MATERIALS TECHNOLOGY FOR CHEMICAL/BIOLOGICAL PROTECTIVE CLOTHING

Dr. Eugene Wilusz
Chemical Technology Team
Natick Soldier Center
U.S. Army Soldier and Biological Chemical Command

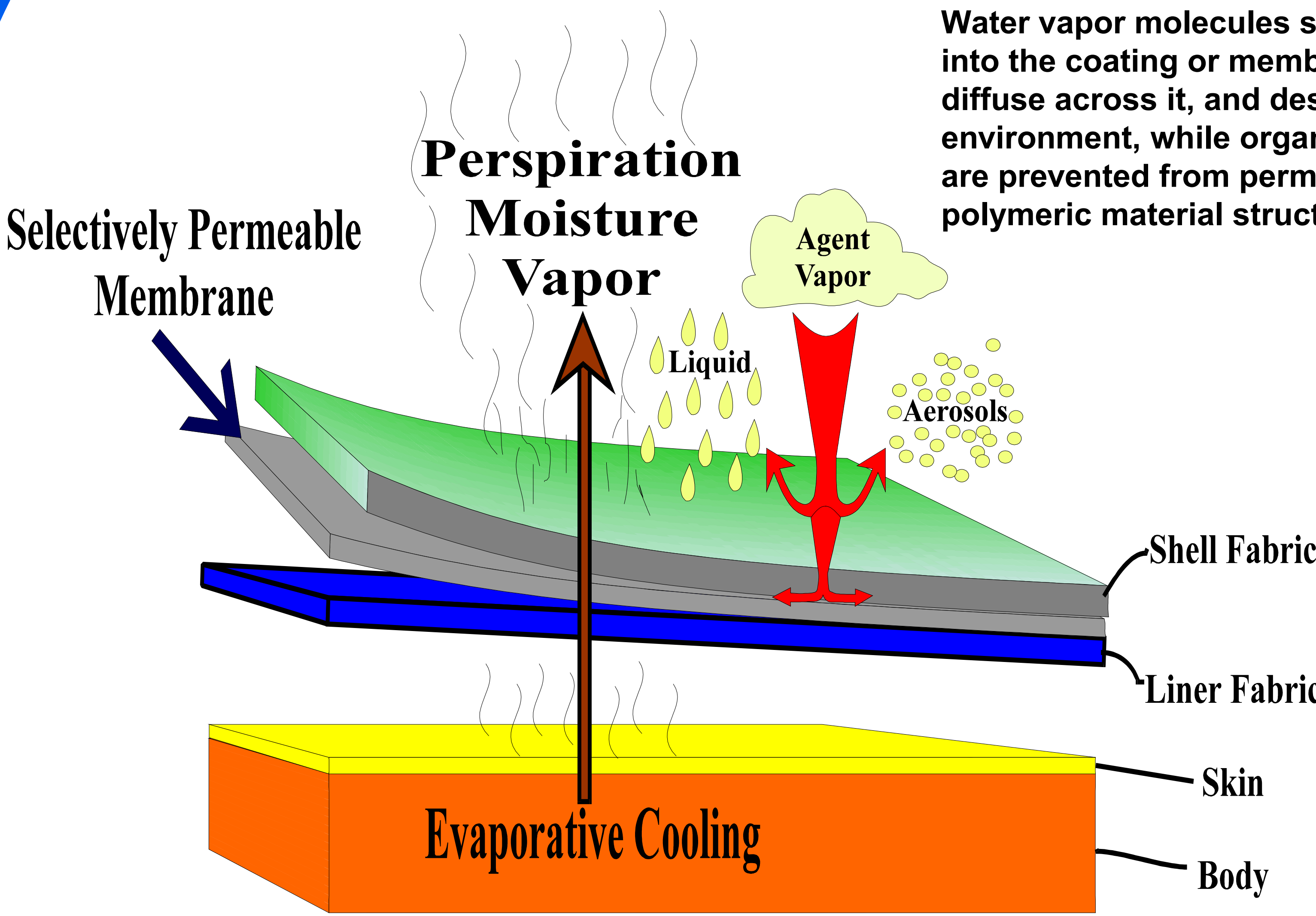
ATTN: AMSSB-RIP-C(N)
Natick, MA 01760
COM: (508) 233-5486
FAX: (508) 233-4331
EMAIL: Eugene.Wilusz@natick.army.mil

OBJECTIVES/TECHNICAL CHALLENGES

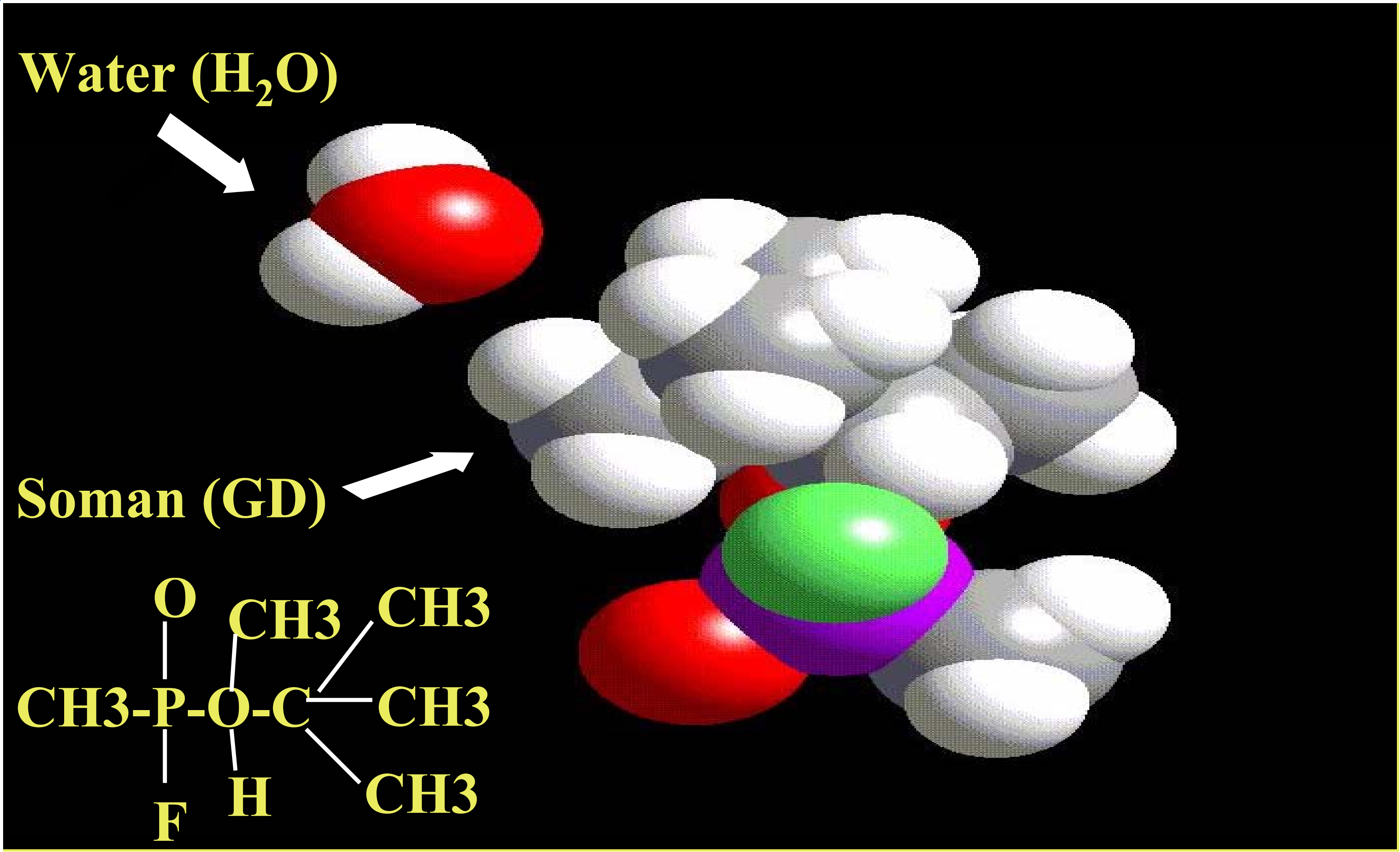
- Develop CB protective materials that:
  - Protect against liquid, vapor, and aerosol CB warfare agents
  - Have high moisture vapor transport and evaporative cooling potential
  - Are flexible, durable, thin, waterproof, low-noise, and low-cost
  - Are lightweight
  - Are launderable
- Develop advanced techniques for characterization of membrane barrier/transport properties
- Develop a lightweight CB protective duty uniform that will be more durable, 30% lighter in weight, and less bulky than the JSLIST duty uniform and overgarment system

MATERIAL CONCEPT

Water vapor molecules selectively dissolve into the coating or membrane material, diffuse across it, and desorb into the environment, while organic vapor molecules are prevented from permeating through its polymeric material structure.



Relative Size of Water and Soman Chemical Warfare Agent Molecules



PERFORMANCE GOALS

Protection - 24 hours (after 45 days of wear)
Chemical Agent Protection: Blister agent (HD), Nerve agents (GB,GD, VX)
Biological Agent Protection: Bacteria and viruses (size: 10 to 10^{-3} μm)

Water Vapor Flux @ $32^{o}C \geq 1800\ g.m^{-2}/24\ h$)
[or Intrinsic Water Vapor Resistance $\leq$ 300 s/m*]

Hydrostatic Resistance $\geq$ 35 lb/in^2

Bonding Strength $\geq$ 10 lb/in^2

Stiffness $\leq$ 0.01 lb

Weight $\leq$ 7 oz/yd^2

Thickness $\leq$ 18 mils

Torsional Flexibility: Pass

Launderable

Water Permeability after flexing at 70 ^{o}F and -25 ^{o}F: Pass

*Natick Dynamic Moisture Vapor Permeation Cell.

Ongoing Membrane Development:

Dual Use Science and Technology (DUST) Program:

-Development of ***dual use,*** selectively permeable, membrane-based fabric systems for CB/environmental protection.

- *-emergency responders*
- *-pesticide applicators*
- *-industrial chemical handlers*
- *-medical personnel*
- *-environmental clean-up workers*

Cooperative Research and Development Agreement (CRADA):

-Development of selectively permeable membranes containing biocides and agent reactive catalysts

Technology Program Annex (TPA) with ARL WMD:

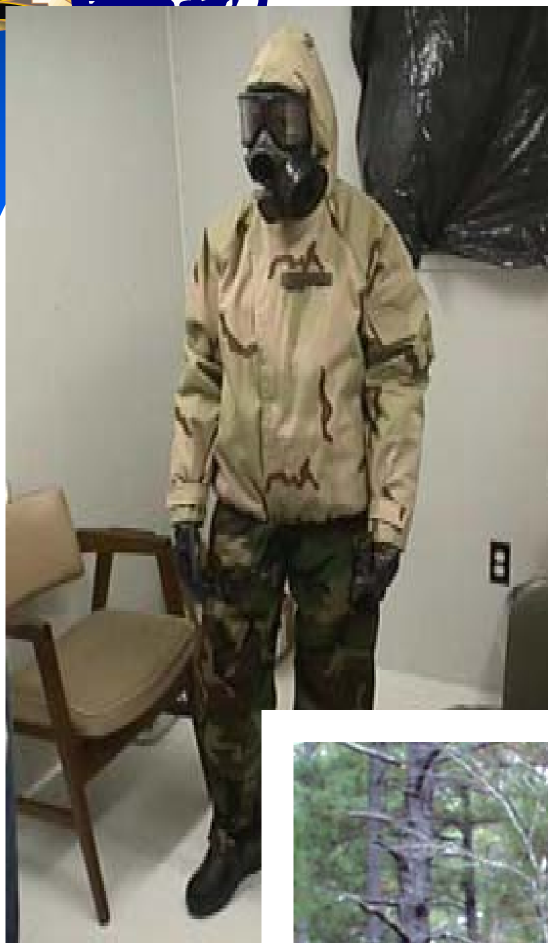
-Development of novel block copolymers for elastomeric, selectively permeable membranes

Memorial Institute for the Prevention of Terrorism

-Development and evaluation of membrane-based garments

Advanced Integrated Warfighter Protection (Objective Force Warrior)

-Development of elastomeric, selectively permeable membranes



Vapor (V) Chemical Agent Protective Closure Systems

Vapor, Aerosol, Liquid, (VAL) Chemical, and Biological Agent Protective Closure Systems

Individual Protection

DTO CB.45

Self-Detoxifying Materials for CB Protective Clothing

Objectives

- Address JFOC J.3.3.2 - Unlimited Individual Protection
- Incorporate agent reactive catalysts into CB protective materials – fiber, film, membrane
- Incorporate biocides into CB protective materials
- Demonstrate neutralization effectiveness of biocides/catalysts
- Demonstrate lightweight , self-detoxifying CB protective clothing with reactive shell & reactive liner

Payoffs

- Increased protection
- In-situ neutralization of CB agents
- Reduced hazard during doffing and disposal
- Reduced logistics burden
- Supports: Objective Force Warrior, JSLIST Upgrade, dual-use for hazmat and counterterrorism

Individual Protection

DTO CB.45

Self-Detoxifying Materials for CB Protective Clothing

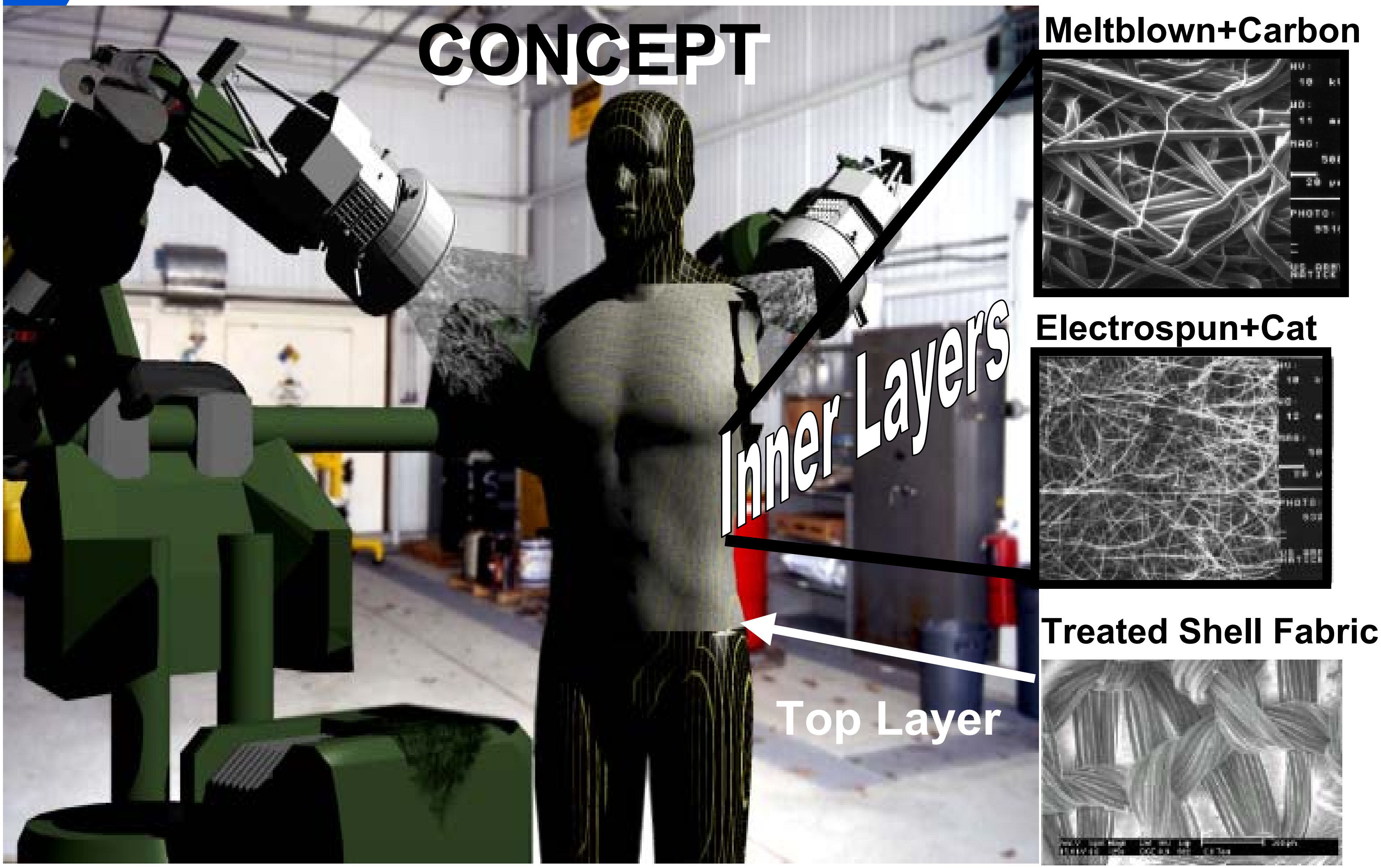
Challenges

- Balance increased protection against added weight
- Identify agent reactive catalysts which are effective in neutralizing more than one specific type of agent
- Identify catalysts and biocides which act rapidly
- Meet catalyst durability and stability needs for clothing

Individual Protection

DTO CB.45

Self-Detoxifying Materials for CB Protective Clothing

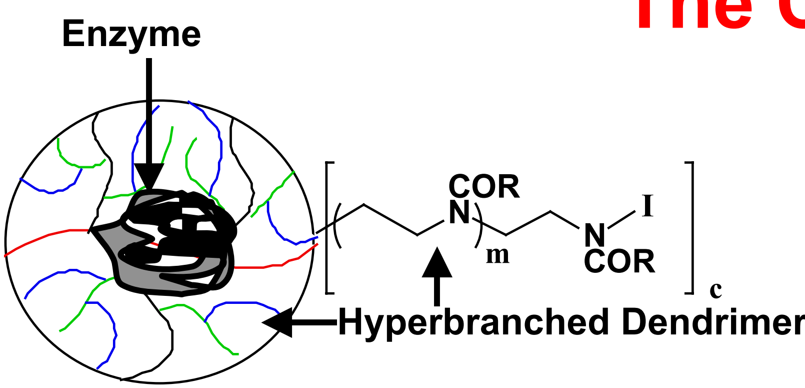


Individual Protection

DTO CB.45

Self-Detoxifying Materials for CB Protective Clothing

The Catalysts



OPAA-C18

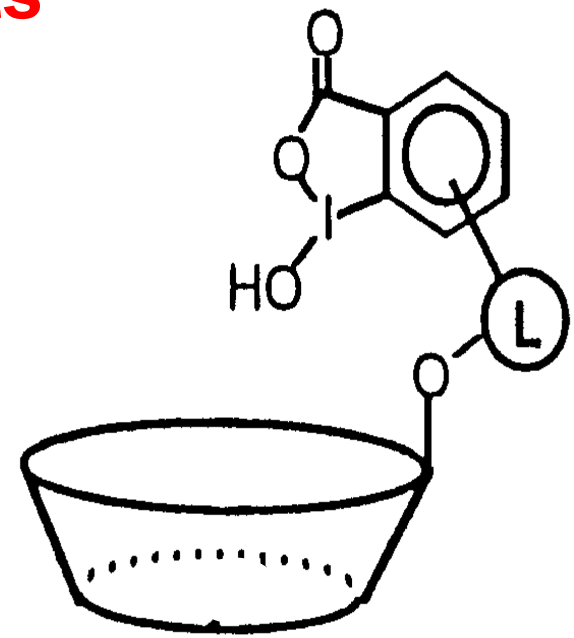
Organophosphorus Acid Anhydrolase

G agents & VX

Polyoxometalate

$Na_5PV_2Mo_{10}O_{40}$

Mustard



IBA-CD

Iodosobenzoic acid-substituted

β-cyclodextrin

G agents

Reactive Nanoparticles for Improved CB Protection

$$Cl\text{-}CH_2\text{-}CH_2\text{-}S\text{-}CH_2\text{-}CH_2\text{-}Cl + [MgO] \longrightarrow$$

"HD"

$$CH_2{=}CH\text{-}S\text{-}CH_2\text{-}CH_2\text{-}Cl + CH_2{=}CH\text{-}S\text{-}CH{=}CH_2 +$$

"vinyl HD" **"divinyl HD"**

$$[\text{-}MgO\text{-}CH_2\text{-}CH_2\text{-}S\text{-}CH_2\text{-}CH_2\text{-}OMg\text{-}]$$

"thiodiglycol"

reported by Wagner, Bartram, Koper, Klabunde, J. Phys. Chem. B (1999)

Biocidal Treatments for Fabrics and Films

N-halamines

- Chlorine compounds
- Chemically grafted onto cellulose
- Effective against bacteria, viruses, molds, algae, and fungi
- Implications for neutralizing chemical warfare agents
  - Effective in destroying pesticides
- Durable
- Refreshable

Quarternary ammonium salts with alkyl chains

- Functionally modify synthetic fibers
- Chemically bond to fibers using dye molecules as bridges
- Effective against E. coli

EFFECTS OF TOXIC INDUSTRIAL CHEMICALS ON CB PROTECTIVE CLOTHING

Objective: Determine the effects of toxic industrial chemicals (TICs) on the effectiveness of CB protective clothing.

Background

- US Forces are likely to encounter environments where they are exposed to TICs
- Protection vs. CW agents is well documented
- Effects of exposure to TICs on the garment properties and the protection afforded by garments has not been determined

Plan

- Establish/verify a list of chemicals most likely to be encountered
- Downselect a representative number of chemicals
- Determine effects of exposure to TICs on textile properties
- Determine effects of exposure to TICs on CW agent protection

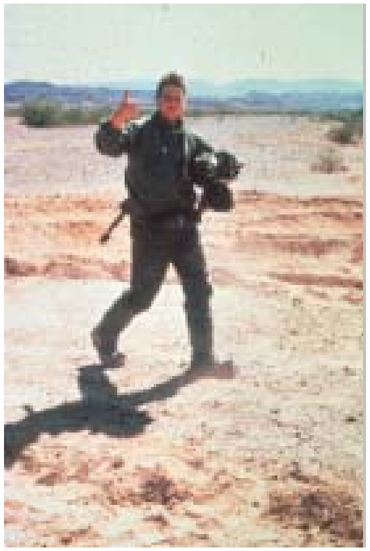
Microclimate Cooling

The Need: A soldier working at a moderate activity level, in MOPP IV in a warm/hot environment will succumb to heat stress in 60-90 minutes.

NSC Mission: Design and develop Microclimate Cooling Systems to mitigate the heat stress effects of personnel encapsulated in protective clothing in hot environments.

The Benefits: Reduction in core/skin temperatures, heart rate and sweat rate resulting in increased mission duration, improved comfort and mental acuity, and decreased hydration needs.

Without Cooling



With Cooling

Microclimate Cooling Systems

Recent Developments

System	Cooling (W)	Weight (lb)	Duration (hrs)	Description/Status
Compact Vapor Compression Cooling System	120	7	3	Small vapor compression cooler prototype to support Objective Force Warrior program.
Portable Vapor Compression Cooling System (PVCS)	300	20	4	Vapor compression cooler prototype.
Air Warrior Microclimate Cooling System*	325	13	-	Vapor compression cooler used on U.S. Army rotary wing aircraft – leveraged PVCS. Fielding expected in 2004.
Personal Ice Cooling System (PICS)	250	11	~0.5	Uses water/ice reservoir to provide cooling to users of STEPO (Level A) ensemble. Type-classified.

*System uses aircraft power; weight is exclusive of power source.

Microclimate Cooling Systems

Performance Goals

Timeline	Cooling (W)	Power (W)	Weight (lb)	Volume (in^3)	Duration (hrs)
2005	150	<50	<7	100	4
2015	150	<30	<5.5	46	4

Plans (FY03 - 04)

- Chemical and water vapor transport mechanisms in membranes
- Modification of membrane surfaces for improved permselectivity
- Optimize novel closure systems
- Development of a flame resistant, CB protective duty uniform
- Vapor protection factor testing of prototype ensembles
- Garment durability and user acceptability field evaluations
- Nanofibers for aerosol threat mediation
- Nanofiber webs incorporating agent reactive catalysts/biocides
- Scale-up nanofiber electrospinning process
- Effects of TICs on protection
- Lighter weight microclimate cooling

Partnering Information and Mechanisms

- www.SBCCOM.army.mil

- Broad Agency Announcement (BAA)

- Small Business Innovation Research (SBIR)

- Cooperative Research and Development Agreements (CRADA)

- Unsolicited Proposals

Summary/Challenges
Clothing Operational Context

Improved system integration with suit, mask, helmet, gloves, boots, body armor, weapons, etc. (JSLIST Upgrade)

Cool, lightweight CB duty uniform based on nanofiber or membrane technology with increased mission duration and a reduced logistics burden. (JSLIST Upgrade)

Reactive clothing materials with increased protection, reduced doffing hazard, and reduced logistics burden. (JSLIST Upgrade)