

1 DECONTAMINATING AND DISPERSION SUPPRESSING
2 FOAM FORMULATION
3

4 CROSS-REFERENCE TO RELATED APPLICATION

5 This application claims the benefits under 35 U.S.C. §119(e) of US
6 provisional application 60/122,091, filed February 26, 1999, which is incorporated
7 herein by reference in its entirety.

8
9 FIELD OF THE INVENTION

10 This invention relates to foam formulations having both blast-
11 suppressant and decontamination capabilities.

12
13 BACKGROUND OF THE INVENTION

14 Improvised explosive devices (IEDs) represent an increasingly
15 dangerous threat to society, particularly when they contain a toxic
16 chemical/biological (CB) agent. It is vital that both the blast effects (a compression
17 or pressure wave, heat and shrapnel) and the CB agent and aerosols, released
18 from the initiation of such devices, are contained. Once released, CB agents also
19 present a decontamination problem when deposited on the surfaces of various
20 equipment and vehicles, or spilled on the ground.

21 In the last decade, patents and papers have been published on the
22 use of foam for blast suppression. For example, in US patents 4,541,947 and
23 4,589,341 to Clark et al., an improved method for blast suppression is disclosed
24 which utilizes fire fighting foams confined in a structural barrier surrounding the
25 blast source. Typically, water-detergent based foams are used, having an
26 expansion 50:1- 1000:1. Clark discloses the use of JET-X, from Rockwell Systems

1 Corporation and having 1 – 6% detergent, containing protein additives and used in
2 the ratio of 1 – 3 parts by volume for each 100 parts of water. The key to this
3 invention is the methodology for containing a high expansion foam in a desired
4 location.

5 US Patent 4,964,329 assigned to Broken Hill Ltd. describes a foam
6 composition consisting of a mixture of foamable liquid and a particulate additive to
7 be supported as a dispersion in the foam. The dispersion is claimed to be effective
8 in sound attenuation and shock wave attenuation.

9 US Patent 4, 442,018 to P. Rand describes a foaming composition
10 which has decreased solution viscosity for high expansion foam capability and
11 decreased liquid drainage. Such a composition comprises a combination of a water
12 soluble polymer of the polyacrylic acid type, a foam stabilizer of dodecyl alcohol, a
13 surfactant, and a solvent. A key is the combination of the stabilizer and polymer
14 used.

15 A very interesting US Patent No. 5,434,192 to Thach et al. describes
16 a composition of surfactants and stabilizers consisting of a mixture of modified
17 natural and synthetic polymer and solvents capable of producing foam viable for 12
18 hours to several days at 75 – 105 degrees F. Such foam is used to suppress the
19 emission of volatile gases and vapors.

20 As described in Clark, a blast may be suppressed using foam
21 contained in a barrier. Applicants initially conducted blast tests with a foam product
22 known as aqueous film forming foam (AFFF) – initially designed for knocking down
23 fire. The AFFF was contained in nylon dome tents that were deployed around the
24 blast threat. The blast suppression results were very inconsistent; the foam would

1 break down very quickly and varied from a watery form to very light and airy. The
2 lessons learned during this phase included the realization that the physical form of
3 the foam could be varied considerably by the foam-dispensing rate, the percentage
4 of surfactant in the composition and the foam-dispensing nozzle characteristics.
5 This work led to the development of a containment system described in Applicant's
6 co-pending US application Serial No. 60/069,533, filed December 12, 1997. That
7 system includes a tent-like enclosure that is deployed over an IED and is filled with
8 an air-aspirated aqueous foam material deemed a Dispersal Suppressant Foam
9 (DSF). When the IED was then detonated, the resulting shrapnel was contained
10 within the enclosure. The foam material used comprised a product sold under the
11 trademark of SILVEX as described by US Patent no. 4,770,794 to Cundasawmy,
12 which issued on 13 September 1988.

13 The inclusion of chemical (CW) and biological (BW) warfare agents
14 (collectively CB agents) or radioactive materials into IED's presents an even greater
15 challenge. Not only must the blast be contained, the agents present in the IED must
16 be effectively neutralized within the area of containment to allow personnel access
17 to the site following activation.

18 Generally, decontamination of radioactive particles is not possible
19 due to their nuclear origin, however, removal by encapsulation significantly reduces
20 aerosolization potential. Decontamination of chemical and biological agents usually
21 occurs by oxidation, reduction or hydrolysis. Ideally a broad spectrum
22 decontaminant, which does not produce toxic by-products in its mode of action on
23 any of the likely contaminants, is of greatest use when the nature of the warfare
24 agent is unknown.

1 Ideally, the blast suppression and decontamination should be a result
2 of a single process, increasing the efficiency of the operation and allowing access
3 to the site as quickly as possible. Further, vital evidence contained within the
4 suppression zone should not be damaged by either the suppressant foam or by the
5 decontaminating agent.

6 In order to provide a single step suppression/decontamination foam,
7 decontaminant must be included as a part of the foam formulation. While foam for
8 blast suppression is currently available, as are decontaminants, it is not merely an
9 obvious step to mix them together for the combined purpose of blast suppression
10 and decontamination.

11 A prior art decontaminant, German Emulsion (C8), was designed to
12 be of low corrosivity, dissolve thickeners and penetrate paint to react with
13 embedded agents in a emulsion formulation. It was discovered however, that the
14 emulsion or foam was somewhat unreliable and sometimes did not form at all. Such
15 decontaminant foams would not be suitable for blast suppression for a period of
16 time after generation.

17 Any inclusion of ingredients into a foam formulation must be carefully
18 assessed to determine their effect on the bubble size and uniformity within the
19 foam. Further, the new formulation must possess sufficient stability, as indicated
20 by low liquid drainage rates and an acceptable expansion ratio, to continue to
21 provide optimum blast suppression.

1 As discussed in US Patent 4,442,018 to Rand, the choice of solvent
2 in a foam formulation can have dramatic effects on the solution viscosity and liquid
3 drainage from the foam. Thus, solvents and co-solvents present in decontamination
4 formulations can act effectively as de-foamers if incompatible with the foam
5 formulation. Particulates or oxidizing components present in decontamination
6 formulations may also have significant detrimental effects on foam characteristics.

7 It remains the challenge to provide an all-in-one, blast suppression
8 and decontamination foam that combines optimum blast suppression
9 characteristics, such as uniform bubble size, slow drainage, vertical cling, vapor
10 suppression and low toxicity and corrosivity, with optimum broad spectrum
11 decontamination characteristics such as solubilization and emulsification of
12 contaminants, rapid and complete degradation of chemical and biological warfare
13 agents to non-toxic products and low toxicity and corrosivity.

14

SUMMARY OF THE INVENTION

The present invention discloses the discovery that a foam formulation exists which is suitable for both blast suppressing and decontamination, particularly desirable when faced with an explosive device which has been rigged with a contaminant for destructive dissemination. In the known cases of blast suppression, a contaminant can be shown to be substantially contained by a foam, but the used foam becomes heavily contaminated.

Accordingly, a serendipitous foam formulation is provided, combining both the advantages of blast suppression and chemical and biological agent decontamination.

A foam formulation which is compatible with a decontaminant includes the following compositions:

- for the surfactant, $[R_nH_{2n+1}(OCH_2CH_2)_mSO_4^{2-}M]$, where R is an alkyl group having from eight to fourteen carbon atoms, m is an integer from 1 to 3, and M is Na^+ or NH_4^+ , in mixture with $CH_3(CH_2)_nCH=CHCH_2SO_3Na$,
- for the co-solvent, $HO(CH_2(CH_3)CHO)_nH$ (PPG of MW about 425) where n=5-49 and most preferably 7; and
- for the foam stabilizer, R-OH where R=C₁₀-C₁₄.

The decontamination components compatible with the above foamer include hydrated chloroisocyanuric acid salts, preferably chloroisocyanuric acid is selected from the group consisting of an alkali metal of monochloroisocyanuric acid, dichloroisocyanuric acid, and a combination thereof with cyanuric acid. A preferred alkali metal of dichloroisocyanuric acid is sodium dichloroisocyanurate.



1 Accordingly, a preferred decontamination formulation suitable also for
2 blast suppression comprises:

- 3 • about 1% to 6% by weight and preferably from about 1% to about
4 3% by weight of hydrated chloroisocyanuric acid salts and more
5 preferably lithium hypochlorite in a ratio of 5 – 10% of the
6 chloroisocyanuric acid salts;
- 7 • about 1% and optionally up to 8% of a co-solvent selected from
8 the group consisting of polypropylene glycols, polyethylene glycols,
9 and derivatives and mixtures thereof;
- 10 • from about 1% to about 5% of a surfactant;
- 11 • a buffer system to initially maintain said formulation at a pH from
12 about 8.5 to about 11 for a minimum of 30 minutes and preferably
13 initially, from about 10 to about 11; and
- 14 • the balance being water.

15 In the preferred formulation, the foamer components have a preferred
16 composition of

- 17 • about 15 w/v% of the sodium salt of an ether sulphate of the
18 formula $\text{CH}_3(\text{CH}_2)_{11}(\text{OCH}_2\text{CH}_2)_3\text{OSO}_3\text{Na}$; 7.75 w/v% of a sodium
19 olefin sulphonate of the formula $\text{CH}_3(\text{CH}_2)_n\text{CH}=\text{CHCH}_2\text{SO}_3\text{Na}$
20 where $n=10$ to 12 , comprising a total of 22.75 w/v% surfactant;
- 21 • about 10 - 25 w/v% of polypropylene glycol co-solvent of the
22 formula $\text{H}(\text{OCH}(\text{CH}_3)\text{CH}_2)_n\text{OH}$ where $n = 5$ to 9 ;
- 23 • about 1 – 2.5 w/v% of an alcohol $\text{CH}_3(\text{CH}_2)_n\text{OH}$ where $n = 8$ to 16
24 to act as a foam stabilizer; and optionally

- 1 • about 0.3% by weight of the above corrosion inhibitors; and
- 2 • the balance being water.

3 Accordingly, a novel method of handling explosive devices is now
4 available. In a broad aspect, a method for dispersal suppression of an explosive
5 CB contamination device comprises the steps of:

- 6 • surrounding the explosive contamination device with a
7 containment structure;
- 8 • and filling the containment structure with an aerated foam
9 comprising both, a high expansion foamer; and a foamer-
10 compatible decontamination formulation effective on chemical and
11 biological agents without significantly and adversely affecting the
12 formation of foam. Preferably a foamer is prepared from a
13 surfactant, a co-solvent selected from the group consisting of
14 polypropylene glycol, polyethylene glycol, and derivatives and
15 mixtures thereof, and a foam stabilizer; a decontamination
16 formulation is prepared from a chloroisocyanuric acid salts, and a
17 buffer to maintain said formulation at a pH from about 11 to about
18 8.5; mixing the foamer and decontamination formulation in water;
19 and foaming the mixture.

1 In a novel combination, a system is provided for dispersal
2 suppression of an explosive CB contamination device comprising:

- 3 • a containment structure for surrounding the explosive
4 contamination device; and
- 5 • aerated foam contained within the structure being formed from a
6 decontamination formulation in water comprising a surfactant, a
7 foam stabilizer, a solvent selected from the group consisting of
8 polypropylene glycol, polyethylene glycol, and derivatives and
9 mixtures thereof, chloroisocyanuric acid salts, and a buffer to
10 maintain said formulation at a pH from about 11 to about 8.5.

11 In the preferred use for surrounding an explosive device, the foam
12 formulation in water comprises about 0.4 – 4 weight % of a surfactant; about 0.03
13 – 0.5 weight % of a foam stabilizer; and about 0.10 – 9.5 weight % of a co-solvent;
14 about 3 – 6 % of the chloroisocyanuric acid salts; the buffer and the balance being
15 water. Preferably, and still effective for decontamination and foaming capability is
16 a formulation 0.6 weight % of the surfactant; about 0.03 weight % of the foam
17 stabilizer; about 0.75 weight % of the co-solvent; and about 3% of the
18 chloroisocyanuric acid salts.

19

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 Figures 1 – 4 relate to Example 2. Figure 1 illustrates the
3 concentration values of methyl salicylate (mustard simulant) in the test chambers,
4 after two baseline shots (no enclosure) and three test device shots (enclosure with
5 foam + placement of a tent over the device followed by the injection of DSF). The
6 percentage of agent capture and containment exceeded 90 %;

7 Figure 2 illustrates the concentration gradient that was measured in
8 the test chamber over a thirty minute duration - NOTE: These are the same shots
9 as in Figure 1, Baseline shots not shown as the scale was too large. This is still
10 within acceptable limits but has prompted an effort to make further improvements
11 to the foam mitigating capacity;

12 Figure 3 illustrates the comparison between unmitigated Baseline
13 shots and Test shots of Example 2. Simulant formed a fine aerosol that behaved
14 like that of a biological agent. The percentage of agent captured was in the order
15 of 95%;

16 Figure 4 shows the over pressure readings collected by a pressure
17 transducer placed at 1.5 meters. The Baseline shots were between 6 and 7 Pounds
18 per Square Inch (psi). The Test shot readings were almost negligible. The
19 enclosure did not tear, all contents remained in the tent;

20 Figures 5 – 11 relate to Example 3. Figure 5 depicts the
21 concentrations of simulant in the test chambers of Example 3 after an unmitigated
22 baseline shot and a contained shot. As well, the lethal level of Sarin for a one
23 minute exposure is displayed. A high level of simulant capture is noted;

1 Figure 6 illustrates the over pressure measurements at the noted
2 distances from the device for both an unmitigated and a contained shot. The
3 findings indicated over pressure containment in the order of 90%;

4 Figure 7 represents the air concentrations of simulant as measured
5 by DAAMS Tube Samplers in an outdoor trial as noted in Fig. 8. This simulated a
6 device being initiated outside of a structure. The data recorded during the Test
7 Device shot indicated containment greater than 95%;

8 Figure 8 illustrates the Range DAAMS Tube Sampler Setup;

9 Figure 9 illustrates the over pressures recorded on two tests, an
10 unmitigated test and a contained test. The readings recorded on the contained
11 shot were barely measurable <1 psi;

12 Figure 10 depicts one baseline unmitigated shot, and three contained
13 test shots with different explosive amounts as noted. Samplers set as noted in Fig.
14 8. Containment realized in excess of 95%; and

15 Figure 11 shows the over pressure values measured at 1.5 meters
16 from the test device unmitigated and three contained shots, each with different
17 explosive loads as noted. Over pressure values were diminished by greater than
18 95%.

19 Figures 12 – 19d relate to Example 4. Figure 12 represents a total
20 ion chromatogram created from Hapsite data after simulant dispersal showing a
21 single organic chemical with a predominant mass 115 fragment, consistent with
22 diethyl malonate;

1 Figure 13 shows the results of the mass spectral data analysis
2 indicating that the chemical in Fig. 12 is indeed diethyl malonate with a probability
3 of 97.5%;

4 Figure 14 shows total ion chromatograms of Hapsite™ readings
5 following vehicle contamination with mustard, prior to application of the foam
6 formulation;

7 Figure 15 shows mass spectral identification of the sample in Fig. 14,
8 containing a predominant mass 109 fragment, as being mustard (bis (2-chloroethyl)
9 sulphide);

10 Figure 16 shows total ion chromatograms of Hapsite data from air
11 samples acquired after vehicle decontamination showing the absence of mustard
12 vapor;

13 Figure 17 shows total ion chromatograms of two separate air samples
14 of tent head-space air, taken at 20 seconds and at one minute during the 5 minute
15 sampling period, following activation of the device;

16 Figure 18a shows the total ion chromatogram of the mustard sample,
17 sampled by Hapsite, from the head-space air of the bottle containing mustard, used
18 for vehicle contamination trials;

19 Figure 18b shows the total ion chromatograms from the mustard head-
20 space air sample of Fig. 18a, showing additional solvent components;

21 Figures 19a-19d show mass spectral library identification
22 chromatograms used to identify the constituents in the mustard head-space air
23 sample of Fig. 18a;

1 Figures 20 – 23 relate to Example 5. Figure 20 shows a total ion
2 chromatogram of an air sample acquired by Hapsite during the Example 5 simulant
3 dispersal trial showing the sample to contain a high concentration of a single
4 component, subsequently identified as DEM;

5 Figure 21 shows a total ion chromatogram of a head-space air sample
6 above a bottle of mustard agent acquired by Hapsite showing a total ion and mass
7 109 reconstructed ion chromatogram identifying the substance as mustard;

8 Figure 22 shows a total ion chromatogram of the tent head-space air
9 sample acquired by Hapsite 10 minutes after detonation in the simulant trial showing
10 a small amount of simulant and dichloroethyl acetate;

11 Figure 23 shows a total ion chromatogram of the tent-head-space air
12 sample acquired by Hapsite after detonation in the mustard trial, not to be mustard,
13 but to be 1,2-dichloroethane instead;

14 Figure 24 is a table illustrating the effectiveness of several
15 decontaminant formulations against selected G-type nerve gases GB, GA and GD
16 and mustard gas, HD;

17 Figure 25 is a table illustrating the effectiveness of a foam formulation
18 containing 9% active ingredient (FS) and one containing 3% active ingredient (Mild)
19 against the nerve agent VX; and

20 Figure 26 is a graph illustrating the effectiveness of the foaming agent
21 by itself to effect decontamination of radioactive dusts from the exterior surface of
22 an armored vehicle.

23

1 DESCRIPTION OF THE PREFERRED EMBODIMENTS

2 In the present invention, a blast suppressing decontamination foam
3 formulation and means for its use are provided for incorporating the known active
4 decontamination ingredient, hypochlorite, in a uniquely buffered solution designed
5 to be incorporated into a blast suppressing foam to be used to suppress the blast
6 shock wave, contain shrapnel and toxic vapors following detonation of IED's and
7 decontaminate chemical and warfare agents contained therein.

8

9 Generally

10 Incorporation of known decontaminant solutions into existing blast
11 suppressing foam formulations requires careful testing and optimization to ensure
12 that neither of the component formulations suffers adverse effects with respect to
13 their intended purpose.

14 Particularly, incorporation of solvents and particulates into foam
15 formulations may adversely effect those characteristics required for blast
16 suppression, those characteristics being slow liquid drainage rates, high expansion
17 ratios and optimum bubble size.

18 Further the addition of foam agents and solvents into decontaminant
19 solutions should not alter the effective pH ranges of the active ingredients and
20 stabilizers, nor should it result in the production of toxic by-products or cause false
21 positive or negative readings on monitoring equipment.

22 Formulations which are suitable for the suppression of blasts are
23 discussed in co-pending US provisional patent application 60/120,874, filed 19

1 February 1999, and replaced by a regular application filed on or about 18 February
2 2000, which is incorporated herein by reference in its entirety.

3 In co-pending application 60/120,874, it was determined that a
4 suitable foamer concentrate comprising (a) a surfactants 40-80%/w; (b) a foam
5 stabilizer 3-7 %/w; (c) a polyalkyleneglycol solvent 10-30%/w; and (d) water balance
6 to 100%.

7 The surfactants was a mixture of two surfactants. The use of the
8 term surfactant herein is defined as individual or a mixture of surfactants as set
9 forth in the context.

10

11 Foam Formulations

12 As suggested, a foam formulation generally comprises a surfactant,
13 a co-solvent and a stabilizer.

14 The surfactant is capable of acting as an emulsifier and forms a foam,
15 over a wide range of pH, when aerated. Ideally the surfactant should be soluble in
16 fresh or seawater and is chosen to be compatible with other ingredients in the foam
17 formulation. The surfactant may be a single ingredient or a mixture of two or more
18 surfactants such as Cedepal® TD-407, a sodium alkyl ether sulfate, and Bioterger®
19 AS-90, an alpha olefin sulphonate.

20 The co-solvent acts as a coupling agent for solubilizing the surfactant
21 and as solubilizer for chemical warfare agents that are not water soluble. The term
22 co-solvent is used herein to define organic-based chemicals that solubilize CB
23 agents, e.g. from alkyd-coated (painted) surfaces. One such co-solvent is

1 polypropylene glycol (PPG425). The PPG425 still permits good foaming
2 characteristics over a wide range of pH in both fresh and seawater.

3 The stabilizer acts to increase foam stability. Long chain, often water
4 insoluble, polar compounds with straight chain hydrocarbon groups of
5 approximately the same length as the hydrophobic group of the surfactant, such as
6 long chain fatty acids, act as foam stabilizers. One such stabilizer is dodecanol
7 :Lorol® 70:30 which is a blend of C12-14 aliphatic alcohols in the ratio of 70:30.
8 Another is Alfol® 1412, a mixture of 1-dodecanol and 1-tetradecanol.

9 Briefly, the foamer consists of a surfactant, a co-solvent and a foam
10 stabilizer. Optionally, in addition, corrosion inhibitors can be added in very small
11 quantities.

12 Generally, suitable surfactants include a composition of either the
13 formula $[R(OCH_2CH_2)_nX]_aM_b$, where R is an alkyl group having from eight to
14 eighteen carbon atoms, n is an integer from 1 to 10; X is selected from the group
15 of SO_3^{2-} , SO_4^{2-} , CO_3^{2-} and PO_4^{3-} ; M is an alkali metal, alkaline earth metal,
16 ammonium or amine derivative; a is the valence of M and b is the valence of
17 $[R(OCH_2CH_2)_nX]$ and the formula $[R-CH=CH(CH_2)_m-X]_aM_b$ where R is an alkyl group
18 having from eight to eighteen carbon atoms; m is an integer from 0 to 3; X is
19 selected from the group of SO_3^{2-} , SO_4^{2-} , CO_3^{2-} and PO_4^{3-} , M is an alkali metal,
20 alkaline earth metal, ammonium or amine derivative, a is the valence of M and b
21 is the valence of $[R-CH=CH(CH_2)_m-X]$ or a mixture thereof.

22 A suitable foam stabilizer is an alkyl alcohol, R-OH, where R is an
23 alkyl group having from eight to sixteen carbons.



1 Combined, one such suitable foamer is Silv-Ex™ made by Ansul Fire
2 Protection described in US Patent 4,770,794 issued to Cundasawmy et al.
3 September 13, 1988. More specifically, the Silv-Ex formulation consists of a
4 surfactant comprising: 20% by weight of a surfactant $C_{10}H_{21}(OCH_2CH_2)_{2,3}SO_4^-Na^+$
5 and 20% by weight of $C_{14}H_{29}(OCH_2CH_2)_3SO_4^-NH_4^+$; a co-solvent of 20% by weight
6 of diethylene glycol monobutyl ether; and a stabilizer of 5% by weight of $C_{12}H_{25}OH$.
7 The balance is water. Optionally, the formulation contains a further 0.5% of
8 corrosion inhibitors.

9 Alternatively, foamers which do not contain diethylene glycol
10 monobutyl ether as the co-solvent are preferable, as residuals of this low molecular
11 weight constituent can be detected by some conventional decontamination
12 monitoring equipment (such as Graseby Ionics™ Chemical Agent Monitor or CAM)
13 and are thus interpreted falsely as positive detection of residual contaminant.

14 Accordingly, a suitable non-residual foamer (or NR-foamer) consists
15 of a composition of alkyl ether sulphate salt, an alpha olefin sulfonate, a co-solvent,
16 an alkyl alcohol, and water. More specifically the surfactant, co-solvent and foam
17 stabilizer are in mixture in water, the component formulas being:

- 18 • for the surfactant, $[R_nH_{2n+1}(OCH_2CH_2)_mSO_4^{2-}M]$, where R is an
19 alkyl group having from eight to fourteen carbon atoms, m is an
20 integer from 1 to 3, and M is Na^+ or NH_4^+ , in mixture with
21 $CH_3(CH_2)_nCH=CHCH_2SO_3Na$,
- 22 • for the co-solvent, $HO(CH_2(CH_3)CHO)_nH$ (PPG of MW about 425)
23 where $n=5-49$ and most preferably 7; and
- 24 • for the foam stabilizer, $R-OH$ where $R=C_{10}-C_{14}$



1 Accordingly, one preferred composition of the NR-foam formulation
2 consists of

- 3 • about 30% weight/volume of the sodium salt of an ether sulphate
4 of the formula $\text{CH}_3(\text{CH}_2)_{11}(\text{OCH}_2\text{CH}_2)_3\text{OSO}_3\text{Na}$; 15.5 w/v% of a
5 sodium olefin sulphonate of the formula
6 $\text{CH}_3(\text{CH}_2)_n\text{CH}=\text{CHCH}_2\text{SO}_3\text{Na}$ where $n=10$ to 12 ;
7 • about 20 w/v% of polypropylene glycol co-solvent of the formula
8 $\text{H}(\text{OCH}(\text{CH}_3)\text{CH}_2)_n\text{OH}$ where $n = 5$ to 9 ;
9 • about 5 w/v % of an alcohol $\text{CH}_3(\text{CH}_2)_n\text{OH}$ where $n = 8$ to 16 ; and
10 optionally
11 • about 0.3% by weight of optional corrosion inhibitors such as
12 sodium tolyltriazole, ammonium dimolybdate and sodium
13 pentahydrate silicate; and
14 • the balance being water, with additional water being added to
15 dissolve other components.

16 Further, this NR-foamer is capable of generating foam of uniform
17 bubble size, is capable of coating vertical surfaces, is compatible with water, gray
18 water and seawater as the main solvent, and is readily removed following
19 decontamination by rinsing with water.

20 This particular NR-foamer is subject to soft thixotropic gelling at
21 temperatures below about 10°C , which could be troublesome if shipped or used in
22 adverse weather at this concentration.

23 It has been determined that to lower the thixotropic gelling point of the
24 surfactant, to be useful in a wider range of environments, one approach is to

1 provide an alcohol stabilizer component which comprises more C₁₂ than C₁₄. It has
2 been found that, even more significantly, diluting the surfactant 1:1 with water for
3 storage and transport further lowers the gelling point.

4 Accordingly, a more dilute NR-foamer consists of:

- 5 • about 15 w/v% of the sodium salt of an ether sulphate of the
6 formula $\text{CH}_3(\text{CH}_2)_{11}(\text{OCH}_2\text{CH}_2)_3\text{OSO}_3\text{Na}$; 7.75 w/v% of a sodium
7 olefin sulphonate of the formula $\text{CH}_3(\text{CH}_2)_n\text{CH}=\text{CHCH}_2\text{SO}_3\text{Na}$
8 where $n=10$ to 12 , comprising a total of 22.75 w/v% surfactant;
- 9 • about 10 - 25 w/v% of polypropylene glycol co-solvent of the
10 formula $\text{H}(\text{OCH}(\text{CH}_3)\text{CH}_2)_n\text{OH}$ where $n = 5$ to 9 ;
- 11 • about 1 - 2.5 w/v% of an alcohol $\text{CH}_3(\text{CH}_2)_n\text{OH}$ where $n = 8$ to 16
12 to act as a foam stabilizer; and optionally
- 13 • about 0.3% by weight of the above corrosion inhibitors; and
14 • the balance being water.

15 Accordingly, to provide the required concentration of foamer
16 ingredients in the final foam formulation, twice the volume of this diluted foam
17 formulation must be added to the decontaminant and buffer solutions to provide the
18 preferred blast suppressing/decontamination foam formulation.

19

20 Decontamination Formulation

21 More detail on the decontamination formulation is disclosed in a co-
22 pending US provisional patent application 60/120,971, filed 19 February 1999, and
23 which was replaced by a regular application filed 14 February 2000, and which is
24 incorporated herein by reference in its entirety.

1 Used as a decontaminating formulation alone, and as disclosed in co-
2 pending application 60/120,971, the decontamination formulation comprises an
3 active decontamination agent in a buffer system designed to optimize the initial
4 reaction pH above 8.5 and more preferably in the range of 10 to 11 for favoring
5 hydrolysis of G-agents, and oxidation of VX and HD agents.

6

7 Active Ingredient

8 The decontamination formulation of the present invention contains as
9 an active ingredient, sodium dichloroisocyanurate. Other chloroisocyanuric acids,
10 their alkali metal salts or a combination of acids including trichloroisocyanuric acid
11 are also suitable for use as the active ingredient. As an example, alkali metal salts
12 of monochloroisocyanuric or dichloroisocyanuric acid or a combination of any of the
13 above salts with cyanuric acid may be used.

14 The decontamination formulation contains from about 1% to about
15 15%, and preferably from about 3% to about 9%, by weight, of the hydrated
16 dichloroisocyanuric acid salt when used for decontamination alone. When used
17 simultaneously as a blast suppressant, the formulation contains from about 1% to
18 about 6% by weight, of the hydrated dichloroisocyanuric acid salt and preferably
19 from about 3% to about 6% by weight, of the hydrated dichloroisocyanuric acid salt.
20 The formulation may additionally comprise lithium hypochlorite to enhance the
21 activity of the dichloroisocyanuric acid salt.

22

1 Buffer

2 The decontamination formulation of the present invention further
3 comprises a buffer that temporarily maintains an initial pH in the range of 10 to 11,
4 sufficient to enable hydrolysis of G-agents and favor oxidation of the V and mustard
5 agents so as to produce non-toxic products. An initial pH in the range of 10 to 11
6 is sufficient to provide adequate hypochlorite ions for decontamination.
7 Subsequently, it is desirable that the buffer fail, allowing the pH to decrease
8 eventually to a more neutral pH to enable more efficient destruction of the BW
9 agents.

10 As the buffer fails and the pH drops to a more neutral pH,
11 hypochlorous acid becomes more prevalent as hypochlorite ions react with
12 available hydrogen ions. Hypochlorous acid is the more active species with respect
13 to the destruction of BW agents as neutral species are able to enter the BW agent
14 cell more easily. Should a BW agent survive the initial decontamination, the BW
15 agent and decontamination formulation may continue to co-reside over time,
16 perhaps after rinsing, and, as the pH falls, BW agent decontamination continues
17 at an even more effective pH. Further, from an environmental standpoint, a more
18 neutral final pH of the decontamination formulation is less hazardous.

19 It is important to maintain the initial moderately high pH over a
20 prescribed duration (such as a NATO designated duration of 30 minutes for a
21 military decontamination), to provide sufficient hypochlorite ions to effect
22 decontamination – favoring hydrolysis of G-agents, favoring oxidation of VX agent
23 which avoids the formation of toxic hydrolysis byproducts, and favoring oxidation
24 of HD agents and avoiding HD reformation. Accordingly, the buffer must be

1 capable of buffering the release of HCl due to hydrolysis of the chloroisocyanuric
2 salts by water. Most preferably, the pH is maintained above 8.5 during the duration
3 available for decontamination.

4 It has been determined that the most suitable buffering system is an
5 inorganic buffering system, adjusted to an initial pH in the range of 10 to 11.
6 Sodium salts, such as a mixture of sodium tetraborate decahydrate and anhydrous
7 sodium carbonate, are preferable since quaternary ammonium compounds result
8 in depletion of hypochlorite through reaction with the hydrolysis product of
9 hypochlorite, chloride ion.

10

11 Augmented Active Ingredients

12 The decontamination formulation may further optionally include
13 lithium hypochlorite to augment the active hypochlorite content of the solution over
14 a short term, thus providing a higher level of active species in the initial stages after
15 the addition of water. Preferably, lithium hypochlorite is present in amounts in the
16 range of from about 5 to about 10% by weight of the active ingredient
17 dichloroisocyanuric acid salt and taking into account that commercially available
18 lithium hypochlorite is normally only available as 30% pure. Alternatively, small
19 amounts of Super Tropical Bleach (STB) or High Test Hypochlorite (HTH), below
20 their solubilisation limits so that no solid or slurry results, could serve the same
21 function as the addition of lithium hypochlorite.

22 The decontamination formulation of the present invention may further
23 optionally include inorganic/organic bromide to increase the reactivity of the

1 chloroisocyanuric acid and generate low levels of hypobromite and bromine
2 chloride.

3

4 Blast suppressing-decontamination foam formulation

5 Therefore, in the present invention, a foamer compatible
6 decontamination formulation is mixed with foamer to provide a preferred foam
7 formulation capable of simultaneous blast suppression and decontamination
8 comprising;

- 9 • from about 1% to 6% by weight and preferably from about 1% to
10 about 3% by weight of hydrated chloroisocyanuric acid salts and
11 more preferably lithium hypochlorite in a ratio of 5 – 10% of the
12 chloroisocyanuric acid salts;
- 13 • about 1% and optionally up to 8% of a co-solvent selected from
14 the group consisting of polypropylene glycols, polyethylene glycols,
15 and derivatives and mixtures thereof;
- 16 • from about 1% to about 5% of a surfactant;
- 17 • a buffer system to initially maintain said formulation at a pH from
18 about 8.5 to about 11 for a minimum of 30 minutes and preferably
19 initially, from about 10 to about 11; and
- 20 • the balance being water.

21 It was tested and determined that the addition of 3% active ingredient
22 and buffer into the foamer had substantially no adverse effects on blast suppression
23 effectiveness, the expansion ratios of the foam or on its liquid drainage rates. It was

1 further determined that the foamer did not affect the ability of the active ingredient
2 to effect total decontamination of CB agents.

3 Should the IED have already detonated, then clean up may be
4 required by a decontaminant with minimal or no blast suppression capability. For
5 example, a 6% active ingredient formulation can be used. In such an instance,
6 additional co-solvent can added to raise the total co-solvent (foamer and added co-
7 solvent) to about 8% for more effectively solubilizing penetrated CB agents from
8 surfaces.

9 The combined foamer and decontamination formulation can now be
10 applied to IED's which contain a contaminant which would require both blast
11 suppression and decontamination capabilities.

12 As described in more detail in co-pending provisional application
13 60/120,874 disclosing blast suppressing foam formulations and also in co-pending
14 provisional application 60/069,533, filed Dec. 12, 1997 and its replacement regular
15 application (both of which are incorporated herein in its entirety), an explosive device
16 including explosive contamination device, is surrounded by an encapsulating foam
17 containment structure. The foamer and decontamination formulation are mixed in
18 water and foamed to fill the containment structure, thereby surrounding the IED.

19

1 Examples - Example 1

2 DECONTAMINATION EFFECTIVENESS EVALUATIONS

3 In the process of foam formulation optimization, the three most promising
4 formulations, # 1, #3 and #4 in Table 1, incorporating the PPG425 co-solvent, were
5 prepared and evaluated for their agent simulant solubilisation capabilities (ability to
6 dissolve and solubilize compounds simulating real agents).

7

8 Table 1. Percentage Composition of Components in New Candidate Foam
9 Formulations.

10

Ingredients	#1	#2	#3	#4	#5
Alkyl Ether Sulfate (FA-406)	30	NIL	NIL	NIL	30
Alkyl Ether Sulfate (TD-407)	26	26	26	26	NIL
α -olefin Sulfonate (AS-90)	NIL	15.5	NIL	NIL	15.5
α -olefin Sulfonate (Stepantan AS 12)	NIL	NIL	15.5	NIL	NIL
Sulfosuccinate (Aerosol OT)	NIL	NIL	NIL	50	NIL
Lauryl Alcohol	5.0	5.0	5.0	5.0	5.0
Co-Solvent	20.0	20.0	20.0	20.0	20.0
Citric Acid to pH 7.5					
Water QS to 100%					

11

12 It was assessed that all three formulations were equal in their
13 effectiveness in reducing the capacity factors or retention times of test simulants on
14 an HPLC assessment column.

15 Further work demonstrated that all three formulations met their
16 requirements for limited inhibition of decontamination reaction times with formulation
17 #3 being the preferred formulation. All subsequent testing and field tests were
18 performed using formulation #3.

1 The decontaminating solution was then prepared by combining two
2 solutions as follows:

3 1) A buffer solution consisting of:

4 a) sodium tetraborate decahydrate, used at a
5 concentration in the decontamination solution so as to
6 produce 0.004167 mol/L after being mixed with the surfactant
7 solution; and

8 b) anhydrous sodium carbonate used at a concentration
9 in the decontamination solution so as to produce a molar
10 concentration of 0.0333 mol/L after dilution with the surfactant
11 solution.

12 2) An oxidizing/decontaminating agent, sodium dichloro-s-
13 triazinetrione (more commonly known as sodium
14 dichloroisocyanuric acid), with a chlorine content of 62% w/w.

15 This material was used at a concentration so as to produce a
16 concentration of 3% w/w in the final solution. It must be
17 pointed out that the oxidizing agent displays signs of
18 precipitation on standing at concentrations above 2%.

19 It was surprising to see that the simultaneous use of the
20 decontamination and foaming solutions had no adverse effect on the foaming
21 characteristics of the blast foam formula #3; there was no change in foam expansion
22 and drainage rate.

23 Furthermore, the foaming solution and the buffer/oxidizing agent
24 solution were directly mixed and foam characteristics were measured as a function

1 of time. It was found that there was no drop in expansion ratio nor increase in
2 drainage rate after the mixture had been standing for over 30 minutes.

3

4 Example 2 and 3

5 Two test series were conducted to determine the mitigation capacities
6 of foam formulations to contain CB agents.

7 The first series of tests, Example 2, were performed using non-
8 fragmenting explosive dissemination models designed to project CB simulants.
9 SILVEX foam formulation was used and the results extrapolated to other foam
10 formulations based on blast tests conducted using the formulation of this invention.

11 The second series, example 3, studied the performance of the
12 preferred foam formulation, when challenged by non-explosive dispersal models as
13 well as by high energy devices. The high energy explosive dispersal models
14 provided an indication of the upper device limits that were containable.

15 During the development stage the nylon tent, used in Example 2, was
16 reinforced by adding a layer of ballistic material over the foamed enclosure. Two
17 ballistic materials were tested; DYNEEMA and KEVLAR. Each fabric was tested
18 alone and in combinations with the other. DYNEEMA was selected as the fabric to
19 be used in the containment structure because it demonstrated superior qualities in
20 capturing high velocity bomb fragments. The dome tent shaped design evolved to
21 a base unit being fabricated from 3 layers of DYNEEMA and an outer and inner
22 layer of rip stop nylon. Two containment structure sizes were produced, one
23 approximately 2.75 meters in diameter and the second approximately 2 meters in
24 diameter (used in Example 3). The contaminant system is the subject of co-pending

1 US application serial no. 60/069,533, filed December 12, 1997, and replaced by a
2 regular application, both of which are incorporated herein in their entirety.

3

4 Example 2

5 The Chemical Agent Device Model used was a simple device that
6 included a 1 liter high density polyethylene laboratory bottle and a center burster
7 of approximately 125 grams of C-4 explosive, initiated by an electric blasting cap.
8 The bottle was filled with approximately 950 milliliters (mL) of methyl salicylate, a
9 chemical agent simulant for mustard agent.

10 The Biological Agent Device Model used was essentially the same
11 design as was used in the chemical simulant test, except that the methyl salicylate
12 was replaced by a biological agent simulant, calcium hydroxide.

13 The tests were conducted in a cylindrical shaped blast test chamber,
14 32 feet in diameter and 20 feet high.

15 A four person, dome shaped nylon tent, 2 meters in diameter was
16 used to contain the foam formulation. The foam formulation used was SILVEX foam
17 concentrate diluted to 1.7 %/w in water. It will be appreciated by those skilled in
18 the art that these results can be extrapolated to other foam formulations according
19 to the invention based on the evaluation of various physical properties of the foam
20 produced with these formulations as compared to SILVEX foams, and a blast test
21 with a preferred formulations against an actual improvised chemical dispersant
22 device containing weapons grade material. Similar blast mitigation properties were
23 observed.

1 Effectiveness of chemical containment was measured using a miniature
2 infra-red gas analyzer (MIRAN™). Biological containment was determined using an
3 airborne aerosol mass concentration determination wherein simulant is collected on
4 a filter pad in a Gillian Personnel Sampler pump and airborne aerosol mass
5 concentration is extrapolated given known flow rates and chamber volume. Blast
6 overpressures were determined using ENDEVCO™ piezoresistive pressure
7 transducer and Anderson blast gauges.

8 Two baseline tests were performed without an enclosure or foam
9 formulation to determine the dispersal of the methyl salicylate, mustard simulant.
10 Three tests were performed using the containment tent and the foam formulation.
11 The results, as shown in Fig. 1, show that compared to the baseline test, the tent
12 and foam formulation were able to contain the mustard simulant in excess of 90%.

13 Fig. 2 illustrates the concentration gradient of simulant in the test
14 chamber, over 30 minutes, for the three tests performed in Example 1.

15 Fig. 3 illustrates the comparison between unmitigated baseline tests and
16 biological tests. The biological simulant formed a fine aerosol that behaved like that
17 of a biological agent. The biological simulant was contained in the order of 95%.

18 Fig. 4 illustrates the readings obtained by the pressure transducer,
19 placed at 1.5 meters. The foam suppressed simulant tests showed negligible
20 pressure in PSI compared to that observed for the baseline tests.

21

22 Example 3

23 In contrast to the dispersal device used in Example 1, a more
24 energetic fragmenting device was used to disperse agent as well as a selection of
25 less energetic dispersal systems such as high pressure aerosol formation.

1 Tests were performed using mustard agent simulant, methyl
2 salicylate only. It was felt that chemical contamination represented the worst case
3 scenario and that biological testing would be an unnecessary duplication.

4 The dispersal devices used were as follows:

- 5 • Device 1 - 100 grams C-4 central burster in 1 liter plastic lab
6 bottle containing approximately 950 mL of MS
- 7 • Device 2 - 120 grams dispersal charge on bottom of 1 liter lab
8 bottle containing 1 liter of MS
- 9 • Device 3MX - steel tool box with batteries, timer, circuit, 500
10 mL MS simulant (X denotes grams of C-4 i.e. 115, 230, 345
11 grams)
- 12 • Device 4 - a commercial garden sprayer containing 1 liter MS

13 The tests were conducted on an open range and in a test chamber
14 measuring 20 ft. x 30 ft. x 10 ft. (169 m³)

15 A dome shaped DYNEEMA tent was used as the enclosure structure
16 which was subsequently filled with SILVEX foam (approx. 570 cubic ft.) to suppress
17 the blasts of the various dispersal devices.

18 Effectiveness of chemical containment was measured using a
19 miniature infra-red gas analyzer (MIRAN™). Further, chemical concentration ranges
20 were determined by collecting simulant aerosols on a Depot Area Air Monitoring
21 System (DAAMS) tube followed by thermal desorption into an HP5890 gas
22 chromatography system equipped with a flame ionization detector. Blast
23 overpressures were determined using ENDEVCO™ piezoresistive pressure
24 transducer and Anderson blast gauges.

1 Fig. 5 depicts the concentrations of simulant in the test chamber after
2 an unmitigated baseline test and a contained test. The lethal level of Sarin after a
3 one minute exposure is shown for reference. A high level of simulant capture was
4 observed.

5 Fig. 6 illustrates the over pressure measurement at the noted
6 distances from the device for both unmitigated and contained tests. Over pressure
7 containment was observed in the order of 90% for contained tests.

8 Fig. 7 illustrates the air concentrations of simulant as measured by
9 DAAMS tube samplers in an outdoor trial, their locations further illustrated in Fig.
10 8.

11 Fig. 9 illustrates the over pressures recorded on two tests, one
12 unmitigated and the other contained. The readings recorded for the contained test
13 were barely measurable i.e. <1 PSI.

14 Fig. 10 depicts a baseline unmitigated test and three contained tests,
15 each performed using different explosive amounts. Samplers were located as
16 illustrated in Fig. 8. Containment was realized in excess of 95%.

17 Fig. 11 illustrates the over pressure readings measured at 1.5 meters
18 from the test device for one unmitigated baseline test and three contained tests,
19 each with different explosive loads, as noted. Over pressure readings were
20 diminished by greater than 90% in the contained tests.

21 Examples 4 and 5

22 In Examples 4 and 5, staged field tests were conducted to determine
23 the blast suppression decontamination foam formulation's ability to both
24 decontaminate and to suppress a blast.

1 The presence of G-agent simulant and mustard agent was
2 determined using conventional decontamination monitoring equipment such as
3 Graseby Ionics™ Chemical Agent Monitor or CAM and Chemical Agent Detection
4 Systems Mark II (CADS II) stations, each comprising two CAMs. Further,
5 confirmation of the presence or absence of these agents in air samples was
6 determined using Hapsite™, a portable gas chromatograph/mass spectrometer
7 (GC/MS).

8 Hapsite was adapted for measurement of chemical agents under
9 ambient test conditions by equipping it with an M213 membrane system capable of
10 more rapid permeation of chemical agents, substituting the standard DB-1 GC
11 capillary column by a DB-5 capillary column, adjusting operating temperature to
12 80°C rather than the usual 60°C used for volatile organic chemicals, and operating
13 the probe inlet line at 45°C rather than the usual 35°C. The air samples were
14 subjected to a mass spectral analysis alone, as the agents used in the trials were
15 known. This type of analysis does not require any prior chromatographic separation
16 and allows for longer air sampling times. Typically 5 minute samplings were used for
17 the staged testing. Hapsite was also used for full chromatographic separation and
18 mass spectral analysis in the event that the samples demonstrated unexpected
19 results using mass spectral analysis alone.

20

21 Example 4

22 In a first stage, the ability of the CAMS and Hapsite to measure
23 dispersion of the agent simulant, diethyl malonate, was determined. In a second
24 stage, the ability of the blast suppressing decontamination foam formulation to

1 decontaminate mustard painted onto a vehicle surface was tested. In a third and
2 last stage, the ability of the blast suppressing decontamination foam formulation to
3 suppress blasts while containing G-agent simulant and mustard vapor and
4 simultaneously decontaminating the mustard agent, were tested.

5

6 Stage 1 - Simulant Dispersion Tests

7 Two dispersal devices, each containing 250 ml of a diethyl malonate
8 (DEM)(propanedioic acid, diethyl ester)/water (50/50 v/v) mixture, were secured to
9 ring stands located in the proximity of target vehicles. One was placed 50 cm above
10 the ground and the other at 75 cm above the ground. Witness cards, containing
11 dyed paper for detecting liquid drops were placed on the ground near the dispersal
12 devices, on the nearby vehicles and on the ground 20 meters downwind of the
13 dispersal devices.

14 The dispersal devices were activated (functioned). As soon as the site
15 was declared safe from explosive hazard, the witness cards were examined and the
16 site monitored by personnel carrying CAMs. Hapsite was brought to the site to
17 acquire and test air samples at locations near the ring stands, vehicle surfaces, open
18 ground and witness cards.

19 All witness cards showed evidence of impact from liquid drops. The
20 CAMs produced G-mode readings in the range of 2 to 6 bars indicating mild to
21 heavy contamination with simulant (DEM registers as a G-agent on a CAM). An
22 MS-only survey method, employed on Hapsite, provided data for a total ion
23 chromatogram as shown in Fig. 1, having a single organic chemical with a
24 predominant mass 115 fragment, consistent with diethyl malonate. Fig. 13 shows

1 the results of the mass spectral data analysis indicating that the chemical is indeed
2 diethyl malonate with a probability of 97.5%.

3 Having determined that the detection equipment was capable of
4 monitoring simulant, the foam formulation was tested to determine its ability to act
5 as a decontaminant in Stage 2.

6

7 Stage 2 - Vehicle Decontamination Trial

8 An armored personnel carrier painted with chemical agent resistant
9 coating (CARC) was painted, on one side, with 150mL mustard. Four CADS II
10 monitoring stations were deployed near the vehicle, three placed downwind. A
11 sample of head-space air was taken from the bottle from which the mustard was
12 taken, using Hapsite and CAM readings were taken near the vehicle prior to the
13 application of the foam formulation. Blast suppressant decontaminating foam was
14 applied to the surface of the vehicle using a hose and spray head assembly,
15 followed by manual scrubbing of the surface with long handled brushes. After a 30
16 minute waiting period, the foam was washed away with water and the vehicle
17 surface re-surveyed with CAMs. Hapsite was used to take air samples around and
18 downwind the vehicle.

19 Initial CADS II readings, during the application of mustard to the
20 vehicle showed significant H-mode readings downwind the vehicle. Fig. 14 shows
21 the Hapsite readings prior to application of the foam formulation and Fig. 15 shows
22 the identification of the sample, containing a predominant mass 109 fragment, as
23 being mustard (bis (2-chloroethyl) sulphide), verifying live agent was used for the
24 trials.

1 Immediately following application of the foam formulation the CADS
2 II and CAM H-mode readings dropped to a zero response. Hapsite air samples
3 acquired around the vehicle did not show any mustard content as shown in Fig. 16.

4 Clearly the foam formulation was capable of decontaminating the
5 mustard agent, therefore the remaining stage 3 trials were directed towards the
6 foam formulations ability to simultaneously decontaminate and suppress an
7 explosive blast wave.

8

9 Stage 3 - Blast suppression/decontamination Tent Trials

10 Two separate stage 3 trials were performed, the first using G-agent
11 simulant, diethyl malonate and the second using mustard chemical agent. The
12 ambient temperature during the trials was 6°C.

13 In each trial a dispersal device was loaded with 250 ml of simulant or
14 agent and secured to a ring stand approximately 50 cm off the ground. Four CADS
15 II monitoring stations were deployed near the site, three in the downwind direction.
16 The stations were activated and allowed to collect and provide data to a remote
17 CPU and computer system. In the case of the simulant trial, the dispersal device
18 was placed inside a commercial tent and then the tent was filled with foamed
19 formulation. In the case of the agent trial, a special tent with an opening in the
20 bottom, but of the same shape and size as the commercial tent, was placed over
21 the dispersal device and then filled with the foamed formulation.

22 In each case, the device was armed and then functioned. As soon as
23 the area was declared safe from explosive hazard, a survey of the site around the
24 tent was performed by personnel carrying CAMs. Hapsite was used to acquire air

1 samples from around the tent and, in the case of the agent trial, was inserted
2 through an opening in the top of the tent to sample the head space above the foam
3 to detect any mustard contamination. CAM readings of the tent head space were
4 also taken.

5 In both trials, the tent showed no signs of damage or leakage of foam
6 following activation of the dispersal device.

7 Regarding the effectiveness of decontamination in the simulant trial,
8 the CADS II and CAM readings taken in close proximity to the tent found no G-
9 mode readings. No evidence of diethyl malonate was found on in the Hapsite
10 reading over a 5 minute period.

11 Similarly, in the agent trial, CADS II and CAM readings, taken in the
12 proximity of the tent, also showed no H-mode response. No mustard was found in
13 the tent head space air. However, as shown in Fig. 15, the CAM surveys did show
14 a significant H-mode response coupled with a response indicative of a low
15 reference ion peak. This response was exhaustively determined, through both
16 chromatograph and mass spectral analysis (Figs. 16-19b), to have been chlorinated
17 materials, hypothesized to be related to the chlorinated solvents in the original
18 military grade sample of mustard (Figs. 18-19). It may also be possible that
19 dichloroacetic acid may have been produced from chlorinated alkanes as a result
20 of oxidation, either due to the explosion itself or due to the reaction with the strongly
21 oxidizing decontaminant in the foam formulation.

1 In both stage 3 trials, it is clear that the foam formulation was capable
2 of both suppressing the blast, as evidenced by the intact tent structure following
3 activation, and capable of decontamination, as evidenced by the lack of G-agent
4 simulant and mustard agent following activation.

5

6 Example 5

7 A second staged trial was performed. Two formulations of blast
8 suppressing/decontamination foam were used. A first CB-decontaminating blast
9 suppressant foam formulation contained 3% active decontaminating ingredient and
10 a second surface decontaminating foam formulation, contained 6% active
11 decontaminating ingredient.

12

13 Stage 1 - Open Dispersion trial

14 A 250mL Nalgene bottle filled with DEM was fastened to a ring stand
15 at approximately 0.3 m above the ground and 4 m from a small metal building.
16 Witness cards were set out near the device and affixed to the facing surfaces of the
17 building to indicate dispersed liquid spray.

18 Following detonation, the witness cards were examined and showed
19 a heavy spray of small droplets for at least 20m downwind of the device location.
20 The blast produced a loud noise readily heard at least 200m away. CAMs used to
21 survey the area showed strong G-mode responses 10 minutes after dispersal of the
22 simulant. An air sample acquired by Hapsite showed the sample to contain a high
23 concentration of a single component, subsequently identified as DEM, as shown
24 in the total ion chromatogram of Fig. 20.

1 Clearly the dispersal equipment used was capable of dispersing
2 simulant over the test site and the instrumentation used to measure the
3 contamination, capable of measuring the G-simulant, DEM.

4

5 Stage 2 – Vehicle Decontamination

6 A CARC painted armored personnel carrier (APC) was placed within
7 a plastic-lined containment pit and four CADS stations were deployed in a circular
8 pattern around the pit at a standoff distance of approximately 5 m. Hapsite was
9 used to measure a head-space air sample above a bottle of mustard agent
10 producing a total ion and mass 109 reconstructed ion chromatogram as shown in
11 Fig. 21. This was subsequently verified to be that of mustard, with very few
12 impurities. One side of the APC was painted with approximately 75mL mustard. All
13 CADS II stations, especially those in the downwind direction, showed an immediate,
14 strong response in the H-mode, indicative of mustard vapor. Surface
15 decontaminating foam (6%) was applied to the vehicle, the vehicle was then
16 scrubbed with long handled brushes and allowed to sit for 15 minutes.

17 Within one minute of application of the foam, the CADS stations
18 responses returned to baseline, indicating the absence of mustard vapor. CAMs
19 were used to survey the air around the vehicle 10 minutes following foam
20 application and showed no H-mode response. An air sample acquired by Hapsite
21 during the scrubbing process did not show the presence of mustard vapor. After 30
22 minutes, the vehicle was washed down with water and further CAM surveys were
23 conducted, which verified the absence of mustard vapor.

24

1 Stage 3-Blast Suppressant/Decontamination Tent Trials

2 Two stage 3 trials were performed, one using G-agent simulant
3 (DEM) and one using mustard agent. In both cases, a 250mL Nalgene bottle
4 equipped with detonation equipment and filled with simulant or agent, was placed
5 on the floor of a steel containment tray, placed inside a 12 ft. x12 ft. x 10 ft. wood
6 frame enclosure sealed with polyethylene vapor barrier. Two CAMs and
7 components of a CADS station were located within the enclosure. Further four
8 CADS stations were deployed around the enclosure at a distance of approximately
9 5m. All CAMs were set in G-mode for the simulant trial and in H-mode for the
10 mustard trial.

11 A ballistic tent was placed over the bottle, the tent was filled with CB-
12 decontaminating blast suppressant foam and the bottle was remotely detonated.

13 In both trials, the tent remained intact and containing all materials.
14 Very little detonation sound was heard outside the tent. The head-space air within
15 the tent and the containment shelter were examined using portable CAMs and
16 Hapsite at 10 minutes after detonation.. The temperature of the head space was
17 measured. Further CAM surveys were conducted at 30 minutes post-detonation.
18 Foam was then drained from the tent into the containment tray and CAM surveys
19 conducted to determine the presence of residual simulant or agent.

20 No response for either simulant or agent was recorded by the CADS
21 stations or CAMs deployed within and about the containment. Temperatures
22 measured in the head-space indicated that the explosive event and
23 decontamination process were exothermic.

1 Hapsite GC/MS analysis as shown in Fig. 22 showed a small amount
2 of DEM and dichloroethyl acetate, most likely produced by a reaction between DEM
3 and the chlorinated oxidant in the decontaminant, to be present in the head-space
4 air of the simulant trial. CAM surveys of the released foam materials after 30
5 minutes showed no evidence of DEM.

6 CAM surveys in the head space air of the agent trial showed a strong
7 H-mode response which was subsequently proven by Hapsite GC/MS analysis, as
8 shown in Fig. 12, not to be mustard, but to be 1,2-dichloroethane instead. It is
9 thought this compound may be a reaction product of the mustard with the
10 chlorinated oxidant in the decontaminant. Again CAM readings taken over the
11 released foam after 30 minutes show no evidence of mustard vapor.

12 Clearly the foam formulation is capable of suppressing a blast and
13 decontaminating the CB agents released as a result.

14

15 Examples 6-9

16 Examples 6 through 9 are directed solely at various foam
17 formulation's ability to decontaminate various types of contamination. These
18 include, chemical warfare agents of the G and V classes, mustard agent, biological
19 spore-forming warfare agents and radioactive particulates.

20 Further, in each of Examples 6 - 8, quantitative analyses for residual
21 agents were performed on a high pressure liquid chromatography (HPLC) system
22 for separation of the reaction components, equipped either with a HPLC-UV
23 detector in series with a commercially available dual flame gas chromatographic
24 flame photometric detector (FPD) from Varian Associates, or, where possible, on

1 a Hewlett-Packard 1100 LC-MS system equipped with a diode-array UV-VIS
2 spectrophotometer and mass selective detector (MSD). The water used in the
3 reactions, prepared solutions, and in the HPLC was distilled and deionized. The
4 formulation for the surfactant/foam was first warmed to 32°C to ensure
5 homogeneity. CB agents and simulant DFP were provided by the Canadian Single
6 Small Scale Facility at the Canadian Defence Research Establishment Suffield
7 (DRES) in southern Alberta, Canada and Aldrich Chemical Company, respectively.
8 GB stock calibration solution was prepared by weight in acetonitrile (AcCN) and
9 several dilutions were prepared ranging from 25 to 900 ng/μL for calibration of the
10 FPD, UV, and MSD responses. Stock solutions of the other CW agents were
11 prepared volumetrically in AcCN and similarly diluted for calibration.

12 Unless otherwise specified, in a typical experiment, samples were
13 prepared in 2.0mL autosampler vials. The first addition was a water solution
14 containing the foamer and, if necessary, the co-solvent. This was followed by
15 buffer concentrate, then the decontaminant concentrate which had been separately
16 prepared by adding the active ingredient, anhydrous sodium dichloroisocyanuric
17 acid (SD), to water and heating to 29°C with stirring for 15-30 minutes. Finally, the
18 CB agent was added defining time zero, and aliquots, at noted elapsed times, were
19 directly injected into the LC. The temperature of the vial holder was maintained at
20 25.0°C and a mini stirbar in the vial mixed the components. Fresh samples were
21 prepared for each FPD analysis to obtain residual agent concentration profiles over
22 time and these same solutions were subsequently analyzed by LC-MS.

23

1 Example 6

2 Having reference also to Fig. 24, the effectiveness of several
3 decontaminant formulations against selected G-type nerve gases GB, GA and GD
4 and mustard gas, HD, was determined. The formulations tested consisted of an
5 active ingredient, a foamer, an inorganic buffer mixture and, optionally, co-solvent,
6 in excess of that already present in the foamer mixture. The co-solvent values in
7 Fig. 24 represent added co-solvent and that contained in the foamer.

8 Three decontamination formulations were assessed for effectiveness
9 against typical G-nerve agents; the mildest formulation, using 3% w/w SD, a 2/3
10 strength buffer, and 1.3% w/w foamer; an intermediate strength formulation with 6%
11 w/w SD, full strength buffer, 4.6% w/w foamer and an additional 6.9% w/w to 7.8%
12 w/w co-solvent, and a full strength formulation with 9% w/w SD, full strength buffer,
13 4.8% w/w foamer and 6.9% w/w additional co-solvent. Although anhydrous SD was
14 used in preparation of the solution, percentages are quoted in terms of the
15 equivalent amount of dihydrate. Percentages (w/w) quoted for foamer represent
16 undiluted double-strength foamer which has 45.5% surfactant.

17 In order to standardize concentrations between experiments, the
18 effectiveness was calculated as a percentage of residual agent.

19 Using 0.29% w/w GB, there was no evidence of residual agent in any
20 of the LC-FPD or LC-MS analyses for the mildest and intermediate strength
21 formulations (3% w/w and 6% w/w SD). GB was destroyed in each case before the
22 first sample could be taken (0.43 and 1.13 minutes respectively). For the most
23 potent formulation (9% w/w SD), only LC-FPD analysis was performed at 1.78

1 minutes elapsed time and no agent was detected indicating complete destruction
2 of the agent within 1.78 minutes.

3 Using 0.29% w/w GA, only the mildest and intermediate strength
4 formulations (3% w/w and 6% w/w SD) were evaluated. The mildest formulation
5 was tested in two separate experiments. In the first, containing ~1.6% w/w foamer,
6 LC-FPD analysis indicated that GA was destroyed within 1.33 minutes. In the
7 second, containing ~1.8% w/w foamer, there was no evidence of GA in 1.07
8 minutes elapsed time (LC-FPD) or 3.43 minutes (LC-MS). For the intermediate
9 strength formulation containing an additional 7.5% w/w co-solvent, there was no
10 evidence of GA in 1.07 minutes elapsed time by LC-FPD or 3.35 minutes by LC-
11 MS.

12 Using 0.29% GD, again only the mildest and intermediate strength
13 formulations were each evaluated. The full strength formulation was not tested due
14 to the success with the two milder formulations. The mildest formulation was tested
15 and, in contrast to the other two G-agents examined, small amounts of residual GD
16 appeared to be observed for the shortest reaction time sample. Specifically, as
17 analyzed by LC-FPD, 5.0% residual agent appeared to be present at 1.07 minutes
18 and 0.5% appeared to remain at 4.77 minutes, and the agent was completely gone
19 by 10 minutes, as determined by LC-MS analysis. Similar results were observed
20 using the intermediate solution containing 7.8% additional co-solvent. Complete
21 LC-MS characterization of the peak eluting at GD in a stock solution of GD
22 suggests that a trace of a GD-related impurity, methylpinacolylmethylphosphonate
23 also eluted at this point, possibly contributing to the residual peak observed at short
24 reaction times in HPLC-FP. Thus, although GD appears to be more difficult to

1 destroy than GB or GA, the mildest formulation is still very effective against GD
2 within acceptable time limits.

3 Using 0.27% w/w HD, again due to their success, only the mildest
4 and intermediate strength formulations were evaluated. The mildest formulation
5 was tested for effectiveness against HD in three separate tests. In the first test,
6 there was no evidence of residual HD after 2.67 or 4.92 minutes (reaction solutions
7 had to be mixed more vigorously than the other agents due to limited solubility of
8 HD so earlier sampling was not possible). In the second test, no residual agent
9 was detected after 3.0 or 62.1 minutes, however 6.2% of residual HD appeared to
10 be present after 5.4 minutes assuming that the eluting peak was indeed HD. As a
11 confirmatory test, an third experiment was performed and no HD was detected after
12 3.65 or 4.97 minutes.

13 It is therefore concluded that even the mildest formulation, and least
14 likely to affect a foam's blast suppression capability, is completely effective against
15 this level of HD in less than 2.7 minutes.

16 The intermediate formulation also tested for effectiveness against HD
17 and demonstrated no residual HD after 2.47, 5.27, or 53.3 minutes. Verification by
18 LC-MS could not be performed as HD cannot be detected using positive API-ES
19 under these conditions.

20

1 Example 7

2 Having reference also to Fig. 25, the effectiveness of several
3 formulations against the nerve agent VX was determined.

4 Samples were prepared as described in Example 6. Two
5 decontaminant formulations were assessed for effectiveness against VX-nerve
6 agent: the mildest formulation (MILD) with 3% w/w SD, 2/3 strength buffer, and
7 1.3% w/w foamer, and the full strength formulation (FS*) with 9% w/w SD, full
8 strength buffer, 4.8% w/w foamer and 6.9% w/w additional co-solvent. As with
9 Example 6, percentages quoted for foamer represent undiluted double-strength
10 foamer.

11 Control formulations were also examined. These included a
12 formulation containing only full strength buffer and foamer (Buffer/Surf) and a
13 formulation containing all ingredients of the full strength decontaminant but without
14 active ingredient (FS*wo/SD).

15 In order to standardize concentrations between experiments,
16 effectiveness was calculated as percentage of residual agent. In addition, an
17 authentic sample of a known potential toxic product (Toxic Product), of hydrolysis
18 of VX, S-(2-diisopropylaminoethyl) methylphosphonothioic acid was synthesized
19 and characterized by LC-MS to be used as an indicator of unsuccessful
20 detoxification of VX. All reaction mixtures were examined for the presence of this
21 compound; the presence of significant quantities would be sufficient evidence to
22 disallow the formulation as a possible decontaminant candidate. The results are
23 summarized in Fig. 25.

1 In the first evaluation, the control formulation of buffer and foamer
2 (Buffer/Surf) was tested at a low concentration of VX (4 μ L/ml). After six days, 42%
3 of the VX remained and toxic product in significant quantity was detected. The
4 control formulation of full strength formulation without active ingredient (FS*wo/SD)
5 was tested against a concentration of 12 μ L/ml of VX. Again, significant quantities
6 of VX and toxic product were found at 125 minutes and 6 days. Additionally, there
7 was evidence of VX droplets in the solution at 125 minutes indicating that saturation
8 levels of VX were present in solution and that removal of VX from the system was
9 slow. When full strength formulation with SD was employed in excess (18.2:1
10 active species/VX), all VX was destroyed in less than 7 minutes with no evidence
11 of toxic product.

12 A more extensive examination of the temporal effectiveness of the
13 mildest formulation was undertaken in which the stoichiometric ratios of
14 concentrations of VX to active chlorine present in solution were varied. For the
15 lowest ratio (~6:1), effective decontamination of VX was not achieved although only
16 small traces of toxic product were observed. On the other hand, if the ratio was
17 ~16-18:1, complete decontamination without significant production of toxic product
18 was achieved. As shown in Fig. 25, the mildest formulation at a ratio of 18.2:1 is
19 completely effective in less than eleven minutes. A similar formulation reacting at
20 a ratio of 29:1 resulted in similar effectiveness, however this is most likely due to
21 the fact that the trace recorded by the LC-MS is at its detection limit using this
22 procedure.

1 An analysis of the mild formulation without added VX did not register
2 any response for VX eliminating the possibility of a false positive VX result due to
3 the formulation itself.

4 In conclusion, even the mildest formulation is highly effective against
5 VX provided that the ratio of reactant to agent is maintained over at least 17:1. This
6 finding is in accordance with statements made in Y-C Yang, J.A. Baker, and J.R.
7 Ward, Chem Rev., 1992, 92, p1731, in which the authors state that greater than 10
8 moles of active chlorine are required to oxidize 1 mole of VX.

9
10 Example 8

11 The effectiveness of foam phase-detoxification of anthrax spores was
12 determined. A suspension of *Bacillus anthracis* (Ames strain) was heat shocked
13 to kill the vegetative cells, leaving only the viable spores. Small metal coupons,
14 painted as per in-service military vehicles, were cleaned with ethanol wipes and
15 sterilised by autoclaving. Each coupon to be used was spotted with 200 μ L spore
16 suspension, distributed over the surface of the coupon as 60-70 small droplets and
17 allowed to dry overnight in a biosafety cabinet in a Level 3 Biocontainment
18 laboratory.

19 Two trials were performed on two separate days using freshly
20 prepared foam formulations. Each trial used two of these coupons, one to test the
21 decontamination formulation and one to act as a control. Each coupon was placed
22 in a 100 mm petri dish, supported to keep it from coming in contact with the bottom
23 of the dish and covered with either the decontamination foam of the present
24 invention or a control foam not containing the decontaminant active ingredients.

The lid of the petri dish was replaced and twisted to ensure that the foam contacted the entire coupon. After 30 minutes each coupon was removed from the petri dish using forceps, rinsed with sterile PBS, then swabbed twice over its entire surface with a sterile sampling swab. The swab was placed in 5 ml of Heart Infusion broth and vortexed.

In both trials, 200 μ L of neat broth from the decontamination foam-treated coupon and 200 μ l of a 1×10^{-4} dilution (in PBS) of the broth from the control foam-treated coupon were plated onto each of four Blood Agar plates. The plates were incubated overnight at 37° C and the Colony Forming Units (CFU) observed the following day, are given in Table II. The Control foam results are shown multiplied by 10^4 to adjust for the 10^{-4} dilution.

Trial 1 and Trial 2 indicate, respectively, that, on average, only 0.0108% and 0.00109% of the original material on the decontamination foam-treated coupons remained viable, translating into a 99.989% and 99.999% kill for simple contact with the decontamination foam for a period of 30 minutes.

Table II - Data from Anthrax Spore Decontamination Trials.

Experiment	Colony Counts			
	Plate 1	Plate 2	Plate 3	Plate 4
Trial 1 – Decon foam	33	26	28	21
Trial 1 – Control foam	22×10^4	22×10^4	29×10^4	28×10^4
Trial 2 – Decon foam	13	10	5	3
Trial 2 – Control foam	66×10^4	72×10^4	68×10^4	78×10^4

Example 9

Having reference to Fig. 26, the effectiveness of the one variant of the foaming agent by itself to effect decontamination of radioactive dusts from the exterior surface of an armored vehicle was demonstrated. The vehicle, a French

1 AMX-10 Armored Personnel Carrier, was contaminated by spraying the exterior
2 with ^{140}La particles (100-200 μm) to simulate surface contamination as might be
3 caused by driving across contaminated dusty terrain. Decontamination formulation
4 using Silv-Ex foamer was sprayed over the surface of the vehicle using a powered
5 pressure washer fixed with an air induction foam nozzle of the type normally used
6 in applying fire-fighting foams. Subsequent to the application of decontaminant, the
7 vehicle was towed to a sensing frame where radiation measurements on the
8 exterior could be made. In Figure 15, the radiation level measured inside the
9 vehicle in the first trial was observed to be in the order of 30 mRem/hr. After towing
10 to the decontamination site and commencing application, the radiation level was
11 observed to drop significantly (to approximately 11 mRem/hr) presumably due to
12 foam layers dropping off the sides of the vehicle during the application stage. The
13 radiation level flattened off over the course of the decontamination probably due to
14 residual particles remaining on the vehicle in areas where the foam could not drop
15 off (top, crevices) readily. On commencement of rinsing of the vehicle with water,
16 the radiation level dropped even further (to approx. 6 mRem/hr) presumably due to
17 flushing off some of the remaining radioactive particles. A map of the radiation
18 emitted from the exterior surface of the vehicle as sampled by a frame of 80 probes
19 confirmed that the radiation had been significantly reduced by decontamination
20 using Silv-Ex-based decontamination foam.

21 In a subsequent trial, the same vehicle was contaminated to a level
22 of approximately 45 mRem/hr. During movement of the contaminated vehicle to the
23 site of decontamination, significant loss in the level of radioactivity was observed.
24 The loss was such that the trial was terminated. It was apparent that the exterior

1 surface, having been previously cleaned in an earlier trial, did not retain radioactive
2 particles sprayed onto it. In other words the surface had been degreased and dust
3 adherence had been significantly decreased, suggesting an additional benefit to the
4 use of the formulation.

5 In a related examination in which paint panels were contaminated
6 and subsequently decontaminated by dry scrubbing, the standard approach for
7 decontamination of radioactive particulate matter was observed to attain a low level
8 of 0.55 mRem/hr whereas decontamination with Silv-Ex-based decontamination
9 foam reduced the radiation to a level of 0.33 mRem/hr after one application and
10 0.22 mRem/hr after a second decontaminant application, both of which surpass the
11 standard approach for addressing this hazard.

1 THE EMBODIMENTS OF THE INVENTION FOR WHICH AN
2 EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE AS FOLLOWS:

3

4 1. A method for dispersal suppression from an explosive CB
5 contamination device comprising the steps of:

6 (a) surrounding the explosive contamination device with a
7 containment structure; and

8 (b) filling the containment structure with an aerated foam comprising
9 both,

10 i) a high expansion foamer; and

11 ii) a foamer-compatible decontamination formulation
12 effective on chemical and biological agents without significantly and
13 adversely affecting the formation of foam.

14

15 2. The method of claim 1, wherein before filling the containment
16 structure, further comprising the steps of:

17 (a) preparing a foamer from a surfactant, a co-solvent selected from
18 the group consisting of polypropylene glycol, polyethylene glycol, and derivatives
19 and mixtures thereof, and a foam stabilizer;

20 (b) preparing the decontamination formulation from a
21 chloroisocyanuric acid salts, and a buffer to maintain said formulation at a pH from
22 about 11 to about 8.5;

23 (c) preparing a mixture of the foamer and decontamination
24 formulation in water;

25 (d) foaming the mixture.



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3. The method of claim 2, wherein said chloroisocyanuric acid salts are selected from the group consisting of an alkali metal of monochloroisocyanuric acid, dichloroisocyanuric acid, and a combination thereof with cyanuric acid.

4. The method of claim 3, wherein said alkali metal of dichloroisocyanuric acid is sodium dichloroisocyanurate.

5. The method of claim 2, wherein said buffer fails over time, allowing the pH to fall to a pH about 8.5.

6. The method of claim 5, wherein the buffer maintains the pH of the formulation above 8.5 for at least 30 minutes.

7. The method of claim 2, wherein polypropylene glycol has the chemical formula $R_1-(OCH(CH_3)CH_2)_n-OR_2$, where R_1 and R_2 are independently H, an alkyl, or an ester group and $n > 1$.

8. The method of claim 2, wherein said alkyl group representing R_1 or R_2 is a methyl, ethyl, propyl, or butyl group or a mixture thereof.

9. The method of claim 2, wherein at least one of said R_1 or R_2 is hydrogen.



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1 10. The method of claim 2, wherein said both R_1 and R_2 are
2 hydrogens.

3

4 11. The method of claim 2, wherein said polypropylene glycol
5 derivative is a partially etherified polypropylene glycol.

6

7 12. The method of claim 11, wherein said partially etherified
8 polypropylene glycol has the formulae $R_1-(OCH(CH_3)CH_2)_n-OR_2$, where one of R_1
9 or R_2 is independently H, or an alkyl group and $n \geq 1$.

10

11 13. The method of claim 12, wherein said alkyl representing R_1 or R_2
12 is a methyl, ethyl, propyl, butyl group or a mixture thereof.

13

14 14. The method of claim 12, wherein at least one of said R_1 or R_2 is
15 hydrogen.

16

17 15. The method of claim 2, wherein lithium hypochlorite is present in
18 amounts in the range of from about 5 to about 10% by weight of the
19 dichloroisocyanuric acid salt.

20

21 16. A process for neutralizing an explosive CB contamination device
22 comprising:

23 (a) producing an aerated foam formed from a formulation in water
24 comprising a surfactant, a co-solvent selected from the group consisting of





1 polypropylene glycol, polyethylene glycol, and derivatives and mixtures thereof, a
2 foam stabilizer, chloroisocyanuric acid salts, and a buffer to maintain said
3 formulation at a pH from about 11 to about 8.5; and

4 (b) surrounding the explosive CB contamination device with the
5 aerated foam.

6

7 17. The process of claim 16 further comprising surrounding the
8 explosive CB contamination device with a containment structure and filling the
9 structure with the aerated foam.

10

11 18. In combination, a system for dispersal suppression of an
12 explosive CB contamination device comprising:

13 (a) a containment structure for surrounding the explosive
14 contamination device; and

15 (b) aerated foam contained within the structure being formed from a
16 decontamination formulation in water comprising a surfactant, a foam stabilizer, a
17 solvent selected from the group consisting of polypropylene glycol, polyethylene
18 glycol, and derivatives and mixtures thereof, chloroisocyanuric acid, and a buffer
19 to maintain said formulation at a pH from about 11 to about 8.5.

20

21 19. The system of claim 18 wherein

22 (a) the foamer comprises a surfactant, a co-solvent selected from the
23 group consisting of polypropylene glycol, polyethylene glycol, and derivatives and
24 mixtures thereof, and a foam stabilizer; and





1 (b) the decontamination formulation comprises a chloroisocyanuric
2 acid, and a buffer to maintain said formulation at a pH from about 11 to about 8.5.

3

4 20. The system of claim 19 wherein the foam formulation comprises:

5 (a) about 0.4 – 4 weight % of the surfactant; about 0.03 – 0.5 weight
6 % of the foam stabilizer; and about 0.10 – 9.5 weight % of the co-solvent;

7 (b) about 3 – 6 % of the chloroisocyanuric acid; and

8 (c) the balance being water.

9

10 21. The system of claim 19 wherein the foam formulation comprises:

11 (a) about 3% by weight of a chloroisocyanuric acid;

12 (b) about 0.6 weight % of the surfactant;

13 (c) about 0.03 weight % of the foam stabilizer;

14 (d) and about 0.75 % of the solvent selected from the group
15 consisting of polypropylene glycol, polyethylene glycol, and derivatives and mixtures
16 thereof;

17 (e) a buffer to maintain said formulation at a pH from about 11 to
18 about 8.5; and

19 (f) the balance being water.

