SAND2006-1695C

Knockdown and Neutralization of CBW Agent Clouds Using Charged Sprays of DF-200

Mark D. Tucker, Ph.D., Sandia National Laboratories, 505-844-7264, mdtucke@sandia.gov

Overview of DF-200

Introduction

Sandia National Laboratories has developed, demonstrated and commercialized an aqueous-based decontamination technology (DF-200) that:

- is effective for neutralizing chemical (CW) and biological (BW) warfare agents, biological pathogens, and many toxic industrial chemicals;
- has low toxicity and corrosivity properties;
- can work on a number of anticipated material surfaces;
- can be incorporated into a number of carriers (foams, liquid sprays, mists, fogs) that satisfy a wide variety of operational objectives.

DF-200 is considerably less corrosive than bleach or other potential decontaminants. The photographs below compare unprotected carbon steel coupons that have been exposed to de-ionized water, DF-200 (liquid solution), and a 10% bleach solution for 24 hours.

Deionized Water - 24 Hour Exposure

DF-200 - 24 Hour Exposure

10% Bleach - 24 Hour Exposure

Through a series of tests conducted by the US DOD's Joint Program Executive Office for Chemical and Biological Defense (JPEO), DF-200 was determined to be the best-available decon technology and was staged in the Middle East to support Operation Iraqi Freedom. It is also the only decontaminant qualified by the Canadian Forces following a two year test program. An earlier version of the technology (DF-100) was used to remediate portions of the U.S. Capitol Hill office buildings and office buildings in New York City following the anthrax incidents of October 2001.

Sandia National Laboratories has licensed the DF-200 technology to two private companies for production and sales. These companies are Envirofoam Technologies, Inc. (Huntsville, AL USA) which produces EasyDECON™-200 and Modec, Inc. (Denver, CO USA) which produces MDF-200™. Both products are registered with the U.S. Environmental Protection Agency (EPA).

This section presents results of DF-200 testing against CW and BW agents conducted at the Edgewood Chemical and Biological Center (ECBC; Edgewood, MD USA) and the Illinois Institute of Technology Research Institute (IITRI; Chicago, IL USA). It also presents results of DF-200 testing against toxic industrial chemicals (TICs) conducted at Sandia and at the Southwest Research Institute (SWRI; San Antonio, TX USA).

Test Results Against CW Agents

Live CW agent testing with DF-200 was conducted at ECBC for the U.S. Department of Defense (DOD) against VX, HD, and GD. The tests were conducted in stirred reactors with samples being collected at 10 and 60 minutes followed by analysis by gas chromatography (GC). Results are shown below:

Decon-taminant	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 of live agents in stirred reactor studies at the Edgewood Chemical and Biological Center (ECBC). Challenge ratio is 50:1. Tests were conducted with EasyDECON™-200 Lot 3829 at 25˚C

Test Results Against BW Agents

DF-200 is highly effective against BW agents. Kill tests against BW agents were conducted at IITRI using DF-200 against *Bacillus anthracis* spores (Ames-RIID and ANR-1 strains) and *Yersinia pestis.* The tests against these BW agents were conducted in a solution of DF-200 with an initial concentration of ~10^7 CFU/ml and a minimum contact time of 15 minutes.

	B. Anthracis - Ames-RIID		*B. anthracis* – ANR-1		*Y. pestis* – (ATCC 11953)	
	Average CFU/ml	Log Reduction	Average CFU/ml	Log Reduction	Average CFU/ml	Log Reduction
Control	1.21 x 10^7	0	6.42 x 10^7	0	6.42 x 10^7	0
15 Minute Contact	No Growth	7	No Growth	7	No Growth	7
30 Minute Contact	No Growth	7	No Growth	7	No Growth	7
60 Minute Contact	No Growth	7	No Growth	7	No Growth	7

Results of kill tests conducted against BW agents in DF-200 solution.

Test Results Against Toxic Industrial Chemicals (TICs)

Tests of DF-200 efficacy were conducted against various TICs. The challenge ratio was 200:1 for most TICs on a weight/volume basis [except: HCN (1:1); anhydrous ammonia (~2:1); butyl isocyanate (250:1)]. Residual concentration was determined by GC and GC/mass spectroscopy.

TIC	Residual Measured In:	% Decontaminated		
		1 Minute	15 Minutes	60 Minutes
Malathion	Liquid	89	95	Below Detection
Hydrogen Cyanide	Headspace	96	95	96
Sodium Cyanide	Liquid	93	98	>99
Butyl Isocyanate	Liquid	99	Below Detection	Below Detection
Carbon Disulfide	Liquid	>99	>99	Below Detection
Phosgene	Headspace	98	>99	>99
Capsaicin	Liquid	Below Detection	Below Detection	Below Detection
Anhydrous Ammonia	Headspace	>99	>99	>99

Deployment

DF-200 can be deployed as a foam, liquid spray, or mist. Deployment as a foam through the Intelagard Merlin™ (left) and Falcon™ (right) systems are shown below:

Cloud Knockdown Using Charged Sprays of DF-200

Sandia Aerosol Test Chamber

The Sandia aerosol test chamber facility is an 8-ft wide by 16-ft long by 8-ft high chamber consisting of two compartments, each an 8-foot cube separated by an intervening wall. The facility includes a knockdown spray system that can be used to experimentally investigate the rapid mitigation and decontamination of airborne CBW agent simulants. For investigation of the effectiveness of charged sprays of DF-200 for CBW agent cloud knockdown, 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 as shown below. 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 and the liquid flow rate is 50–200 ml/min for each nozzle.

The Sandia Aerosol Test Chamber

ESS nozzles in the chamber

Primary instrumentation in the test chamber includes: *BioSamplers* (aerosol samplers, SKC Model No. 225-9595, Operated at ~10 liters per minute), *Collison Nebulizer* (BGI Incorporated Model No. CN-60, used to aerosolize chemical simulants), *Aerodynamic Particle Sizer* (TSI Inc., Model 3321, used to characterize the particle diameter of the simulants in the chamber and distinguish between vapor and particulate, and *Malvern Spraytec* (Real-time Liquid Droplet Sizing system, Malvern Inc., Model RS500, used to measure liquid droplet size distributions from the spray nozzles).

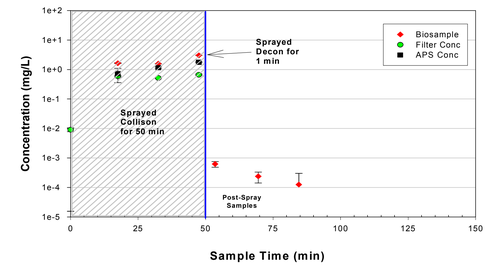
Collison Nebulizer

Aerodynamic Particle Sizer (APS)

Control and Data Acquisition System

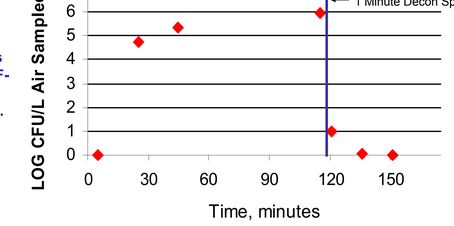
Knockdown Tests of Aerosolized Clouds of CBW Agent Simulants

Tests were conducted to evaluate the effectiveness of DF-200 for knockdown and neutralization of a cloud of aerosolized CBW agents. An aerosolized cloud of a G-agent simulant (diphenyl chlorophosphate) in 1-2 µm droplet sizes was released at a concentration of 3.2 g/m^3 in the 8' x 8' x 8' Sandia Aerosol Test Chamber. The cloud was well mixed by a series of fans in the test chamber for a period of 50 minutes. DF-200 was then deployed as a spray for one minute through a series of nine electrostatic spray nozzles that were located in an array at the top of the test chamber (the air pressure supplied to the nozzles was approximately 80 psig). The total spray volume deployed was 2 L and the concentration of DF-200 was approximately 138 g/m^3 in the chamber making the challenge ratio (decontaminant to simulant) approximately 40:1. The G-agent simulant was collected by aerosol sampling and the concentration in the chamber was determined by GC immediately after the end of the spray period and again at 15 and 30 minutes after the end of the spray period. The results demonstrated a nearly 4 log knockdown and neutralization of the simulant immediately after the spray was stopped.



Results of cloud knockdown tests using a mist of DF-200 against a G-agent simulant.

Similar tests were conducted against 'weaponized' *Bacillus atrophaeus* spores (an anthrax simulant) obtained from the Dugway Proving Ground. The spores were introduced into the chamber at a concentration of 10^6 log CFU/l. After 120 minutes of mixing, DF-200 was deployed as a spray for one minute through the ESS nozzles. The total spray volume deployed was 2 L and the concentration of DF-200 was approximately 138 g/m^3 in the chamber. The anthrax simulant was collected by aerosol sampling and the 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 while a 4 log knockdown and kill was observed using a 46 g/m^3 spray density. These tests clearly demonstrate the ability of DF-200 to knockdown and neutralize clouds of CBW agent simulants.



Results of cloud knockdown tests using a mist of DF-200 against an anthrax simulant.

Synergism of DF-200 and BIT™

The Binary Ionization Technology (BIT™) is a patented process developed by L-3/Titan Corp. that creates highly oxidative particles by a cold plasma activation of aerosolized hydrogen peroxide. It is effective in decontaminating CBW agents and TICs. L-3 has conducted tests to compare standard BIT™ formulations to DF-200 and to DF-200 applied through BIT™ hardware. 10g/m^2 of diazinon (a VX simulant) was applied to a steel coupon. DF-200, BIT™ and DF-200/BIT™ were then applied to the coupon at the recommended 100:1 challenge ratio (decontaminant:agent). A 12:1 challenge ratio was also used to cause partial neutralization of the simulant to provide better comparative results between the formulations. DF-200/BIT™ was clearly superior to either technology alone demonstrating the potential use of this combination of technologies in future cloud knockdown work.

Decontaminant to agent ratio	DF-200		BIT™		DF-200/BIT™	
	Dwell time (min)	Log reduction	Dwell time (min)	Log reduction	Dwell time (min)	Log reduction
100:1	0 5 45	1.15 2.64 ≥4.0	0 5 45	≥4 ≥4 ≥4	0 5 45	≥4 ≥4 ≥4
12:1	-- -- 45	-- -- 1.5	0 -- 45	0.8 -- 2.0	**0** **--** **45**	**1.7** **--** **4**
Control experiment, water replaced decon, 100:1	45	~0	45	~0	45	~0

Log reduction of diazinon on steel coupons.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a LockheedMartin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

National Nuclear Security Administration

Sandia National Laboratories