Abstract Technical Report

EnviroFoam Technologies™
September 2003

EnviroFoam Technologies™
1012 Oster Drive. Suite A
Huntsville, Alabama 35816
Ph: 256-489-9245
Fax: 256-489-9248
www.easydecon.com

Formulations for the Decontamination and Mitigation of CB Warfare Agents, Toxic Hazardous Materials, Viruses, Bacteria and Bacterial Spores

Updated September 15, 2003

Abstract

A non-toxic, non-corrosive aqueous solution/foam with enhanced physical stability for the rapid mitigation and decontamination of chemical and biological warfare (CBW) agents and toxic hazardous materials was developed at Sandia National Laboratories in 1999. The foam formulation was and is based on a surfactant system to solubolize sparingly soluble agents and increase rates of reaction with nucleophilic reagents and mild oxidizing agents. The formulation also included water-soluble polymers to enhance the physical stability of the foam.

Experimental results demonstrated effective decontamination of both chemical warfare (CW) and biological warfare (BW) agent simulants and live agents on contaminated surfaces and in solution. Testing also showed that the foam decontaminated thickened agent simulants as well. Other experimental work demonstrated that the foam effectively decontaminated CW agent simulants on a variety of surfaces. The foam also killed anthrax spores. In biological tests, a 7-log kill of the spores was achieved after exposure to the foam solution. Additional testing also demonstrated that the foam was effective in killing vegetative cells of Erwinia herbicola (a simulant for plague) and the MS-2 virus (a simulant for smallpox).

Additional tests indicated that the formulation could be effective as a universal decontaminant on a variety of toxic industrial materials and other hazardous bacteria, & viruses.

EFT, Inc. of Huntsville, Alabama was selected by the Department of Energy to commercialize the invention pursuant to License No. 00-C00900. EFT has compiled this report for potential end-users for evaluation and analysis. The data herein is based upon previously issued documents in official reports including patent disclosures and Department of Energy documents. (Patent Application No. 60/146,432 dated July 29, 2000, and Sandia Report SAND2000-17419 dated June 2000) and internally generated information which is proprietary to EFT, Inc.

In October 2000, Sandia received funding from the Department of Energy CBNP program to develop an enhanced version of the foam product to optimize performance for the military and the civilian first responder. The result of this work produced an enhanced version of the Sandia decontamination formulation.

TABLE OF CONTENTS

INTRODUCTION

A revolutionary technology of a non-toxic, non-corrosive aqueous solution/foam with enhanced physical stability for the rapid mitigation and decontamination of chemical (CW) and biological (BW) warfare agents was developed at Sandia National Laboratories. The formulation is based on a surfactant system to solubolize sparingly soluble CW agents and to increase rates of reaction with nucleophilic reagents. The formulation was the first known to be effective on a broad spectrum of chemical agents as well as biological agents, bacteria, viruses, and bacterial spores.

This original decontamination technology was attractive for civilian and military applications for several reasons: (1) a single decon solution could be used for both CW and BW agents; (2) it was rapidly deployable; (3) mitigation of agents could be accomplished in bulk, aerosol, and vapor phases; (4) it exhibited minimal health effects and collateral damage, (5) it required minimal logistics support, (6) it had minimal run-off of fluids and no lasting environmental impact, (7) when applied as a foam, it had a high expansion rate making it logistically desirable; and, (8) contact times were reasonable.

The Decon Formulation decontaminated both CW and BW agents and simulants. For CW work, live agent testing was conducted with GD (Soman), VX, and HD (Mustard) at governmental facilities. The half-lives for the decontamination of these agents in the foam system were on the order of two minutes to twenty minutes. The majority of the work with BW agents was focused on anthrax where the solution achieved a 7-log kill (99.99999%) of anthrax spores after a one-hour exposure to the foam. Other BW work demonstrated rapid kill of the simulants for plague (a vegetative bacterial cell) and for the smallpox virus.

The technology was licensed to EnviroFoam Technologies, Inc. (EFT), of Huntsville, Alabama, for the purpose of unrestricted commercialization pursuant to License No. 00-C00900. EFT, Inc. has prepared the following information for the benefit of end-users desiring to utilize the technology. EFT has been involved with optimizing the formulation for use by virtue of advanced chemical compounding as part of its commitment to maximize the technology's performance in detoxification and neutralization of toxic materials.

TECHNOLOGY DEVELOPMENT

A. Background

The objective of the research project at Sandia was to develop an effective, rapid, and safe (non-toxic and non-corrosive) decontamination technology. Ideally, the technology would be applicable to a variety of scenarios such as the decontamination of open, semi-enclosed, and enclosed facilities, vehicles, personnel and sensitive equipment.

The initial research effort was directed to materials for neutralization of chemical and biological compounds or agents, and especially chemical and biological weapons agents and their method of making. This Program was funded by the United States Government under contract DE-AC04-94AL85000 awarded by the U.S. Department of Energy's DOE-NN-20 CBNP Program's Decontamination and Restoration Thrust Area.

In particular, the research was directed to materials containing solubilizing compounds and reactive compounds that could be delivered as foams, sprays, liquids, fogs and aerosols to enhance the rate of reactions leading to neutralization of chemical compounds, and other additives which serve to kill or attenuate certain biological compounds or agents.

THE NATURE OF CBW AGENTS

Certain CW agents share chemical characteristics that present an opportunity for the development of countermeasures. The chemical agents sarin, soman, and tabun (G-agents) are all examples of phosphorus-containing compounds which, when altered chemically, can lose their toxicity. Mustard, which is an example of the blistering-agents, and VX, which is an example of the V-agents, can also be altered chemically and rendered harmless. In addition, certain of the known BW agents, i.e., botulinum toxin, anthrax and other spore-forming bacteria, vegetative bacteria, including plague and various viruses can also be deactivated chemically.

A CW or BW attack can involve either local placement or wide dispersal of the agent or agents so as to affect a population of human individuals. Because of the flexibility with which CW and BW (CBW) agents can be deployed, respondents might encounter the agents in a variety of physical states including bulk, aerosol and vapors.

Decontamination of chemical compounds have focused primarily on chemical warfare agents, particularly on the nerve agents (such as G-agents and V-agents) and on the blistering agents (such as mustard gas, or simply, mustard). Reactions involved in detoxification of chemical agents can be divided into substitution and oxidation reactions. Decontamination of biological agents is primarily focused on bacterial spores (e.g. anthrax) which are considered to be the most difficult of all microorganisms to kill.

For the first responder, it is critical to decontaminate facilities or equipment to an acceptable level in a very short time so casualties can be located and treated. In the restoration scenario, time is of less importance but collateral damage, public perception, and re-certification (i.e., complete decon) is of greater consequence. Thus, there were numerous research and development challenges associated with this effort. One challenge was to develop a common formulation effective against all chemical and biological agents, while being suitable for use on a wide variety of building materials commonly found in civilian facilities. A second challenge was the development of a decontamination formulation that could be rapidly deployed in large quantities by first responders to effectively destroy (or detoxify) chemical or biological agents while remaining relatively harmless to both people and property. In addition, a formulation was desired that renders chemical and biological agents harmless in a reasonable period of time so that relatively rapid restoration of facilities may be achieved.

B. Reaction Mechanisms

Decontamination of chemical agents has primarily focused on the nerve agents e.g., Sarin, Soman, (G-agents) and VX (V-agents) and on the blistering agents, e.g., Mustard. Reactions involved in detoxification of chemical agents may be divided into substitution and oxidation reactions. Decontamination of biological agents is primarily focused on bacterial spores (e.g., anthrax), which are considered to be the most difficult of all microorganisms to kill. Important reagents and mechanisms for these reactions are summarized below.

Hydrolysis Substitution Reaction

Hydrolysis of chemical agents can be carried out with water, hydroxyl ions or other nucleophiles. The rate of hydrolysis of mustard and the nature of the products formed depends primarily on the solubility of the agent in water and on the pH of the solution. In the detoxification of Mustard, for example, the molecule first forms a cyclic sulfonium cation, which reacts with nucleophilic reagents. The dominant product is thiodiglycol but this product may react with sulfonium ions to give secondary intermediates HD-TDG and CH-TDG shown below (Figure 1-1).

+
$CH_2CH_2S(CH_2CH_2OH)_2$
S<
CH_2CH_2C1

HD-TDG

+
$CH_2CH_2S(CH_2CH_2OH)_2$
S<
CH_2CH_2OH

CH-TDG

FIGURE 1-1: *Secondary intermediate products generated by the hydrolysis of mustard.*

The hydrolysis of Sarin (GB) and Soman (GD) occurs rapidly under alkaline conditions and gives the corresponding O-alkyl methylphosphonic acid. In contrast, the hydrolysis of VX and OH ions is more complex. In addition to displacement of the thioalkyl group (i.e., P-S bond breakage), the O-ethyl group is displaced (i.e., P-O bond breakage) producing a toxic product known as EA-2192. This concept is rationalized by considering that nucleophilic substitution at phosphorous centers involves addition to form a trigonal bipyramidal intermediate (TBP). Nucleophiles enter and depart the intermediate from an apical position. Electronegative groups, such as RO groups, preferentially occupy apical positions and groups that are bulky or electron donors, such as RS groups, occupy equatorial positions. If the lifetime of the TBP allows pseudorotation to occur, the final product will depend on the balance between apicophilicity and leaving group ability. The result is that P-S bond cleavage is favored over P-O bond cleavage by a factor of about 5. Peroxyhydrolysis, on the other hand, using OOH ions in alkaline medium was shown to involve quantitative P-S cleavage at rates 30-40 times that with OH. This selectivity was related to the relative basicities of the anionic nucleophile and the leaving anions.

Catalytic species for acceleration of substitution reactions have been reported. An important example is o-iodosobenzoate (IBA). IBA is converted to iodoxybenzoate (IBX) via oxidation that then participates in the reaction with the CW agent.

The compound was also functionalized to introduce surface activity (surfactant character) to the active group. Metal ion-amine complexes, with surface-active moiety, were also developed and shown to exhibit catalytic effects in substitution reactions. (Enzymes such as organophosphorous acid anhydrolase have also been shown to accelerate substitution reactions with the G and VX agents.)

Oxidation Reaction

Oxidative decontamination methods are especially useful for Mustard and VX. An early oxidant used was potassium permanganate. Recently, Oxone (a mixture of $KHSO_5$, $KHSO_4$, and K_2SO_4) has been developed. Several peroxygen compounds have also been shown to oxidize chemical agents (e.g., perborate, peracetic acid, m-chloroperoxybenzoic acid, magnesium monoperoxyphthalate, and benzoyl peroxide). More recently, hydroperoxycarbonate anions produced by the reaction of bicarbonate ions with hydrogen peroxide have been shown to effectively oxidize Mustard. VX Polyoxymetalates are being developed as room temperature catalysts for oxidation of chemical agents, but the reaction rates are reported to be slow at this stage of development. Some of these compounds undergo a color change upon interaction with chemical agents. This phenomenon is being exploited in the formulation of barrier creams and solid sorbents to indicate the presence of chemical agents.

Kill of Biological Agents

Some consider the BW threat to be more serious than the CW threat. This is in part because of the high toxicity of BW agents, their ease of acquisition and production, and difficulty in detection. There are hundreds of biological warfare agents available for use by terrorists. They may be grouped into the categories of spore forming bacterium (e.g., anthrax), vegetative bacterium (e.g., plague, cholera), virus (e.g., smallpox, yellow fever), and bacterial toxins (e.g., botulism, ricin). The focus of this work is on the decontamination of spores because they are recognized to be the most difficult microorganism to kill.

Bacterial spores are highly resistant structures formed by certain gram-positive bacteria usually in response to stresses in their environment. The most important spore-formers are members of the genera, *Bacillus* and *Clostridium*. Spores are considerably more complex than vegetative cells. The outer surface of a spore consists of the spore coat that is typically made up of a dense layer of insoluble proteins usually containing a large number of disulfide bonds. The cortex consists of peptidoglycan, a polymer primarily made up of highly cross-linked N-acetyglucosamine and N-acetylmuramic acid. The spore core contains normal (vegetative) cell structures such as ribosomes and a nucleoid.

Since their discovery, considerable research has been carried out to investigate methods to kill bacterial spores. Although spores are highly resistant to many common physical and chemical agents, a few antibacterial agents are also sporicidal. However, many powerful bactericides may only be inhibitory to spore germination or outgrowth (i.e., sporistatic) rather than sporicidal. Examples of sporicidal reagents, using relatively high concentrations, are: glutaraldehyde, formaldehyde, iodine and chlorine oxyacids compounds, peroxy acids, and ethylene oxide. In general, all of these compounds are considered to be toxic.

There are several mechanisms generally recognized for spore kill. These mechanisms, which may operate singularly or simultaneously, are described below:

1. The dissolution or chemical disruption of the outer spore coat may allow penetration of oxidants into the interior of the spore. Several studies (King and Gould, 1969; Gould et al., 1970) suggest that the S-S (Disulfide) rich spore coat protein forms a structure which successfully masks oxidant-reactive sites. Reagents that disrupt hydrogen and S-S bonds increase the sensitivity of spores to oxidants. A typical protein with disulfide linkage:

H_2N-CH-COOH
I
CH_2
I
S
I
S
I
CH_2
I
H_2N-CH-COOH

FIGURE 1-2: *Protein with cysteine linkage.*

2. Peptidoglycan, which is loosely cross-linked and electronegative, makes up the cortex of a spore. Interaction between a disinfectant solution and peptidoglycan may cause collapse of the ortex and loss of resistance.

3. The peptidoglycan of spore-forming bacteria contains teichoic acids (i.e., polymers of glycerol or ribitol joined by phosphate groups). Disruption of the teichoic acid polymers may cause deficiencies in the peptidoglycan structure making the spore susceptible to attack.

4. Certain surfactants may increase the wetting potential of the spore coat to such an extent as to allow greater penetration of oxidants into the interior of the spore.

With all of these mechanisms, it is generally agreed that actual spore kill is only achieved when the SNA of the spore has been sufficiently disrupted or destroyed.

C. Past Decontamination Formulations

Historically, decontamination solutions have focused strictly on the kill and neutralization of chemical and biological agents. Little emphasis has been placed on restoration and re-use of facilities and equipment. Instead, these items were considered to be expendable and were expected to be replaced in the event of a CBW attack. Thus, most decontamination formulations currently in use are both highly toxic and highly corrosive. A review of many of these current decontamination formulations is presented here.

Liquid Decontaminants Against CW Agents

In this section, a number of liquid decontamination formulations that have been developed for the decontamination of chemical agents are documented. As indicated, each of these formulations is highly toxic and/or highly corrosive.

Supertropical Bleach. The neutralization of chemical warfare agents began in 1798 when Charles Tennant discovered bleaching powder. In 1917, the Germans used bleaching powder to neutralize mustard agent. Supertropical bleach was standardized in the 1950's. It is a mixture of 93% calcium hypochlorite and 7% sodium hydroxide and is more stable than bleach in long-term storage and easier to spread. Mustard gas reacts with bleach by oxidation of the sulfide to sulfoxide and sulfone and by dehydrochlorination to form compounds such as O_2S $(CHCH_2)_2$. The G-agents are converted by hydrolysis to the corresponding phosphonic acids with the hypochlorite anion acting as a catalyst (Epstein et al., 1956). In acidic solutions, VX is oxidized rapidly by bleach at the sulfur atom and dissolves by protonation at the nitrogen. On the other hand, at high H, the solubility of VX is significantly reduced and the deprotonated nitrogen is oxidized leading to consumption of greater than stoichiometric amounts of bleach.

Decontaminant Solution 2 (DS2). Decontamination Solution Number 2 (DS2) was introduced in 1960. This is a non-aqueous liquid composed of 70% diethylenetriamine, 28% ethylene glycol monomethyl ether, and 2% sodium hydroxide. The reactive component in the conjugate base is $CH_3OCH_2CH_2O^{-1}$. While DS2 is a highly effective decontaminant for CW agents, ethylene glycol monomethyl ether has shown tetragonicity in mice and replacement with propylene glycol monomethyl ether was proposed (DS2P). In addition, DS2 attacks paints, plastics, and leather materials. To minimize these problems, the contact time with DS2 is limited to 30 minutes followed by rinsing with large amounts of water. Personnel handling DS2 are required to wear respirators with eye shields and chemically protective gloves. The reactions of DS2 with mustard lead to elimination of HC1. The nerve agents react with DS2 to form diesters, which further decompose to the corresponding phophonic acid. DS2 is not very effective in killing spores. Only 1-log kill was observed for *Bacillus subtilis* after one hour of treatment (Tucker, 1999).

D. Effect on Toxic Hazardous Materials

EFT's Decon Formulation known as "EasyDECON™ has exhibited similar mitigation and neutralizing effects on a wide variety of toxic industrial materials and other generally considered hazardous chemicals, compounds and materials.

TOXIC INDUSTRIAL MATERIALS
EasyDECON™ has been tested and is effective in neutralizing or controlling a wide variety of toxic industrial chemicals. Such chemicals present a hazard in regular production due to the possibility of leaks and spills, to say nothing of the effect of a transportation accident or terrorist attack on storage or production facilities. EasyDECON™ has been tested and is very effective against:

Ammonia (anhydrous0
Carbon DiSulfide
Chlorine
Formaldehyde
Hydrogen or sodium cyanide
Hydrogen Fluoride
Phosgene
Many other materials – call us about a specific material or need

Unique Patented Characteristics – The Formulation contains reactive ingredients that will both hydrolyze and oxidize organophosphates and mitigate many other toxic/hazardous materials.

Disinfection/Bio-control – Contains biocides that eliminate biogrowth. Capable of prolonged disinfection and works as a fungicide.

Toxicity reduction/Biodegradability improvement – Chemically digests complex organics into smaller, less toxic and safe biodegradable fragments.

Catalytic Formulation – More difficult-to-oxidize materials can be mitigated with the EFT Formulation. The catalytic reaction of the formulation speeds up the oxidative reactions that may otherwise take hours or days to complete. The reaction requires a slightly basic pH and results in the formation of highly reactive species that degrade most organic pollutants more quickly and efficiently as compared to chlorine. EFT can also adjust the pH of the formulation for specific agents/contaminants for optimal performance.

Safe – Despite its power, the primary oxidizers within the EFT Decon Formulation will decompose into oxygen and water. Consequently, the formulation has none of the problems of gaseous release of using chlorine (chlorinated organics) or chemical residues that are associated with other chemical oxidants. In addition, since the Formulation is totally miscible with water, it is perfectly safe to handle and apply to many materials.

Versatile – The EFT Decon Formulation (“EasyDECON”) is very versatile. As a biocide, it can kill vegetative biological agents as well as difficult-to-kill spores like anthrax and molds. Similarly, it can treat both easy-to-oxidize pollutants (iron and sulfides) and difficult-to-oxidize pollutants (pesticides, toxic industrial chemicals, various flammable lab chemicals, etc.) as well as immediately reducing the flammability. And there is no residual effect on the environment. Further, it can be deployed in a variety of formats (liquid, foam, and vapor) which optimizes contact time and emulsification of target contaminants.

Bactericide/Fungicidal Targets – Many gram-positive bacterial cells form highly resistant, dormant structures called endospores in response to stresses in their environment. Endospores (commonly referred to as spores) are very difficult to kill without the use of highly toxic or corrosive chemicals, high thermal sources or radiation. Chemicals typically used to kill spores include peracetic acid (very toxic and corrosive), hypochlorite (toxic and corrosive and creates chlorinated organic by-products), glutaraldehyde (toxic) and formaldehyde (toxic). In addition, certain bacteria form chemical-resistant films after repeated exposure to hypochlorites. Most of these solutions are environmentally unfriendly and potentially toxic to users – the use of glutaraldehyde, for example, has generated numerous lawsuits by hospital workers.

Killing of spores has become important in many disinfecting, decontamination and detoxification applications in a variety of industries. The technological development of the formulation was based upon killing one of the moist difficult spore foams – bacterium anthrax.

EFT EasyDECON™ FORMULATION

A. Objectives

The decontamination program at Sandia National Laboratories focused on the development, demonstration, and commercialization of products for effective response and consequence management in the event of a release of chemical and/or biological weapons agents on U.S. civilians and facilities. The project is supported by the DOE NN-20 Chemical and Biological Non-Proliferation (CBNP) Program's Decontamination and Restoration Thrust Area.

Its stated objectives were to develop rapid, effective, and safe (non-toxic and non-corrosive) decontamination technologies for a range of chemically and biologically contaminated surfaces in civilian facilities primarily in the urban environment (U.S. Department of Energy, 2000). For the three years, Sandia National Laboratories worked on a reagent formulation that has been extremely effective in meeting these overall objectives.

The foam formulation has the following characteristics:

- it is effective for neutralizing both chemical and biological agents;
- it is environmentally benign to both people and property;
- it works on all currently anticipated material surfaces;
- it can be incorporated into a wide variety of carriers (foams, gels, and gases) that satisfy a wide variety of operational objectives;
- it can be retrofitted into many existing decon apparatus.

The initial efforts were spent on developing a foam formulation that could be used to decontaminate large surface areas such as the interiors of facilities. Progress on this research objective proceeded to the point where developmental testing against live agents was completed and the formulation was shown to be effective. This section describes the physical and chemical characteristics of the foam as well as its effectiveness against chemical and biological agents in both laboratory and field tests.

B. Foam Formulation

The original EFT foam was a unique formulation developed exclusively for the decontamination of chemical and biological warfare agents. The foam formulation was based on a surfactant system to increase solubolization of chemical agents and reactivity with nucleophilic reagents. A mild oxidizing agent (hydrogen peroxide) was also added to the foam at a low concentration.

The second important physical property of foam was its stability. Foam stability is measured by its half-drainage time, which is defined as the time required for a foam to lose half of its original liquid volume. For example, if 1L of solution is used to generate a foam, the half-drainage time is defined as the amount of time for 500 ml to drain from the foam. This property was important because a stable foam allows for a greater contact time between the formulation and the chemical or biological agent. The objective of this program was to develop a formulation that produced foam with half-drainage times of several hours.

C. Decontamination Effectiveness

Certain chemical agents share a similar chemical property in the fact that they contain phosphorus bonds that can be altered when subjected to nucleophilic attack. These agents (i.e., the nerve agents) include the G-agents (e.g., Sarin, Soman, and Tabun) as well as the V-agents (e.g., VX). Each of these agents can be chemically detoxified and neutralized if the phosphorus bond is chemically altered by hydrolysis or by oxidation.

Blistering agents such as mustard (HD) are chemically distinct from the nerve agents in that they do not have a phosphorus-containing group. However, the carbon-chloride bonds in mustard are also subject to hydrolysis and the central sulfur can be oxidized to sulfone and sulfoxide, thereby detoxifying the molecule. Mustard does share a similar property with the nerve agents in that they all are only sparingly soluble in water.

D. Independent Live Agent Test Results

Live agent tests of the original formulation were conducted at Edgewood Proving Grounds (ECBC), Maryland. Two types of tests were performed: kinetic (reaction rate), and contact hazard tests under controlled test protocol. All tests were conducted with CASARM grade agents (Chemical Agent Standard Analytical Reference Material) at ambient room temperature.

DECONTAMINANT	**HD**		**GD**		**VX**	
	10 Min	**1 Hour**	**10 Min**	**1 Hour**	**10 Min**	**1 Hour**
DS2	100	100	100	100	100	100
Sandia Foam	47	100	>99	100	100	100

TABLE 3-1: *Percent decontamination in ECBC reaction rate tests. Data for DG and HD collected at pH 9.2. Data for VX collected at pH 10.5.*

The results from those tests clearly indicated that the foam was very effective in the decontamination of CW agents. It was also clear that DS2 was a very effective decontamination solution and that the primary motivation for finding a replacement was due to its high toxicity and high corrosivity, not its inability to decontaminate CW agents. Results from the contact hazard tests are shown in Table 3-2 below. These results were compared to DS2 and water.

Decontaminant	CARC			AC Topcoat			Ship Low IR			Non-Skid		
	HD	VX	TGD	HD	VX	TGD	HD	VX	TGD	HD	VX	TGD
DS2	1	4.3	8.8	2.6	0.01	0.2	9.8	9.2	0.4	1.8	0.02	3
Sandia Foam	72.3	6.5	2.4	22.6	0.2	0.2	125.3	42.4	20.4	11.3	0.4	4.5
Water	27	38.4	237.9	32.8	9.7	349.6	155.4	21.7	153	19	4	74.7

TABLE 3-2.

A fundamental issue about the solution or foam formulation concerned the use of foam by first responders versus personnel involved in facility restoration. When used for facility restoration, the exact chemical or biological agent that had been used would most likely be known. In that case, the pH of the formulation could be easily adjusted to the optimum value for that specific agent. This pH adjustment could be accomplished through the use of pre-measured packets in which a base (such as NaOH) was included with the solid hydrogen peroxide and was added to the liquid foam formulation immediately before use. The optimum pH values for each agent are shown in Table 3-3.

Agent	**Optimum pH of Foam Formulation**
G-Agents (soman, sarin, tabun)	8.0
Mustard	8.0
VX	10.5
Anthrax	8.0

TABLE 3-3: *Optimum pH values for destruction of CBW agents*.

However, for first responders, the specific agent would, in general, be unknown. Therefore, an intermediate pH had to be selected that would effectively react with all agents. This intermediate pH value was, by necessity, a compromise. Testing in the laboratory revealed that the best pH for first responder use was 9.2. Decontamination effectiveness of the foam against various CBW agents and simulants is summarized in Table 3-4.

Agent/Simulant	Time	pH 7.0	pH 8.0	pH 9.2	pH 10.5
Anthrax Spores	30 min.	99.99	99.99	-	-
	1 hour	99.99999	99.99999	-	-
Anthrax simulant (B. Globigii spores)	30 min.	99.99	99.99	99	-
	1 hour	99.99999	99.99999	99.99	-
GD	10 min.	-	100	>99	-
	1 hour	-	100	100	-
VX	10 min.	-	-	-	100
	1 hour	-	-	-	100
VX Simulant	15 min.	-	18	59	100
	30 min.	-	38	-	100
	1 hour	-	-	89	100
HD	10 min.	-	48	47	-
	1 hour	-	98	100	-

TABLE 3-4: *Decontamination effectiveness of the foam against CBW agents and simulants at various pH values.*

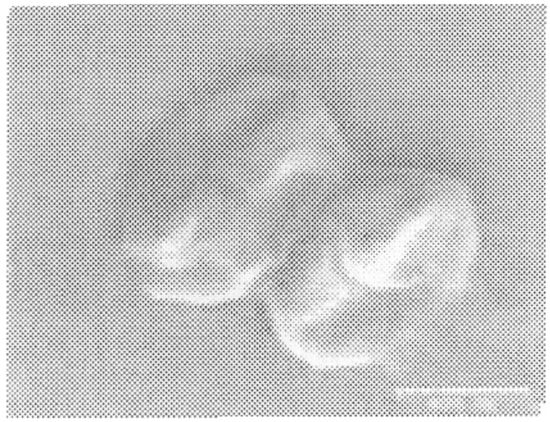
Results with BW Simulants and Agents – Laboratory Tests

Work with biological agents focused on what was perceived to be the most difficult of agents to kill, bacterial spores (e.g., *Bacillus anthracis* or anthrax). Numerous tests were conducted with the spore-forming bacterium *Bacillus globigii* (a recognized simulant for anthrax) to determine the effectiveness of the liquid or foam formulation in killing this microorganism. Tests were also conducted to determine the killing efficiency of the foam on a simulant for plague (*Erwinia herbicola* – a vegetative bacterial cell) and on a simulant for the smallpox virus (the MS-2 bacteriophage). In addition, live agent testing was conducted with *Bacillus anthracis* ANR-1 at the Illinois Institute of Technology Research Institute in Chicago, Illinois. The foam proved to be effective in killing all of these organisms in a timely manner.

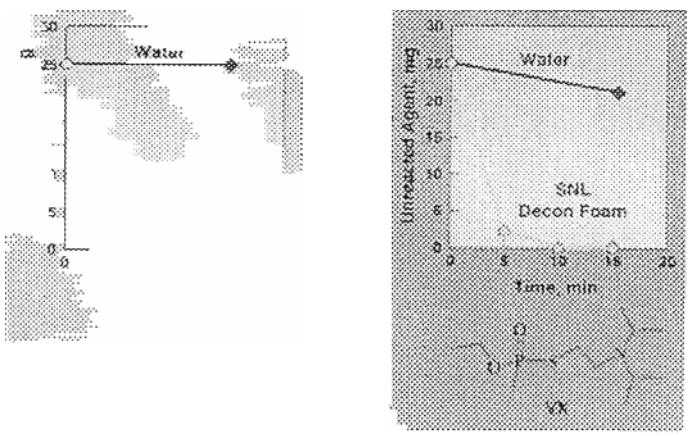
Two basic types of tests were conducted to test the foam's effectiveness in the killing of BW simulants and agents. In the first type of test, a solution test, the microorganisms were dispensed directly into the liquid solution from which the foam is generated. After specified periods of time, the microorganisms were extracted from the solution by centrifugation, washed, and then plated on an appropriate biological medium to determine if they had been killed.

Microorganisms used for the spore tests were *Bacillus globigii* (ATCC 9372) and *Bacillus anthracis* ANR-2. The microorganism used for the vegetative cell tests was *Erwinia herbicola* (ATCC 39368). The MS-2 bacteriophage (ATCC 15597B) with the bacterial host *Escherichia coli* (ATCC 15597) was used for the viral inactivation tests.

Photo of *Bacillus globigii* (anthrax spore simulant) killed during tests.



Decontamination of GD, VX and HD (25 mg of agent on 25 cm^2 of paper).



Nuclear magnetic resonance studies (NMR) demonstrated that the destruction of CW simulants occurred without the formation of potentially toxic by-products.

E. Deployment Methods

The formulation of the original invention could be delivered to the toxins in a variety of manners and phases to provide the necessary detoxification. One useful form of delivery was foam. A non-toxic, non-corrosive aqueous **foam** with enhanced physical stability for the rapid neutralization of toxins, especially CW and BW agents, was the primary focus of the development work. The foam formulation was based on a surfactant system to solubilize sparingly soluble toxins and to increase rates of reaction with nucleophilic reagents. The formulation also included mild oxidizing agents to neutralize biological toxins along with components to enhance the physical stability of the foam.

This neutralization technology was attractive for civilian and military applications for several reasons including: (1) a single neutralization solution could be used for both chemical and biological toxins, (2) it was rapidly deployable, (3) mitigation of agents was accomplished in bulk, aerosol, and vapor phases; (4) it exhibited minimal health and collateral damage, (5) it required minimal logistics support, (6) it had minimal run-off of fluids and no lasting environmental impact, and (7) it was relatively inexpensive.

The solution or foam formulation could be delivered by various methods. Foams generated had been shown to have a maximum expansion ratio of about 60-100:1, and were shown to be stable for approximately 1-4 hours depending on environmental conditions (temperature, wind, relative humidity). The foam could also be generated by compressed air foam systems where air is directly injected into the liquid foam. Foam generated by this method generally has expansion ratios of about 20-60:1, and is also stable from 1-4 hours. The use of foam was desirable as less concentrate was used (therefore less weight and logistical burden) for combat or response operations.

The formulation of the original invention accomplished these goals. The foam formulation was effective for neutralizing both chemical and biological toxins; was environmentally benign to both people and property; worked on all currently anticipated material surfaces; and could be incorporated into a wide variety of carriers (foams, gels, fogs, liquid applicators and sprayers, aerosols) that satisfied a wide variety of operational objectives.

EFT, Inc. has designed and patented a high volume CAF system that can be easily deployed by a single operator. This system affords the user ~~with~~ an easy to use device that rapidly discharges foam to an intended target. The formulation of the original Sandia solution showed it had the capability to neutralize toxins in bulk, aerosol and vapor states, and could be applied in a variety of manners to protect or clean up targets including equipment, open areas, facilities and buildings. The formulation of the original invention could also be used in disinfection scenarios for both animals and inanimate objects.

Alternative deployment methods for the foam formulation were also available with the formulation of the present invention. Foam is nothing more than a liquid solution with a gas phase (in this case, air) blown through it. It is the formulation that is effective in the destruction/neutralization of the CBW agents, not the foam (in other words, the liquid formulation decontaminates CBW agents, not the air).

Methods such as **sprays, mists and fogs** can be utilized with the same basic formulation. The objective of these alternative methods is to minimize the quantity of water that is required to be used in the restoration of controlled environments (such as indoor facilities) and facilitate access of the formulation to the CBW agents. The formula can also be dispersed through aerial spray systems such as the MASS (Mobile Aerial Spray System) fielded by the USAF at the 910th Airlift Wing Command.

The alternative deployment methods have various advantages over foam deployment for small or difficult area decon. A **fog**, for example, can be used to achieve effective decon in areas where decontamination by a foam is difficult, if not impossible. One example is the interior of air conditioning ducts. A fog can be generated at registers and other openings in the duct and travel a significant distance inside of the duct to decontaminate hard to reach places. An additional advantage of a fog is that a relatively automated or semi-automated decontamination system can be set-up at the scene of an attack. Remotely activated foggers can be placed inside of a facility and turned on at periodic intervals (from a remote location) to completely decontaminate the facility. This method greatly decreases the potential for decontamination personnel to be exposed to a CBW agent.

In one embodiment, the formulation of the original invention was an aqueous-based formulation that was capable of being deployed as a fog (i.e., as an aerosol with particulate sizes ranging from 1-30 microns) for the rapid neutralization of chemical and biological warfare (CBW) agents. The formulation exhibited low-corrosivity and low-toxicity properties and could be deployed through commercially available fog generating devices. Current decontamination formulations utilize toxic and/or corrosive chemical to achieve destruction of CBW agents that can potentially damage sensitive equipment in which it comes into contact.

Greater than 99% neutralization of the G-agent simulant (diphenyl chloro-phosphate) was achieved after one-hour exposure to the fog in a test chamber on all surfaces tested and complete neutralization was achieved after four successive fog treatments (with a one-hour wait between each treatment) for all surfaces. Between 70% and 99% neutralization was achieved after four successive foggings of the VX simulant (O-ethyl-S-ethyl phenyl phosphonothioate) and between 30% and 85% neutralization was achieved with the mustard simulant (chloroethyl ethylsulfide) after four successive foggings. For the anthrax simulant (B. globigii spores), 7 log kill was achieved after four successive foggings.

F. Additional CBW Toxins Covered

The chemical toxins addressed by the formulation include, but are not limited to:

- o-alkyl phosphonofluoridates, such as sarin and soman
- o-alkyl phophoramidocyanidates, such as tabun
- o-alkyl, s-2-dialkyl aminoethyl alkylphosphonothiolates and corresponding alkylated or protonated salts, such as VX
- mustard compounds, including 2-chloroethychloromethylsulfide, bis (2-chloroethyl) sulfide, bis (2-chloroethylthio) methane, 1,2-bis (2-chloroethylthio) ethane, 1,3-bis (2-chloroethylthio)-n-propane, 1,4-bis (2-chloroethylthio)-n-butane, 1,5-bis (2-chloroethylthioethyl) ether
- Saxitoxin
- Ricin

These compounds and other chemical compounds that are neutralized (e.g. detoxified) by nucleophilic and oxidizing reactive agents of the present invention, were neutralized by the formulations of the original invention.

G. Industrial Applications

The formulation was a revolutionary product that would reduce bacteria, bacterial spores and viruses – yet remain people and environment friendly.

In the past, if sanitizers or disinfectants were strong enough to kill any bacteria or virus, the product would generally be caustic, toxic and/or environmentally unfriendly. Yet, these products have been unsuccessful in completely killing in the most difficult situations – chemical resistant bacterial bio-films, spores, and molds. The formulation discussed here had proven to be unique in solubilizing and reacting with compounds to neutralize many toxic materials and contaminants without producing toxic by-products or toxins. Due to the versatility of the EFT Decon solution and the enhancements made by EFT, this product solved numerous environmental clean-up and remediation problems.

- ***Eliminating Sick Building Syndrome*** – As a liquid, this product can be fogged into the air handling systems of buildings to eliminate any bacteria or virus growth in the ventilation systems.

- ***Eliminating Molds (including toxic molds)*** – The product can be deployed as a fog, foam or spray to reduce the mold spores and neutralize mycotoxins emitted by the molds. (The Mayo Clinic attributed 37 million reported cases of flu-like symptoms to mold in 1999.)

- ***Food Processing*** – When deployed as foam, it has sufficient dwell time to decontaminate bacteria, endospores, or viruses even on ceilings and walls of food processing plants, bottling and beverage plants.

- ***Pools and Spas*** – There have been wide-spread cases of "lifeguard sickness" resulting from what many believe is airborne contamination resulting from chlorinated organics at pools and whirlpool spas. The solution can mitigate this 'sickness'

- ***Agricultural Applications*** – The formula can be used to thoroughly clean and disinfect areas used to raise livestock such as chickens to effectively control all forms of bacteria.

- ***Petroleum Product Spills*** – Solubilizing hydrocarbons is an effective method of decontaminating chemical and petroleum spills. Use of the solution helps both solubolization as well as providing a foam fume cover and some fire protection.

LOGISTICAL CONSIDERATIONS

The Decon Formula licensed by EFT is produced under strict quality controls. The unique formulation is very beneficial to end-users as it can be produced in several formats to fulfill operational and logistical requirements such as handling, transportation and dispensing.

The Power of Expansion – The unique expansive properties of the foam affords end-users tremendous tactical advantages previously not available with DS2. As the foam expands effectively up to 50:1, minimal bulk concentrate can be used to produce large amounts of decontaminant without outside water sources – somewhat difficult to find at times during combat operations. The following scenario was demonstrated at Decon 2000 Dugway Proving Grounds, Utah and shown in Table 4.1.

Description of Decon Application	Amounts
M-17 A/M-2/CASCAD:	
Amount of desired decontaminate required	10,000 gal.
Amount of water/chemical required	10,000 gal.
Total weight of water and decontaminant	83,000 lbs.
EFT DECON FORMULATION:	
Amount of desired decontaminate required (50:1 Expansion)	10,000 gal.
Amount of binary concentrate required (1 pallet)	200 gal.
Total weight of decontaminant	1,600 lbs.

TABLE 4.1

Logistical Weight Improvement – 98% Weight Reduction and immediately deployable without outside water sources. Fifty times the performance from 40 tons less water.

Calculation of Desired Coverage – End-users can calculate the amount of decontaminant required for the intended application based upon the total square meters expected to be mitigated. The guidelines presented herein are based on the NATO Standard of 10 grams of CB warfare agent per square meter. Based on application testing done at Sandia National Laboratory, 0.5L/M² liters of decontaminant foam are required, or 1 gal/ 75 sq. ft. Following are tables of baseline requirements based on assumed minimal expansion rates. Users should also be aware that operating conditions can impact results based on the type of delivery equipment to be utilized and variations arising from foam depth, expansion rates, temperatures, wind, and contact surfaces.

RESULTS AT 15:1 EXPANSION	Amounts
Applied Foam Depth	Up to ¼”
Foam Volume Produced/Liter of Formula	57 liters
Foam liters per Square Meter – Note 1	5.94
Square meters covered per liter of formulation	2.54
Approximate cost per square meter of application	$2.08

TABLE 4.2

COVERAGE OF FORMULATION AT 15:1 EXPANSION	Area
5 gallons (18.925 liters)	48 sq. meters
25 gallons (94.625 liters)	240 sq. meters
100 gallons (378.5 liters)	960 sq. meters
200 gallons (757 liters)	1,920 sq. meters

TABLE 4.3

TABLE 4.2 AND 4.3: ***Coverage Charts*** *– The calculations are based on baseline foam performance at baseline 15:1 expansion rate. Testing was performed under ideal controlled conditions using set standards to be easily duplicated in the field. The decon spray tip (SS Veejet H1/40 5090) was set to apply foam at ¼ inch thickness, which amply covers the target surface with double passes.*

Note 1: *This represents 0.3942 liters of liquid/square meter that provide a safety factor of approximately twice the required decontaminant level of 0.2 liters of liquid per square meter.*

Design Considerations - EFT also brings unmatched experience and expertise from its decades of service to the military and nuclear, chemical and biological protection and mitigation industry. We understand the logistical burdens and difficulty that end-users face when combating NBC warfare agents in MOPP (Mission Oriented Protective Position) Gear and Level A & B Personnel Protection Equipment (PP&E). Our Concept of Operations for equipment design and use always keeps the warfighter and first responder in mind as response to a CBW incident continues to be a complex and stressful mission which is generally far from controlled lab conditions.

EasyDECON ENHANCED FORMULATION

In October 2000, Sandia received funding from the DOE CBNP program to develop an enhanced version of the DF-100 product to optimize performance for the military and the civilian first responder. Further, EnviroFoam Technologies, Inc worked closely with Sandia on scale up and final formulation optimization. The result of this work is EasyDECON™ 200, an enhanced version of the original Sandia decontamination formulation. EasyDECON™ 200 is not pH sensitive, and does not require any type of pH adjustment in the field. EasyDECON™ 200 is naturally biodegradable, and does not present an environmental hazard.

The following tables show the improved performance of EasyDECON™ 200 as compared to EasyDECON™ 100. The notation 'ND' refers to a concentration below detectable limits. For EasyDECON™ 100, performance data is given for both the optimal pH against a specific agent and for an intermediate pH (9.2) where the formulation works against all agents (but not optimally against any one agent).

Formulation	Mustard Simulant (% Decontaminated)		
	1 Minute	**15 Minutes**	**60 Minutes**
EasyDECON™ (pH 8)	18	42	81
EasyDECON™ (pH 9.2)	16	38	83
EasyDECON™ 200	**94**	**98**	**ND**

Figure 1: Summary of the reaction rates for the Mustard simulant (2-Chloroethyl phenyl sulfide).

Formulation	VX Simulant (% Decontaminated)		
	1 Minute	**15 Minutes**	**60 Minutes**
EasyDECON™ (pH 10)	45	99	ND
EasyDECON™ (pH 9.2)	33	71	93
EasyDECON™ 200	**66**	**99**	**ND**

Figure 2: Summary of the reaction rates for the VX simulant (0-Ethyl S-ethyl Phenylphosphonothioate).

Formulation	G Agent Simulant (% Decontaminated)		
	1 Minute	**15 Minutes**	**60 Minutes**
EasyDECON™ (pH 8)	53	ND	ND
EasyDECON™ (pH 9.2)	ND	ND	ND
EasyDECON™ 200	**ND**	**ND**	**ND**

Figure 3: Summary of the reaction rates for the 0 Agent simulant (Diphenyl chlorophosphate).

Formulation	Anthrax Simulant	Anthrax Simulant
	% Kill after 30 Minute	% Kill after 60 Minute
EasyDECON™ (pH 8)	99.99	99.99999
EasyDECON™ (pH 9.2)	90	99.9
EasyDECON™ 200	**99.99999**	**99.99999**

Figure 4: Summary of the kill rates for the Anthrax simulant (Bacillus globigii spores)

Live agent tests on three chemical agents (Soman, VX, and Mustard) and two biological agents (anthrax spores and Yersinia pestis) were conducted at the Illinois Institute of Technology Research Institute (IITRI) in Chicago, Illinois. The results of kinetic testing of DF-200 on the chemical agents are shown in Figure 5.

Chemical Agent	% Destruction of Chemical Agent at Time Interval		
	1 Minute	15 Minutes	60 Minutes
GD	99.98 ± 0.01	99.97 ± 0.01	99.98 ± 0.01
VX	91.20 ± 8.56	99.80 ± 0.08	99.88 ± 0.04
HD	78.13 ± 10.53	98.46 ± 1.43	99.84 ± 0.32

Figure 5: Reaction rates in kinetic testing for DF-200HF against chemical agents.

Detection of very low levels of GD in the 15 and 60 minute samples was determined to be from carryover in the gas chromatography columns and not from unreacted agent.

Methylphosphonic acid (MPA) and pinacolyl methylphosphonic acid (PMPA) were identified as byproducts in the decon/OD mixtures. Ethyl methylphosphonic acid (EMPA) and MPA were identified as byproducts in the decon/VX mixtures. This indicated that the destruction of the VX followed the more desirable path to the phosphonic acids rather than to EA2192 (a toxic byproduct which can also be produced during VX degradation). The initial degradation products for HD are a mixture of the sulfoxide and sulfone byproducts followed by nearly complete disappearance of each of these byproducts after 60 minutes. The byproducts of the HD reaction are currently undergoing further analyses.

Results of tests utilizing DF-200 against anthrax spores is shown in Figures 6 and 7 and against Yersinia pestis (i.e., the plague bacterium) are shown in Figure 8 (NG refers to 'no growth'). The detection limit for these tests were 10 CFU/ml. Note that the 'error bars' in the '% Reduction' column takes into account this detection limit.

B. anthracis AMES-RlID	Average CFU/ml	Log Reduction	% Reduction
Control	1.21 E+07	0	0.00
15 min contact	NG	7	100±.00004
30 mm contact	NG	7	100±00004
60 mm contact	NG	7	100±00004

Figure 6: Kill rates for B. anthracis AMES-R1ID spores in a solution of EasyDECON™ 200HF.

B. anthracis ANR-1	Average CFU/ml	Log Reduction	% Reduction
Control	6.42E+07	0	0.00
15 min contact	NG	7	100±.00004
30 mm contact	NG	7	100±00004
60 mm contact	NG	7	100±00004

Figure 7: Kill rates for B. anthracis ANR-1 spores in a solution of EasyDECON™ 200HF.

Y. pestis (ATCC 11953)	Average CFU/ml	Log Reduction	% Reduction
Control	1.33E+07	0	0.00
15 min contact	NG	7	100±.00004
30 mm contact	NG	7	100±00004
60 mm contact	NG	7	100±00004

Figure 8: Kill rates for Y. pestis cells in a solution of EasyDECON™ 200HF.

The petri dishes used for cell growth on each of these tests were saved for 21 days following the tests to verify that DF-200 actually killed the spores rather than just inhibited their growth. No growth on any of the petri dishes was observed after the 21 day period.

PACKAGING OPTIONS FOR EASYDECON™

1. **Binary Blend - Liquid** – EFT produces a proprietary binary configuration for optimal performance and rapid deployment known as EFT EasyDECON Binary Blend. Originally a two liquid component system, the new EasyDECON 200 is a three component system. EFT Penetrator Part I is a liquid concentrate containing surfactants, biocides, and additional reactive agents. EFT Fortifier Part II is an oxidizer. EFT Booster Part III is a catalyst/energizer that when combined with Parts I & II, creates a supercharged oxidizer that destroys WMD agents. All components are equally safe to handle and ship without restriction.

   EFT's proprietary chemical compounding and unique stabilization system allows the formulation to be stored for extended periods (2 years or more if stored at room temperature) and produces the decontaminant at the proper pH level for optimal performance for the detoxification of chemical agents, viruses and other biological agents. This eliminates the need for end-users to measure and mix the concentrate and powder additives or find outside water sources that can be logistically burdensome and/or extremely difficult to accomplish (in MOPP gear) in arid combat situations or remote locations.

   Advantages

   - pre-measured formula needs only to be added together and mixed briefly
   - no transportation restrictions
   - rapidly deployable
   - can be used for existing military assets such as the M-11 DAP and
   - Lightweight M-17A
   - can be stored long-term with no loss of effectiveness (at room temperature)
   - no outside water source is required
   - packaged in 5 & 10 gallon kits, 100 gallon drum kits (two 5 gallon drums), and 500 gallon tote container kits (two 250 gallon totes)
   - packaging available in military approved portable tanks that
   - conform to the 463L aircraft pallet system for standardized military
   - handling (Reference WFI-0320 320 tank system)

The above formulations can be rapidly deployed as a high expansion foam, liquid spray, fog or vapor. Delivered through specially designed binary delivery devices or existing assets, our customers have a complete array of tools to combat the effects of WMD including the four Critical Elements of Decontamination established by the Joint Services

2. **Go/No Go Test Kit**
   Since Fortifier strength is critical to the efficacy of decontamination, EnviroFoam has developed a simple to use test kit to periodically check the condition of the Fortifier in stock. Similar to a kit to test swimming pool conditions, the kit can be used to monitor product in storage. If stored properly, it may be possible to go beyond the recommend two years safely, by knowing that the material is within specification.

OPERATIONAL CHARACTERISTICS AND ADHERANCE TO MILITARY STANDARDS AND REQUIREMENTS

Efficacy Standards – The military has established baseline requirements for decontaminant performance. The EasyDECON Formulations produced by EFT presently conform to the following general requirements:

- Reduces the concentration or neutralizes the effects of biological warfare agents listed on the Joint Chiefs of Staff's Threat List (and biological pathogens of operational concerns) present on resources to a safe concentration level for return to unrestricted operational (worldwide) use for intended mission duration.

- Reduces the concentration or neutralizes the effects of Toxic Industrial Materials (identified "TIM's") present on resources to a safe level for return of the resources to unrestricted operational (worldwide) use for intended mission duration.

- Reduces the concentration or neutralizes the effects of chemical agents to the safe concentration levels for return of the resources to unrestricted operational (worldwide) use for the intended mission duration such that the single dose hazard levels are not exceeded.

- Reduces the concentration and/or fully neutralizes contamination within 15 minutes (immediately) of application.

- Removes or neutralizes toxic substances absorbed into the surface materials.

- Decontaminates heavily soiled items, including items exposed to petroleum, oils and lubricants.

Material Effects Standards – The formulation adheres to the requirements of minimizing the impact on materials:

- Usable on any surface (e.g., terrain, concrete, asphalt, paint, metal, plastics, composite surfaces, low-observable materials, rubber seals) without causing degradation of the surface to acceptable level.
- No significant adverse effect on systems being decontaminated (such as individual protective equipment, collective protective equipment, and detection devices) to acceptable levels of degradation.
- Does not create residues or vapors during decontamination operations that are known or potential teratogens or carcinogens, or are acute dermal, oral, or inhalation hazards to levels in accordance with guidelines of the Office of Prevention, Pesticides and Toxic Substances.
- No residues or vapors produced during decontamination operations that are hazardous waste to the levels according to recommendations of the Resource Conservation and Recovery Act.
- No hazard to the environment. Significantly better than current decontaminants (e.g., DS2, STB, and Hypochlorite). EasyDECON™ does not produce toxic by-products as shown in tests.
- Prevents contamination from condensing or reforming in cracks, crevices, and other hidden areas.
- Ready for use within 5 minutes including mixing and preparation.
- Once ready, remains effective for at least 8 hours.
- Can be applied using liquid, fog, and/or vaporized foam methods
- Note: not approved for human decontamination (currently being submitted to FDA for approval).

NOTES: The EFT EasyDECON 200 Formulation has been tested on numerous surfaces without causing degradation of any surface material. The Solution is non-toxic and non-corrosive. All systems being decontaminated can be treated thoroughly to reduce contamination to negligible risk levels, and reduce or eliminate the need for protective clothing. EFT EasyDECON 200 Formulation allows for Operational Decon and Thorough Decon without degradation of equipment, collective protective equipment, or detection devices. When utilizing the EFT EasyDECON 200 Formulation, end-users do not have to worry about containment of run-off solutions. No toxic by-products are generated with the EFT formulation, and the solution is biodegradable.

The EFT EasyDECON 200 Formulation can be produced in several forms as prescribed by end-users dependent on their operational requirements and Concept of Operations. The formulation performance criteria indicated herein is based upon the fully mixed baseline formulation created at a final blended pH of 9.8. Data contained herein is based upon laboratory results in controlled conditions. End-user standards should be established to create proper procedures for mixing and applying the formulation to contaminated objects as well as requirements for contact times and rinse.

Manpower Standards – The EFT family of decontaminant products:

- Require no increase in operator, maintainer, repairer, or supporter manpower requirements. Often times, less manpower is required due to the high output capability of the equipment. Thus, there is **no force structure increase.**
- Require no new Military Occupational Specialty (MOS), Air Force Specialty (AFS), Additional Skill Identifier (ASI), or Naval Enlisted Code (NEC), no increases in physical or cognitive requirements for the following personnel: Army MOS 54B and 63J, Marine 571/5702, and Air Force AFS 3EXX1, 4E0X1 and 2P0X1.

Existing Equipment Standards – The EFT formulation can be dispensed by existing military assets for portable decon such as the M11 and M-13 DAP, M-17 lightweight decon systems and the M12A1 PDDA, thus saving millions in new equipment requirements. Due to foam expansion, the overall decontaminant **output** of this equipment can be **increased by up to 50 times**, thus making the existing systems even more effective for soldiers in the field.

Environmental Requirement Standards – The family of decontaminants produced by EFT complies with the Pollution Prevention Act, the Clean Air Act, and Public Law regarding the use of hazardous and toxic materials and Ozone Depleting Substances. It is biodegradable.

- All materials and processes used in producing the family of decontaminants comply with all environmental, health, and safety regulations at the Federal, State and local levels. EFT is applying for a product specific EPA certification.
- The family of decontaminants do not require the use of the Environmental Protection Agency's (EPA's) list of seventeen hazardous and toxic chemicals as well as Class I Ozone Depleting Substances (ODS's).
- The production of the family of decontaminants has no substances that have a detrimental impact upon the environment.

Operational Environment Standards – EFT decontamination products can be utilized for worldwide operations and deployment without degradation under climatic conditions, e.g., rain and/or wind, and heat where agents or TIM's can be encountered. The formulations perform under basic climatic conditions and hot (-3°C-49°C), while meeting the functional requirements in this specification. When subjected to solar radiation, there is no direct impact on the functionality of the product and it will perform in 0-100 percent humidity, during and after exposure to blowing rain. {Long term exposure to extremely high temperatures (>130^{o}F) may cause accelerated loss of Fortifier activity.}

In addition, the formulations meet or exceed the following operational environment standards:

- **Fungus Standard** – uses no fungal supporting materials – kills mold, fungus, and algae
- **Salt Fog and/or Spray Standard** – effective during and after exposure to salt fogs and/or sprays
- **Dust and Sand Standard** – performs during and after continuous exposure to blown dust and sand
- **High Altitude Standard** – Survives and operates in altitudes from 0-3050 meters above sea level
- **Shock Standards**
  - Operates after being subjected to shock profiles of common military wheeled/tracked vehicles, aircraft and ships in its mounted configuration
  - In transport mode, survive a standard military airdrop re-supply mission
  - Survive and operate without degradation following exposure to transit drop shocks
  - Survive and operate without degradation following exposure to temperature shock
- **Vibration Standards**
  - Operate after subjection to vibration of common military wheeled/tracked vehicles, aircraft and ships
  - Survive loose cargo vibration profiles of common military wheeled/tracked vehicles, ships and aircraft in the transport mode
  - Survive the vibration profiles in the individual application during an airdrop
- **Explosive Environment Standards**
  - Operates in a safe manner within an explosive vapor environment and with 50 feet proximity of explosives and/or munitions and/or ordnance
  - Will not cause unsafe conditions to arise to the explosives and/or munitions and/or ordnance. Direct contact of oxidizing agents and explosives in general should be avoided.

- **Rapid Decompression Standards**
  - During transport and while packaged in a GFE transportable container, survives rapid decompression between 2438 and 12802 meters altitude during a 30-second interval, with no degradation to follow-on full functional performance operation
- **NBC Contamination Survivability Standards**
  - Performs all mission essential function in an NBC contaminated environment
  - Meet the requirements of AR 70-71
  - Resist surface or subsurface degradation by decontamination procedures
  - Resist surface or subsurface degradation by NBC/TIM agents
- **Transportability Standards** – The EFT decontaminants and containers are produced to meet the following transportation requirements: *Unrestricted air, highway, rail and marine transportation worldwide including air, land, airmobile, and airborne operations.*
- **Safety Parameter Standards** – EFT's products are designed to:
  - Perform safely in Flightline and hangar (ground environments
  - Perform safely in shipboard (flight, hangar and well decks) environments
  - Limit undesirable or uncontrolled safety hazards to personnel throughout its life cycle
  - Eliminate acceptable levels of health hazards
  - Limit any new or increased survivability risks to the user, the host platform or unit
  - Be safe to operate, transport, store and maintain throughout its lifecycle
  - Limit hazards to equipment and personnel in appropriate Mission Oriented Protective Posture (MOPP)
  - Provide a design free of any hazards created from special materials used in its production
- **Packaging Standards** – All shipments (packaging, preservation, unit packing, and marking) comply with the following:
  - Provide special packaging and handling procedures to comply with hazardous material regulatory requirements
    - 49 CFR, Parts 171-179
    - International Civil Aviation Organization Technical Instructions for Safe Transportation of Dangerous Goods by Air (ICAO-TDGA)
    - International Maritime Organization-International Maritime Dangerous Goods Code (IMO-IMDGC), electrostatic discharge packaging protection
    - Electrostatic discharge packaging protection

    - Provides storage/movement containers for decontaminant and hazardous runoff/residue, if necessary
    - The decontaminant is being packaged in accordance with EPA and OSHA regulations

- **Storage Maintenance Standards** – The EFT formulations do not require routine or periodic maintenance during storage. We state a two year warranted shelf life when stored properly. Actual storage may go much longer.

CONCLUSIONS

The new technology commercialized by EFT, Inc. represents a revolutionary new development for response to and mitigation of CB warfare agents, toxic industrial materials, viruses, bacteria and bacterial spores. In addition, the operational characteristics and unique delivery devices offered by EnviroFoam afford end-users with state-of-the-art means of handling remedial situations.

A non-toxic, non-corrosive aqueous solution or foam with enhanced physical stability for the rapid mitigation and decontamination of CBW agents has been developed at Sandia National Laboratories. The formulation is now commercially available with advanced delivery devices from Sandia's commercial licensee, EnviroFoam Technologies, Inc. Results have shown effective decontamination of both CW and BW agents. In addition, 99.99999% kill of anthrax spores was achieved after a one-hour exposure to the foam solution. Tests have demonstrated that the foam is effective in killing vegetative cells of *Erwinia herbicola* and bacterial viruses (MS2), which are simulants for plague and smallpox.

The formulation is non-toxic to animals, including humans, generally non-corrosive, and can be used for the neutralization of many toxicants, both chemical and biological. The formulation allows decontamination of areas populated with both people and sensitive equipment, works safely on all currently anticipated material surfaces, and can be incorporated into a wide variety of carriers (foams, gels, fogs, aerosols) that satisfy a wide variety of operational objectives. The formulation has low toxicity and low corrosivity properties. This allows the formulation to be used where exposure to people, animals, or equipment may be necessary.

This technology was demonstrated in the Fixed Site Decon Trials at the Edgewood Chemical Biological Center (ECBC) where the foam successfully neutralized TGD (thickened soman), VX and HD. At the U.S. Army Dugway Proving Grounds, the formulation successfully killed *Bacillus globigii* spores (an anthrax simulant) as well as live anthrax in independent tests.

This advanced technology represents a significant breakthrough to allow end-users the ability to effectively combat CB warfare agents, viruses, bacteria, toxic industrial materials and bacterial spores.