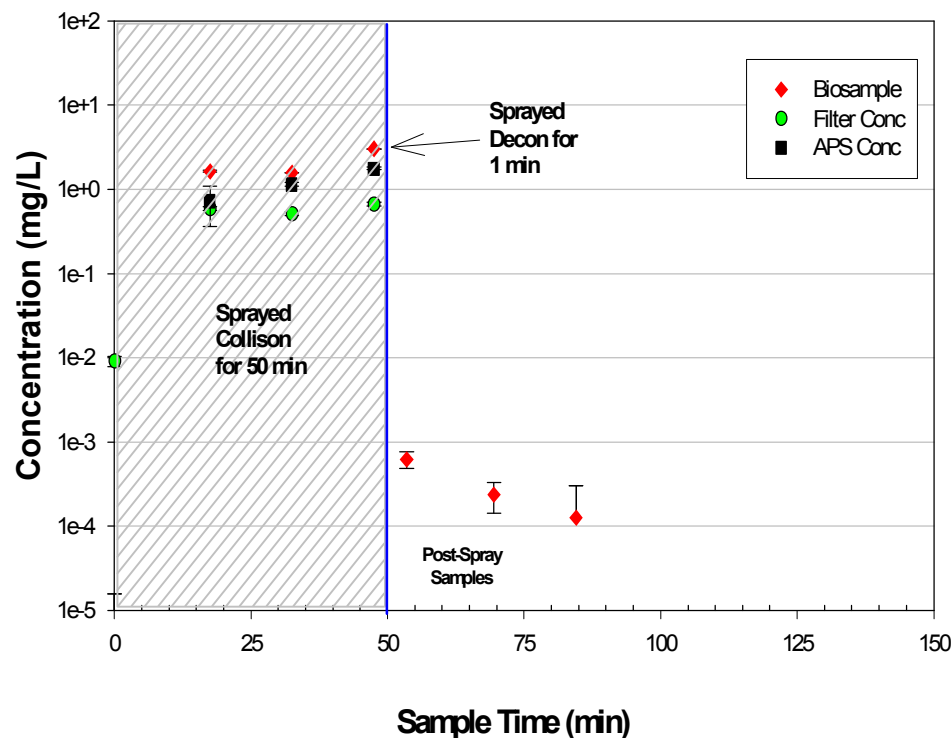
DF-200 Knockdown & Neutralization Spray

CW Agent Simulant Data

- Charged spray system
- 3.2 g/m³ G-agent simulant
- 138 g/m³ DF-200 Spray density
- Immediate decrease of nearly 4 orders of magnitude
- Knockdown/neutralization proof of concept
- Various simulant and spray densities have been evaluated



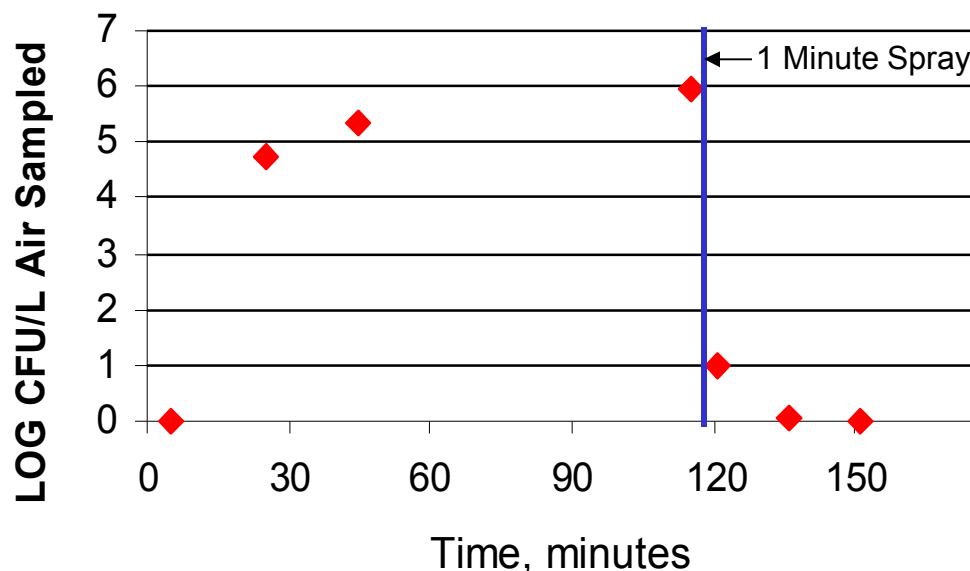
G-Simulant Characterization Tests
1 Minute Decon Spray
December 3, 2004



DF-200 Knockdown & Neutralization Spray

BW Agent Simulant Data

- Tests were conducted against 'weaponized-like' *Bacillus atrophaeus* spores
- Spores were introduced into the chamber at a concentration of 10^6 log CFU/l. After 120 minutes of mixing, DF-200 spray was deployed for one minute through the ESS nozzles.
- Total spray volume deployed was 2 L and the concentration of DF-200 was approximately 138 g/m^3 in the chamber.
- The simulant was collected by aerosol sampling and concentration in the chamber was determined by culturing at <1, 15, and 30 minutes after the end of the spray period.
- The results demonstrated a **5 log knockdown and kill** of the simulant immediately after the spray was stopped. A 5 log knockdown and kill was also observed using a 92 g/m^3 spray density and a 4 log knockdown and kill was observed using a 46 g/m^3 spray density.



Results of cloud knockdown tests using a mist of DF-200 against *Bacillus atrophaeus* spores (an anthrax simulant).

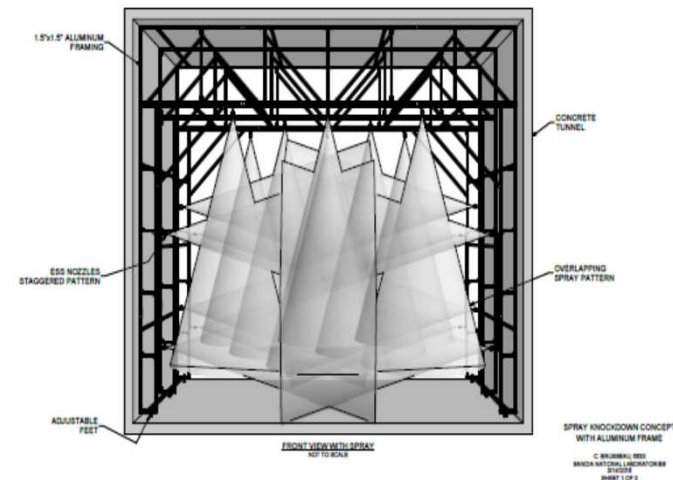
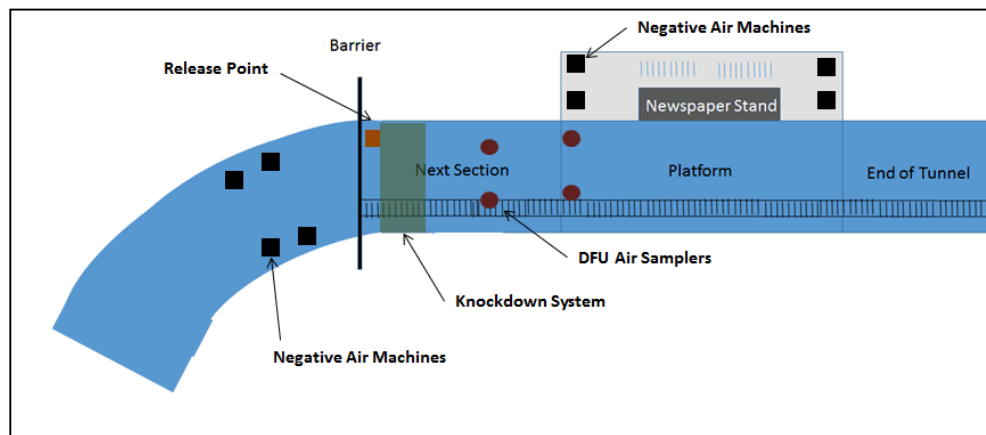
Potential Spray Knockdown Applications

- Many applications for fundamental capability
- Potential applications for military use
 - Force protection (battlefield)
 - Force protection (fixed sites)
 - Chemical demilitarization
 - Immune building
- Potential applications for civilian use
 - Chemical plants
 - Subways
 - Nuclear plants
 - High-profile buildings



Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways

Spray Knockdown Test at the OTD



Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways



Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways

Test Parameters:

- Airflow was approximately 40 ft/min
- Spray was turned on for 1 minute, 30 seconds
- B.g. spores were released (25 mg)
- Spray continued for 18 minutes, 30 seconds
- Approximately 12 gallons of modified DF-200 liquid was deployed
- 6 Liquid (pool) and 4 DFU samples were collected 15 minutes after the end of the spray
- Control (release with no spray) and background (pre-test) samples were collected



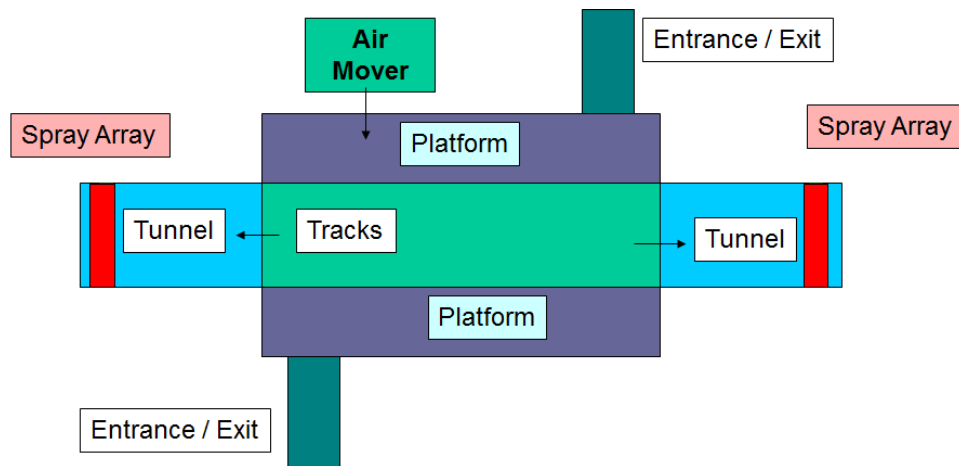
Average Spore Count (Preliminary Data)

| DFU | Background | Control | Spray |
|-----|------------|---------|-------|
| 1 | ND | 18000 | ND |
| 2 | ND | 24100 | ND |
| 3 | ND | 28900 | ND |
| 4 | ND | 27000 | ND |
| 5 | 13.3 | 13800 | ND |

Results:

- Control (i.e., no spray) resulted in ~ 4 log CFU on DFUs
- Spray Test resulted in non-detects on all DFUs
- Spray Test resulted in non-detects in all liquid (pool) samples

CBW Spray Knockdown & Neutralization Subway System Concept



Advantages:

- Large order of magnitude knockdown
- Low regret action

Disadvantages:

- Depends on detection
- Must be pre-installed

Summary of Sandia Chemical and Biological Spray Knockdown Effort

- The Sandia Decon Formulation (DF-200) can neutralize CW agents, BW agents, and many toxic industrial chemicals
- DF-200 is considered to be the “best available technology” by the US Military and was staged in Iraq
- DF-200 is commercially available in several all-liquid packaging options
- Sandia has successfully demonstrated knockdown and neutralization of agent simulant clouds
- Various deployment scenarios have also been developed
- A demonstration system was successfully tested in a mock subway system as part of the Underground Transport Restoration project



Charged spray of modified DF-200 in the Sandia Aerosol Test Chamber during a spray knockdown test.