

# **The Role of PPE in Contamination Control Protection & Cleaning**

**Firefighter Health & Wellness Conference**

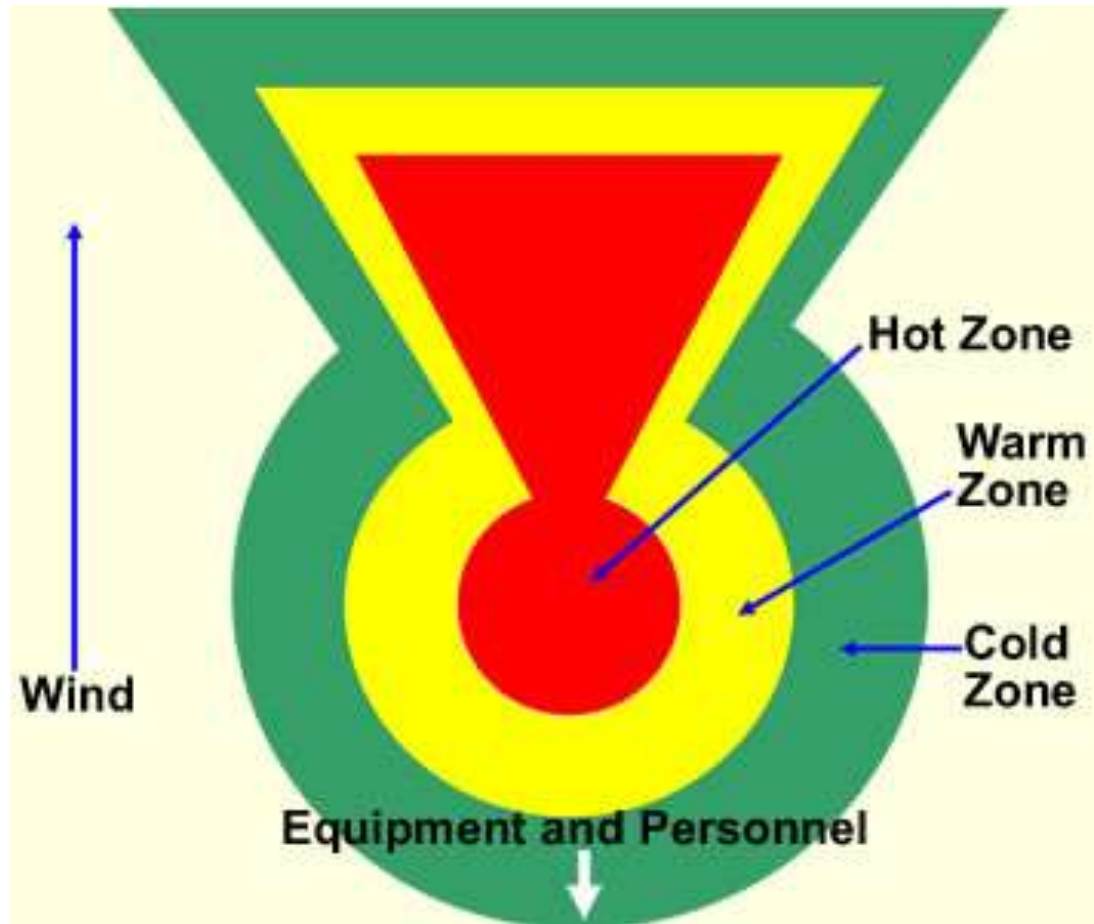
**Dayton, Ohio**

**Thursday 24 October 2010**

Jeffrey O. Stull

International Personnel Protection, Inc.

# Controlling Contamination Exposure



**Mitigation of fireground contamination occurs**

- On the fire ground

***Preventative measures***

- In transition off the fireground

***Near term actions***

- Away from the fire

***Long term actions***

# Persistent Contamination is Everywhere



**On the fireground**



**Inside apparatus**

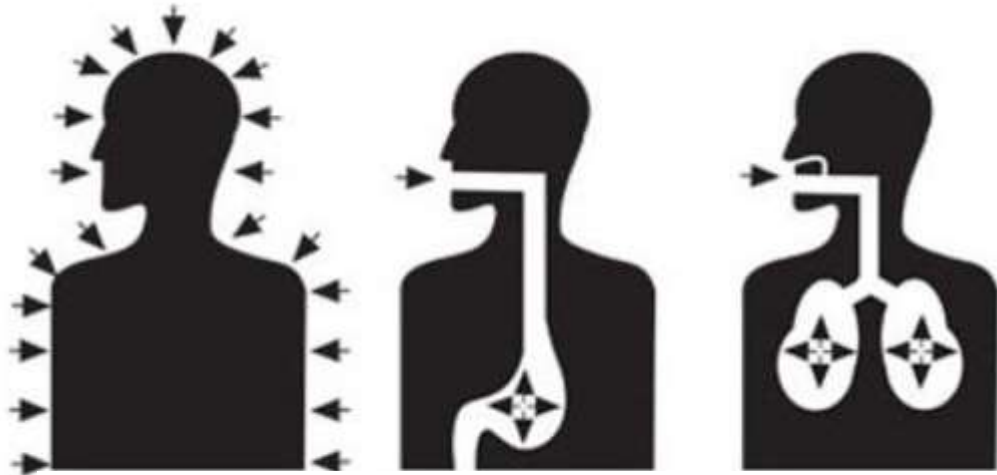


**At the fire station**

- Most contamination leaves the fireground through PPE, hose, and tools and spreads through contact

# Contamination Basics

## Routes of Entry



*Skin Contact*

*Ingestion*

*Inhalation*

Impact of contaminant depends on substance properties

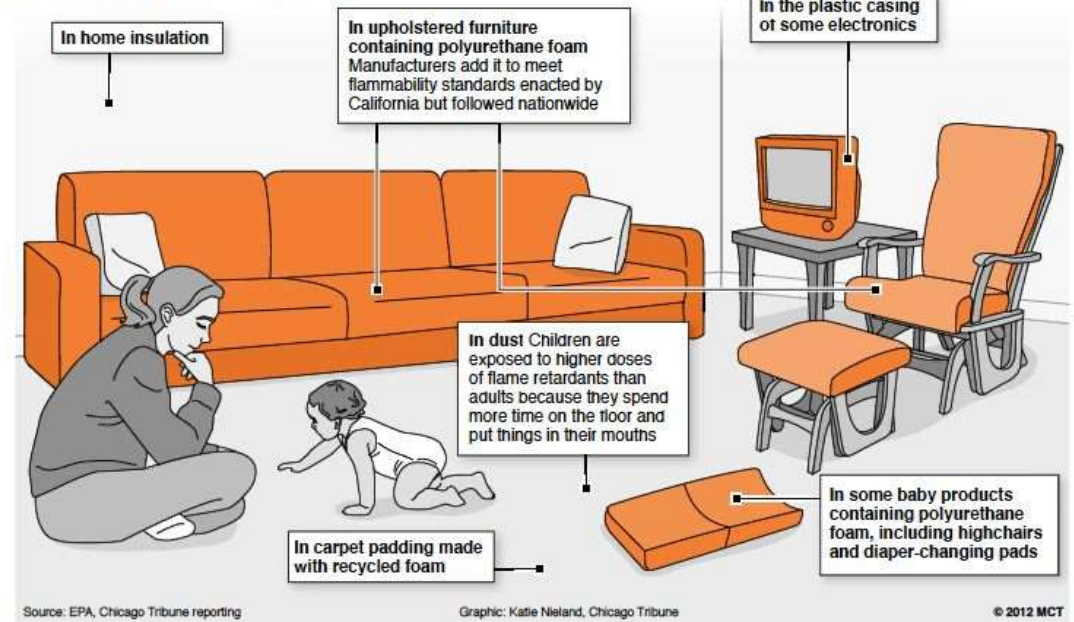
- Most common ways firefighters are affected:
  - Smoke and fire gases are inhaled
  - Direct skin contact with corrosive or harmful chemicals
  - Fire gases and liquids absorb through skin
  - Smoke particles stay on skin long enough to release chemicals that then absorb through skin
  - Smoke particles or other substances on hands/face contaminate food

# Common Contaminants of Concern

- Volatile organic compounds
  - e.g., benzene, formaldehyde
- Semi-volatile organic compounds
  - e.g., polynuclear aromatic hydrocarbons (PAHs), phthalates, various fire retardant chemicals
- Heavy metals
  - e.g., Arsenic, Cadmium, Chromium
- Dangerous particulates
  - e.g., asbestos, lead dust, fentanyl

Flame retardants are present in virtually every American home even though some of the compounds have been linked to neurological deficits, developmental problems, impaired fertility and other health risks.

## Where flame retardants are found



Research | Review

## Brominated Flame Retardants: Cause for Concern?

Linda S. Birnbaum<sup>1</sup> and Daniele F. Staska<sup>2</sup>

<sup>1</sup>U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Experimental Toxicology Division, Research Triangle Park, North Carolina, USA; <sup>2</sup>University of North Carolina, Curriculum in Toxicology, Chapel Hill, North Carolina, USA

*Various chemicals are present of different persistency and toxicity in all fire environments*



# PPE in Preventing and Causing Exposure

- Historically PPE is used for heat and physical protection
- New shift to full ensemble protection against contamination exposure
- While providing protection, clothing itself becomes source of exposure
- Additional shift to more frequent effective cleaning and controlling contamination on fireground and at the station



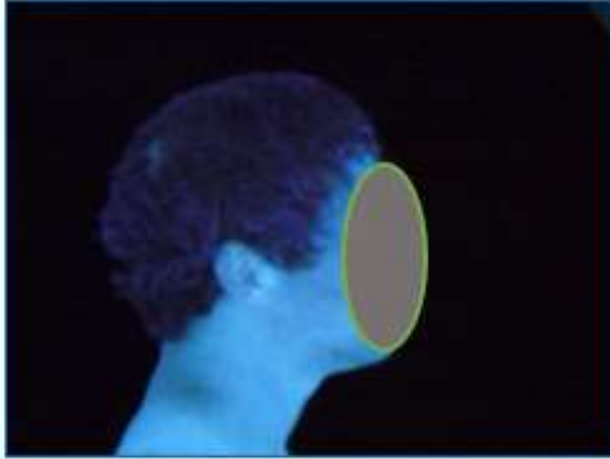
# IAFF Assessment of Particulate Exposure

- IAFF conducted particulate exposure study in 2015
- Military method used to simulate smoke exposure
- Full, used turnout gear evaluated
- Particles tagged with fluorescent tracer to allow observation under UV light

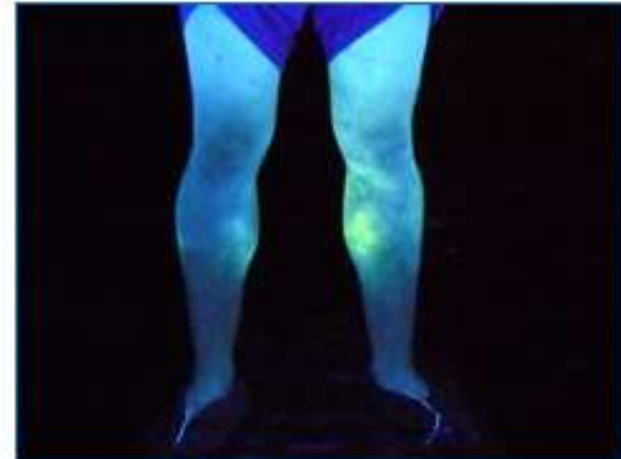
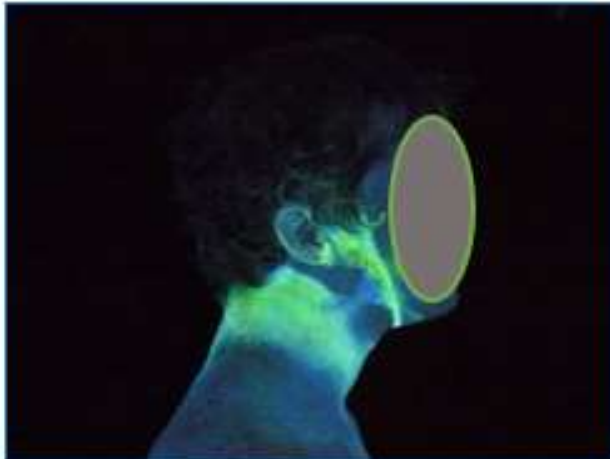


# Key Visual Findings from IAFF Particulate Study

**Before**



**After**





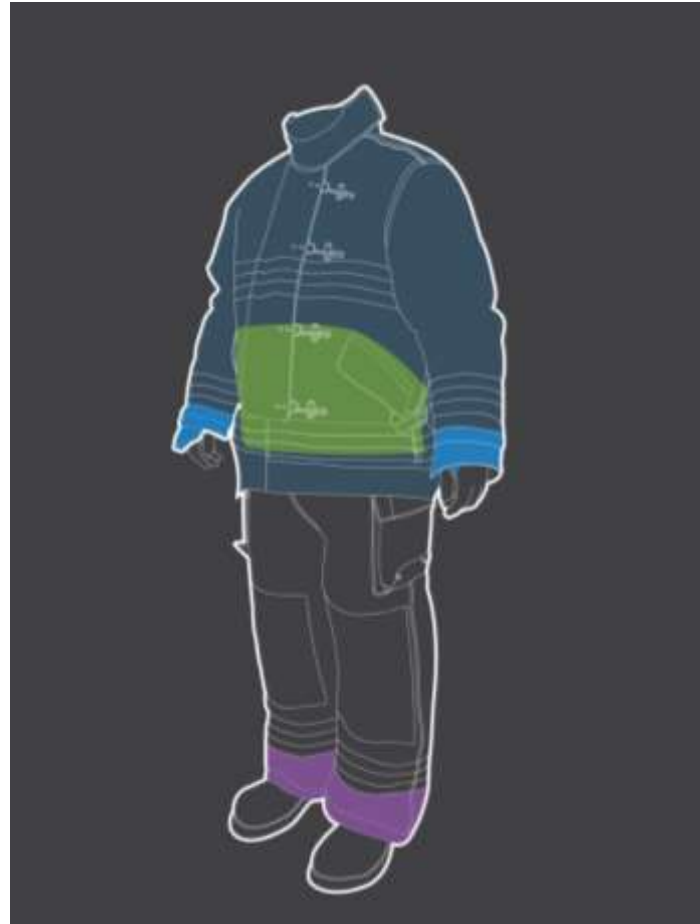
# Initial Focus on Protective Hoods

- Hoods originally considered most vulnerable interface owing to porous fabrics
- NIOSH study found:  
*“Better protection to the neck could reduce dermal absorption of combustion products.”*
- Efforts were launched to create industry criteria in NFPA 1971 for particulate blocking hoods



# PPE Solutions for Reducing Exposure

- Industry efforts to address other interfaces
- Further innovation needed to account for increased encapsulation
- Good “metrics” still not in place





## The Nature and Consequences of Exposure

- Smoke particulate and other hazardous materials accumulate in firefighter PPE in different layers
- Continued wearing of contaminated clothing increases levels of exposure
- Soiled PPE and tools cross contamination other items
- Active steps must be taken to minimize exposure after initial response

# Practices to Minimize Contamination

1. Properly wear correct PPE
2. Perform “gross decon” after fire
3. Carefully doff, isolate, and bag PPE
4. Use wipes to clean skin on scene
5. Properly transport contaminated items
6. Change clothes and take shower
7. Keep contaminated items segregated at station
8. Clean and decontaminate exposed items
9. Document exposures, get regular check ups

# Wearing of PPE



- Select appropriate PPE
  - Conduct thorough hazard assessment
- Ensure that selected PPE is properly integrated to provide needed level of protection
- Wear PPE according to manufacturer instructions
- Continue wearing PPE where hazards still remain





# Preliminary Exposure Reduction

- Integrate “gross decontamination” as part of rehabilitation process
- Use rinsing and wash firefighter while still in full PPE at fire scene
  - o Intended to remove surface contamination and minimize transfer of contamination to fire fighter when doffing PPE
- Apply variants in procedures depending on circumstances and resources



# On Scene Decontamination Effectiveness



Journal of Occupational and Environmental Hygiene



ISSN: 1545-9624 (Print) 1545-9632 (Online) journal homepage: <http://www.tandfonline.com/loi/uoeh20>

Contamination of firefighter personal protective equipment and skin and the effectiveness of decontamination procedures

Kenneth W. Fent, Barbara Alexander, Jennifer Roberts, Shirley Robertson, Christine Toennis, Deborah Sammons, Stephen Bertke, Steve Kerber, Denise Smith & Gavin Horn



- IFSI Study showed varying levels of chemical removal\* based on approach:
- Wet (with soap): 85%
- Dry brush: 25%
- Blower: < 5%
- Use of detergent is believed to aid removing some exterior soils
- Be wary of products advertising 100% chemical removal (no current standards)

*\* Related to amount of PAHs obtained in wipe samples*

# Handling of Contaminated PPE

- Properly remove PPE to avoid contamination transfer
  - Specific attention glove and hood doffing
- Isolate and bag contaminated PPE for later cleaning
  - Use of >3 mil bags
- Provide clean clothing for personnel at scene
- Avoid transporting contaminated PPE in apparatus cab or personal vehicles





# Cleaning and Decontamination

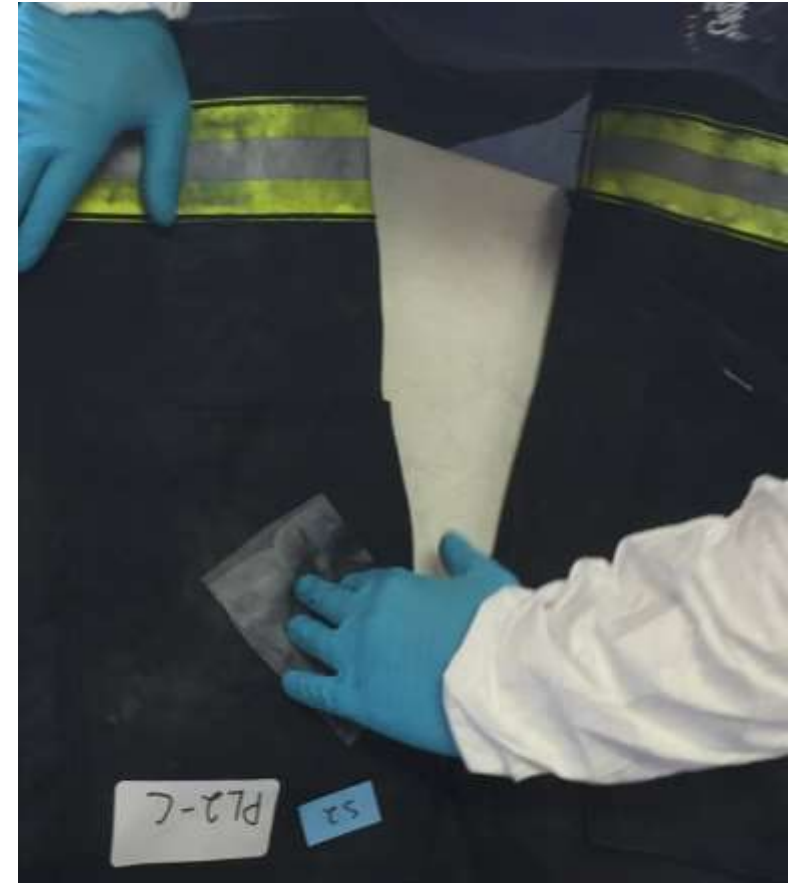
- Clean all contaminated items
  - Other items: SCBA, boots, gloves, hoods, hose, tools should be addressed
- Subject contaminated items to proper cleaning
  - Pick effective processes
- Ensure that items can be safely returned to service



# Question

What is the best way to tell if turnout clothing is “clean”?

- A. I see no visible soiling
- B. It smells clean to me
- C. The rinse water looks dirty
- D. I wipe a small white cloth against it and the cloth shows no dark residue
- E. I run an analytical test on the clothing and it shows no chemicals
- F. None of the above



**Wipe Sampling of Turnout Gear**



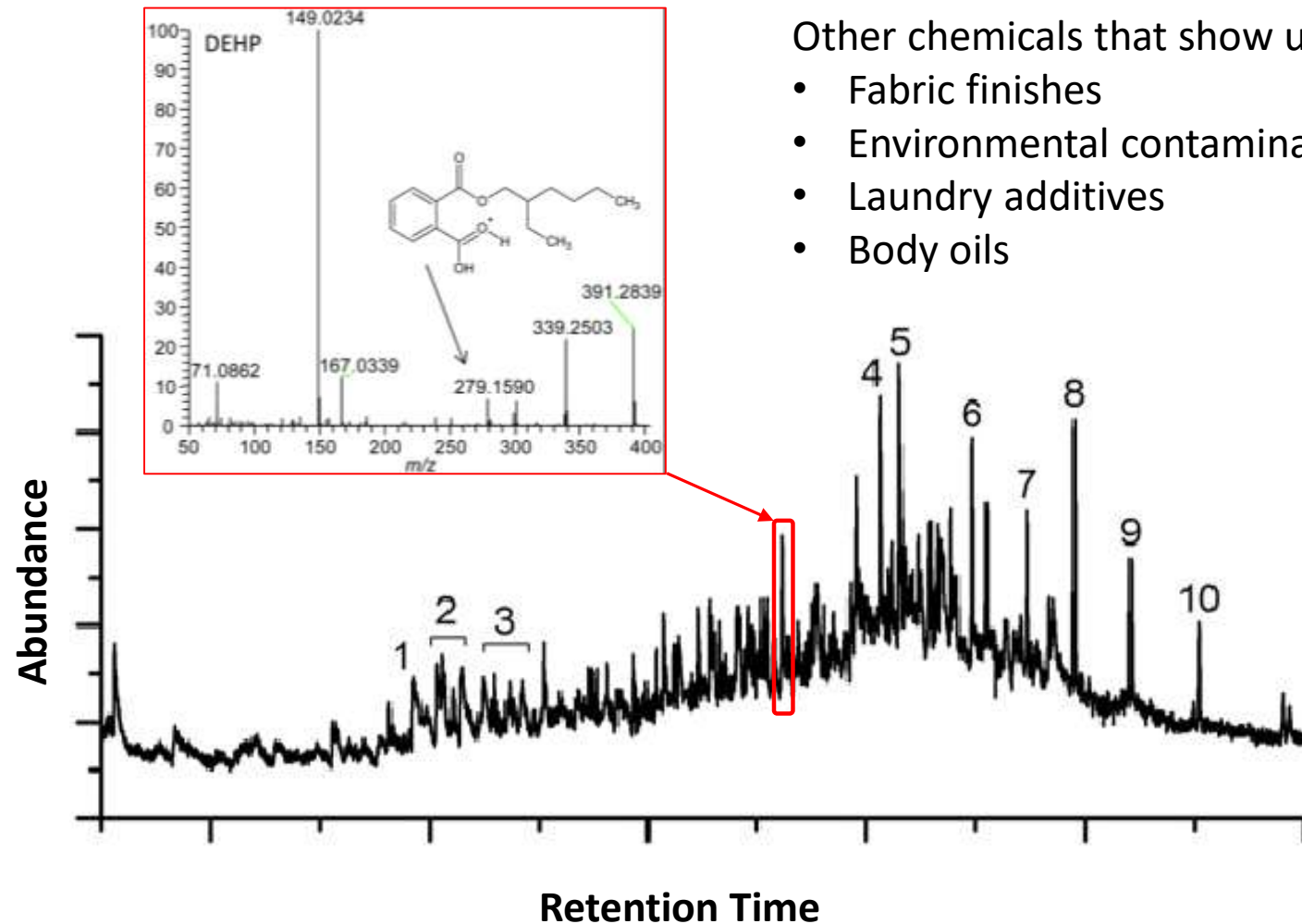
# Chemical Analysis of Outer Shell Fabric



Fabric Extraction



GC-MS



# Why Cleanliness is Hard to Define



**HazMat**

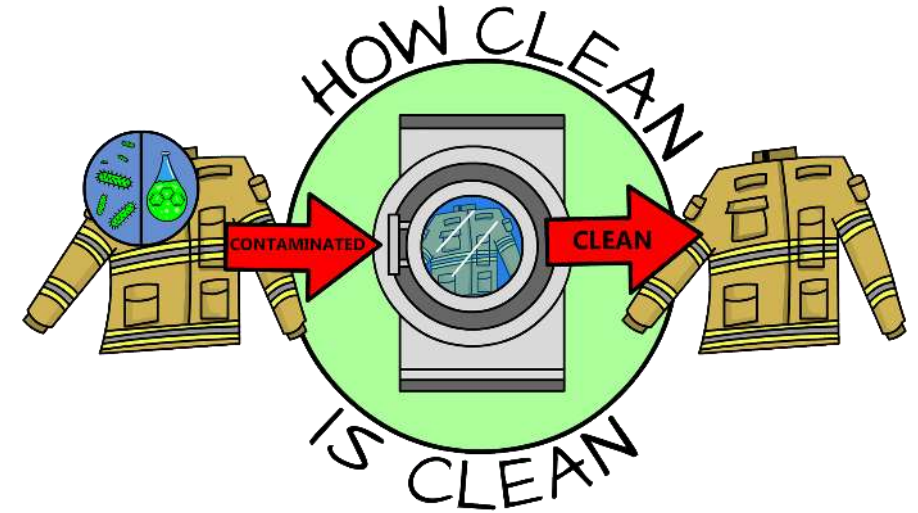


**Real HazMat**

- Cleanliness is more than soiling
- Enormous number of different contaminants
- Different sources for contamination
- Lack of acceptable levels of exposure for majority of substances

# Quick Project Overview

- Started Aug. 2015/Completed Dec. 2018
  - Followed earlier Foundation project aimed at turnout clothing cleaning practices
- Project Team



Project Logo

Updated project information at:

<http://www.nfpa.org/ppecleaning>

# Project Goal

*Reduce firefighter exposure to harmful contaminants in unclean or inadequately cleaned PPE*

- Key questions being answered:
  - Can better gear cleaning guidance be provided to the fire service?
  - Does cleaning adequately remove chemical and biological contaminants?
  - When do departments know their gear is clean?
  - How can research findings best be transitioned to practice?

***Comprehensive project to validate cleaning procedures***

NFPA®

# 1851

Standard on  
Selection, Care, and  
Maintenance of Protective  
Ensembles for Structural  
Fire Fighting and Proximity  
Fire Fighting

2020



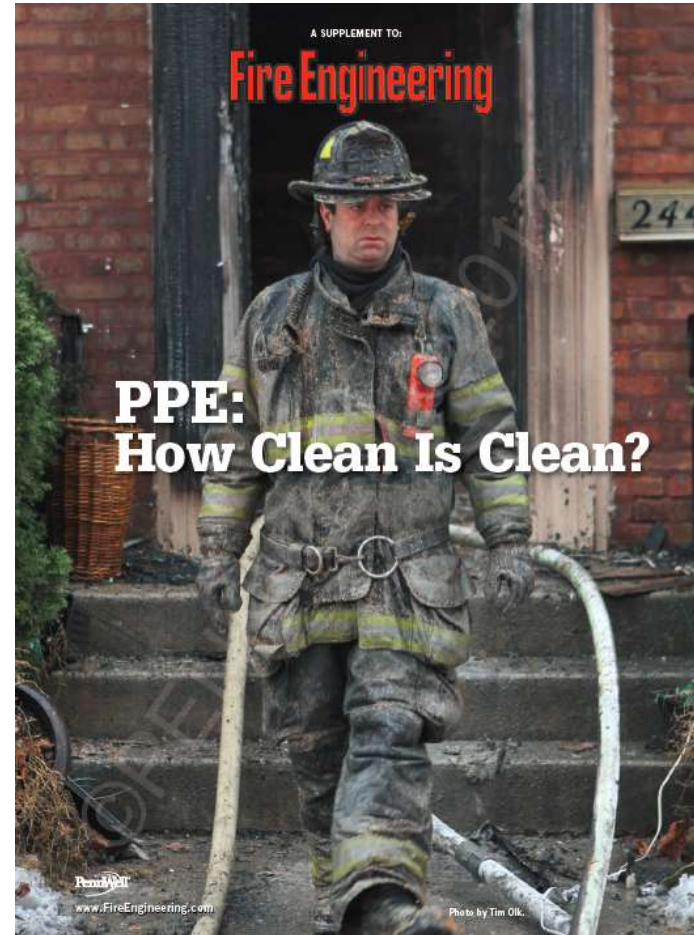
## Revised NFPA 1851

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- Cleaning chapter overhauled
  - Decision matrix to support cleaning and decontamination decisions
  - Distinctions made between advanced cleaning and sanitization (biodecontamination)
  - Use of PPE on fireground requires advanced cleaning (**SMOKE = CONTAMINATION**)
  - Extensive guidance in annex
- Cleaning verification requirements applied to ISPs and manufacturers



# Creating Fire Service Awareness



## Project Outputs

- ***YouTube video*** explains project approach
- ***Instructional video*** helps implement cleaning verification procedures
- ***Brief project synopsis*** describes principal findings
- ***Detailed technical report*** being finalized

# Research Approach & Challenges

## Multiple Objectives



Chemical

- Range of contaminants
- Lack of exposure standards

Biological

- Need for surrogates
- Different metrics

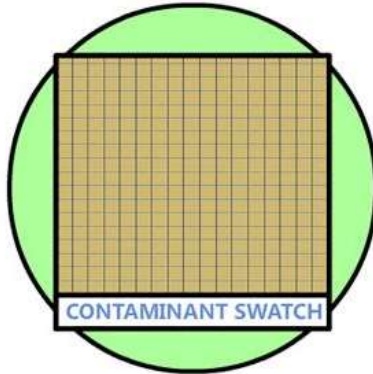
Outreach

- Short-term: Affect NFPA 1851
- Long-term: Create industry change

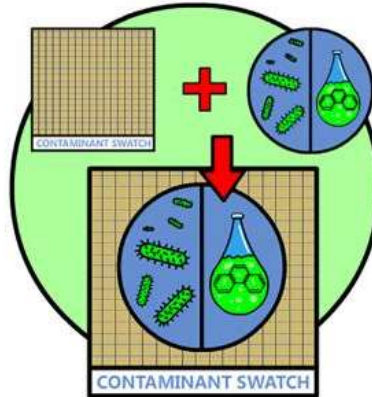
## Significant Challenges

# CLEANING VERIFICATION KIT PROCESS

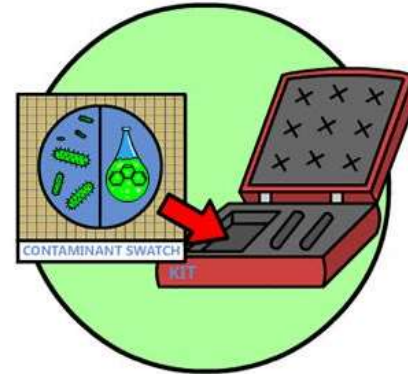
Representative sample prepared



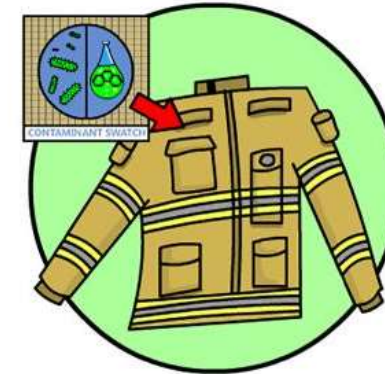
Sample contaminated in laboratory process



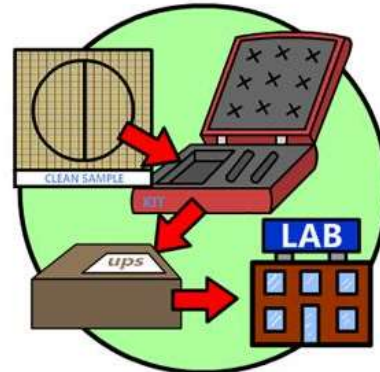
Sample packed in kit and sent to organization seeking verification



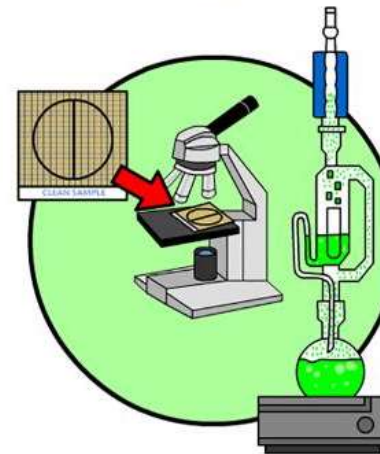
Sample placed inside surrogate turnout clothing item



Clothing and sample washed according to organization's existing process



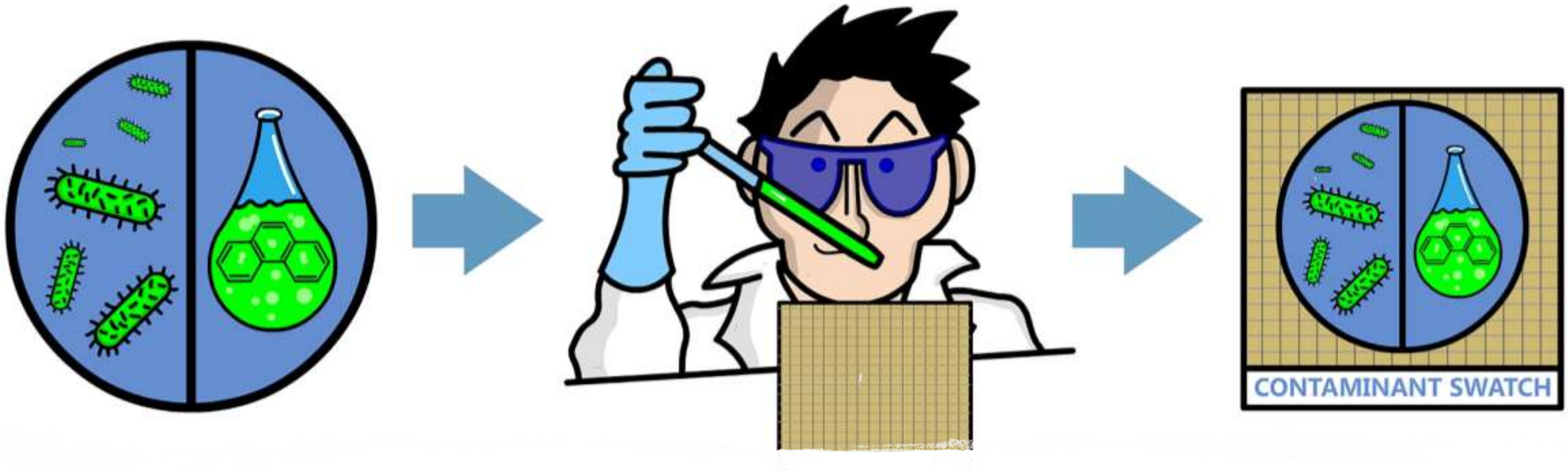
Sample packed in kit and sent to qualified lab



Sample analyzed for different contaminant levels







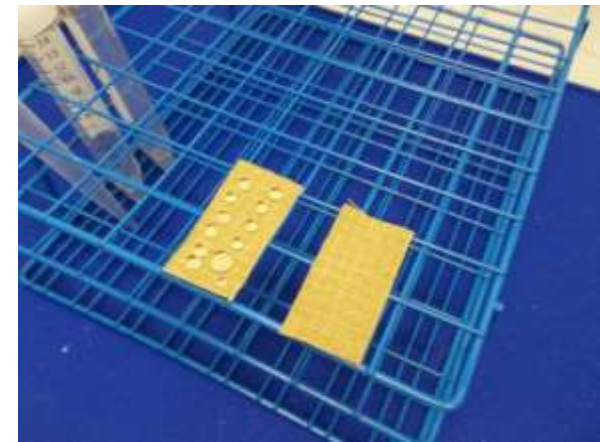
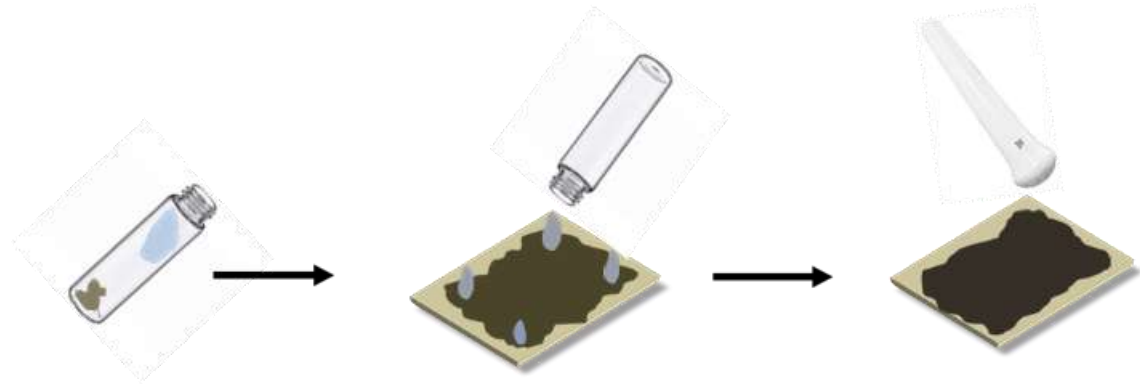
## Biggest Challenge – Specimen Contamination

- Problem 1 – Pick from myriad of different contaminants
- Problem 2 – Find a meaningful way to contaminate samples

# Specimen Contamination Approaches



**ITS Specialized Furnace**



**NIOSH Contamination Methods**



# Contaminant Selection

- Principal factors
  - Persistency
  - Representative
  - Easily extracted/analyzed
- Biological
  - Derived from EPA regulations

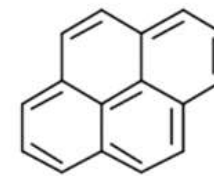


*K. pneumoniae*

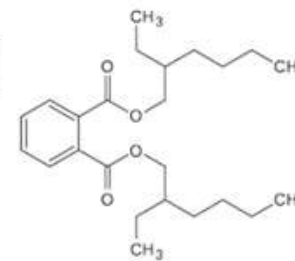


*S. aureus*

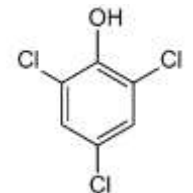
- Inorganics
  - Focus on common toxic and skin absorbing heavy metals (Antimony, Arsenic, Cadmium, Chromium, Cobalt, Lead)
- Semi-volatile organic compounds (SVOCs)
  - PAHs
  - Phthalates
  - Phenols



*Pyrene*

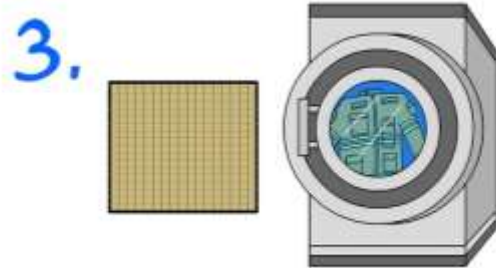
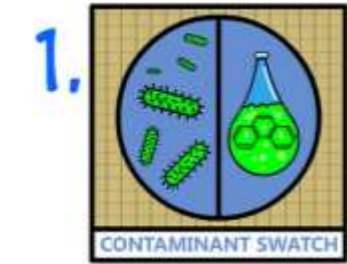


*DEHP*



*TCP*

# Sample Processing at Wash Facility



- Key Challenges and Solutions
  - Wide range of clothing materials
    - Choose single representative material in suitable condition
  - Clothing is highly complex
    - Use surrogate, simplified clothing samples
  - Wash procedures generally different between facilities (machine, detergent, process)
    - Establish consistent wash load to remove variability
    - Allow for adjustment depending on facility procedures

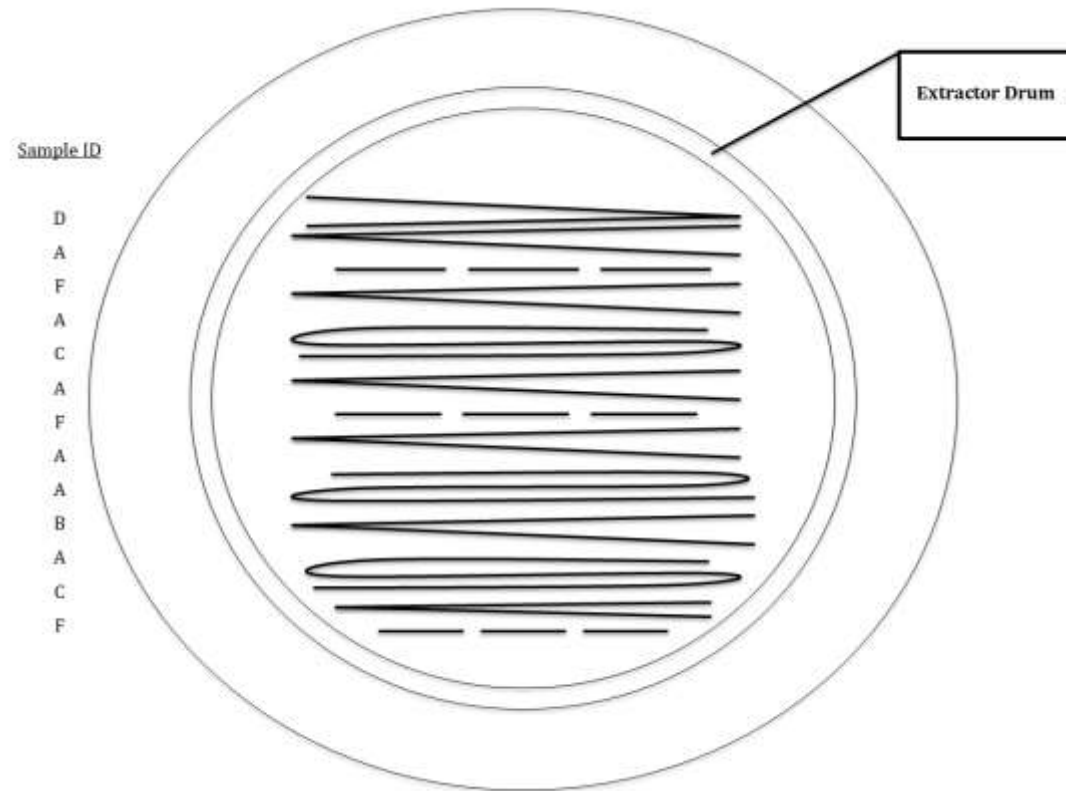
**Overall theme:** *Promote uniformity of procedures for reliability and reproducibility*

# Sample Containment and Transfer

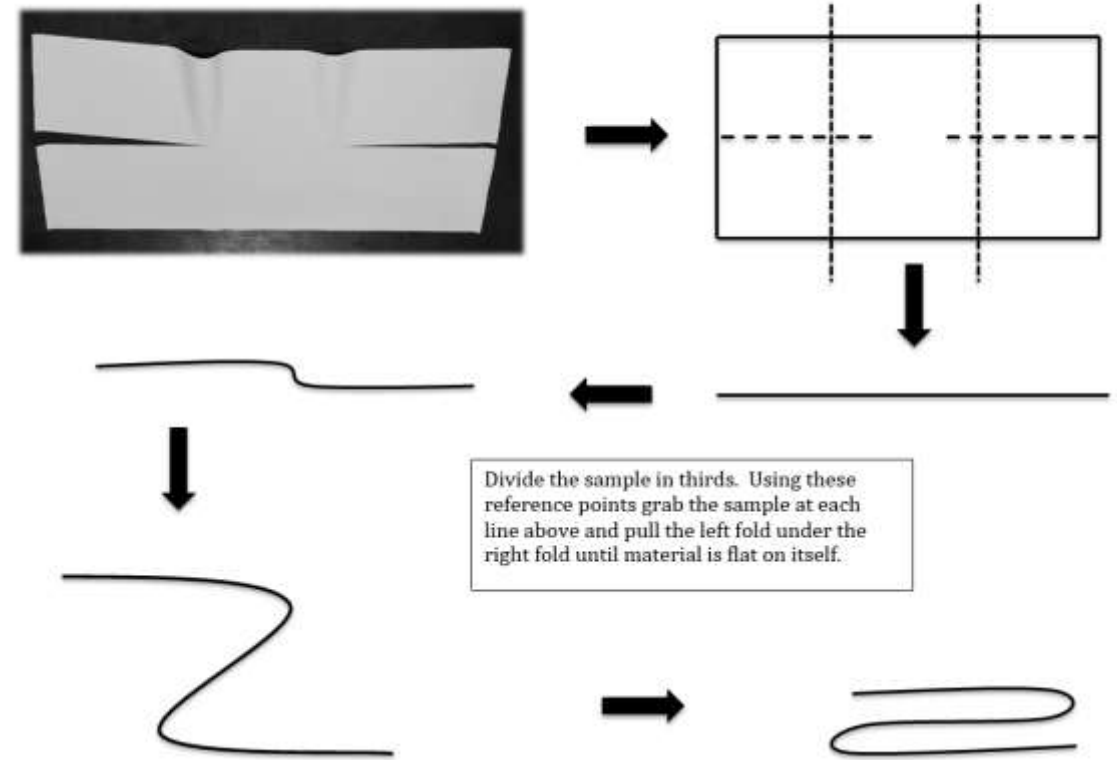


Specific procedures for shipping, handling, and returning specimens and clothing

# Wash Load Assembly

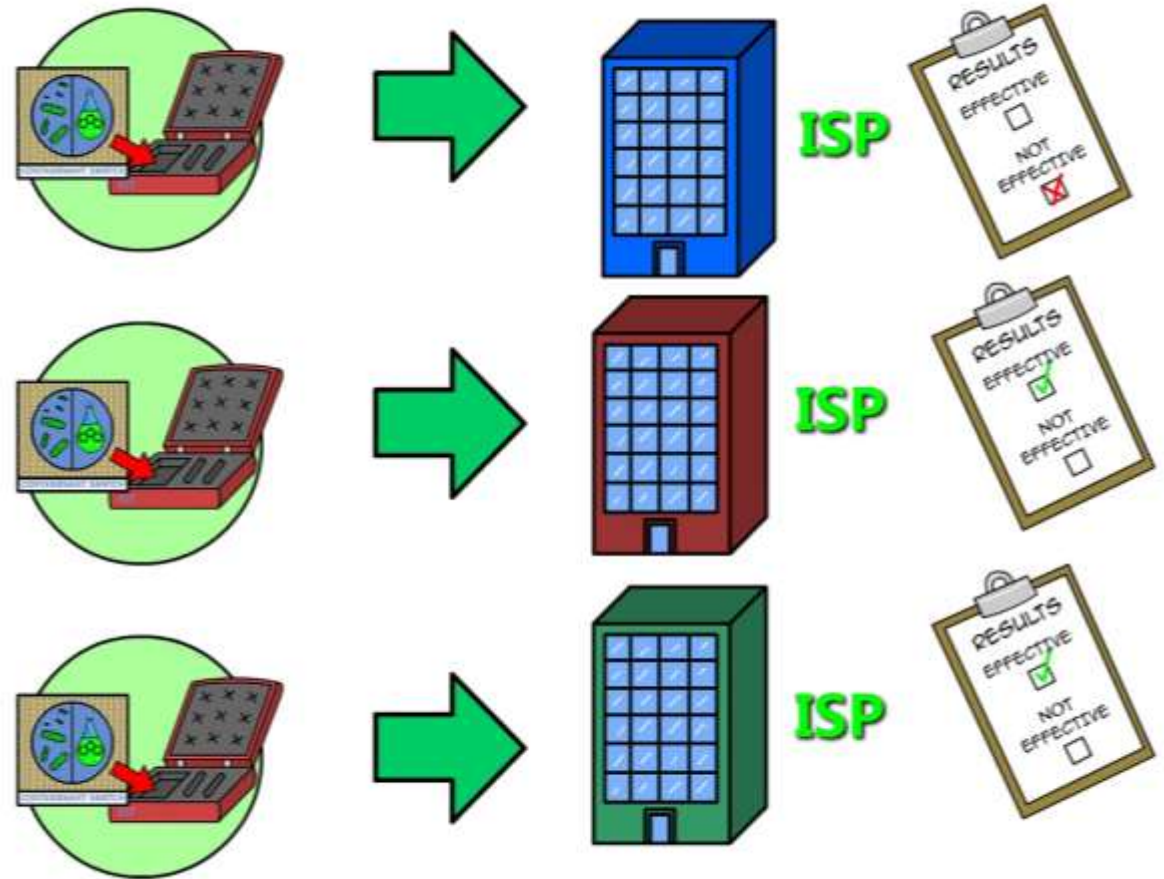


Panel "B"  
Steps for folding and placement in wash load



# Applying Test Results

- Translation of cleaning results into standard requirements
- Key questions
  - Which test results are most important?
  - How should criteria be set as minimum requirements?
  - What organizations should be held accountable?





# Development of Acceptance Criteria

Metal and Chemical Contaminant	Product Class			
	I	II	III	IV
Sb (Antimony)*	30.0	30.0	30.0	
As (Arsenic)*	0.2	1.0	1.0	1.0
Pb (Lead)*	0.2	1.0	1.0	1.0
Cd (Cadmium)*	0.1	0.1	0.1	0.1
Cr (Chromium)*	1.0	2.0	2.0	2.0
Sum of all pesticides (2,4-D, Chlorpyrifos, and Parathion*)	0.5	1.0	1.0	1.0
DEHP*, BBP*, and sum of regulated phthalates	0.1	0.1	0.1	0.1
Benzo[a]pyrene	0.5	1.0	1.0	1.0
Benzo[e]pyrene	0.5	1.0	1.0	1.0
Benzo[a]anthracene	0.5	1.0	1.0	1.0
Chrysene*	0.5	1.0	1.0	1.0
Benzo[b]fluoranthene	0.5	1.0	1.0	1.0
Benzo[j]fluoranthene	0.5	1.0	1.0	1.0
Benzo[k]fluoranthene	0.5	1.0	1.0	1.0
Dibenzo[a,h]anthracene	0.5	1.0	1.0	1.0
Sum of PAHs	5.0	10.0	10.0	10.0

\* Specific target contaminant

- Approaches for setting criteria:
  - Biological: based on EPA registration
    - Sanitize: 99.9%
    - Disinfect: 99.9999%
  - Chemical
    - % by contaminant
    - % by group
    - Other index

**OKEO-TEX Standard 100 for Textile Quality**

# Test Method / Criteria Implementation

- NFPA test methods created
  - Procedures allow labs to use different equipment
- Proposed criteria
  - Biological: Log 3 reduction, two bacteria (*S. Aureus*, *K. pneumoniae*)
  - Metals: 50% reduction (average of all 6 metals)
  - SVOCs: 50% reduction (average over group of chemicals)
- Involves phased-in implementation (minimum of 2 years)
  - Allows industry transition
- Commercial capabilities established

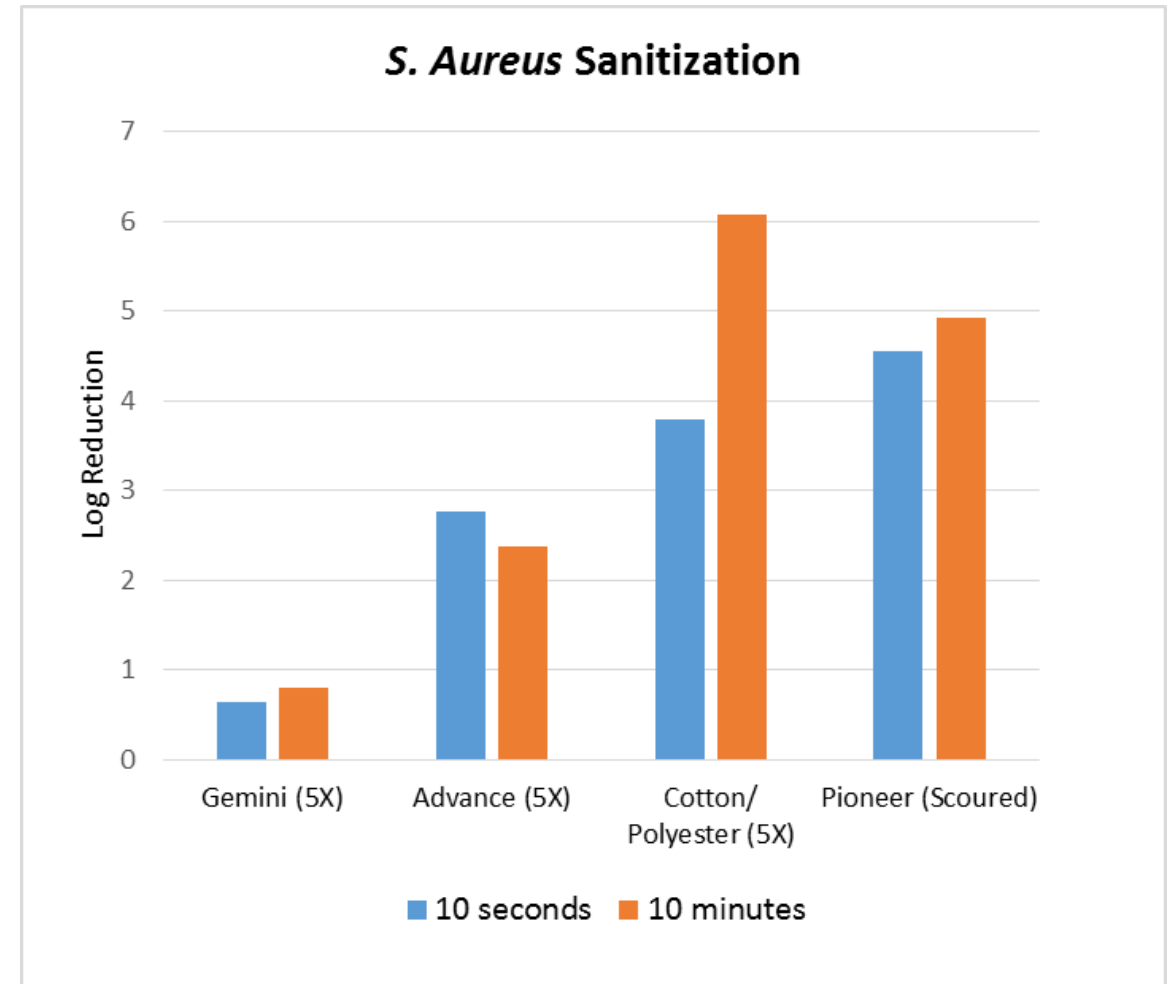
# Validation and Supporting Efforts

- **Part I** – Ensure reliability/reproducibility of kit procedures and ease of use
  - Initial work performed at one ISP
  - Three ISPs involved in final testing
- **Part II** – Establish comparisons with actual contaminated turnout gear
  - Analysis of decontamination efficiency for field-soiled gear
- **Part III** – Compare results between different laboratories



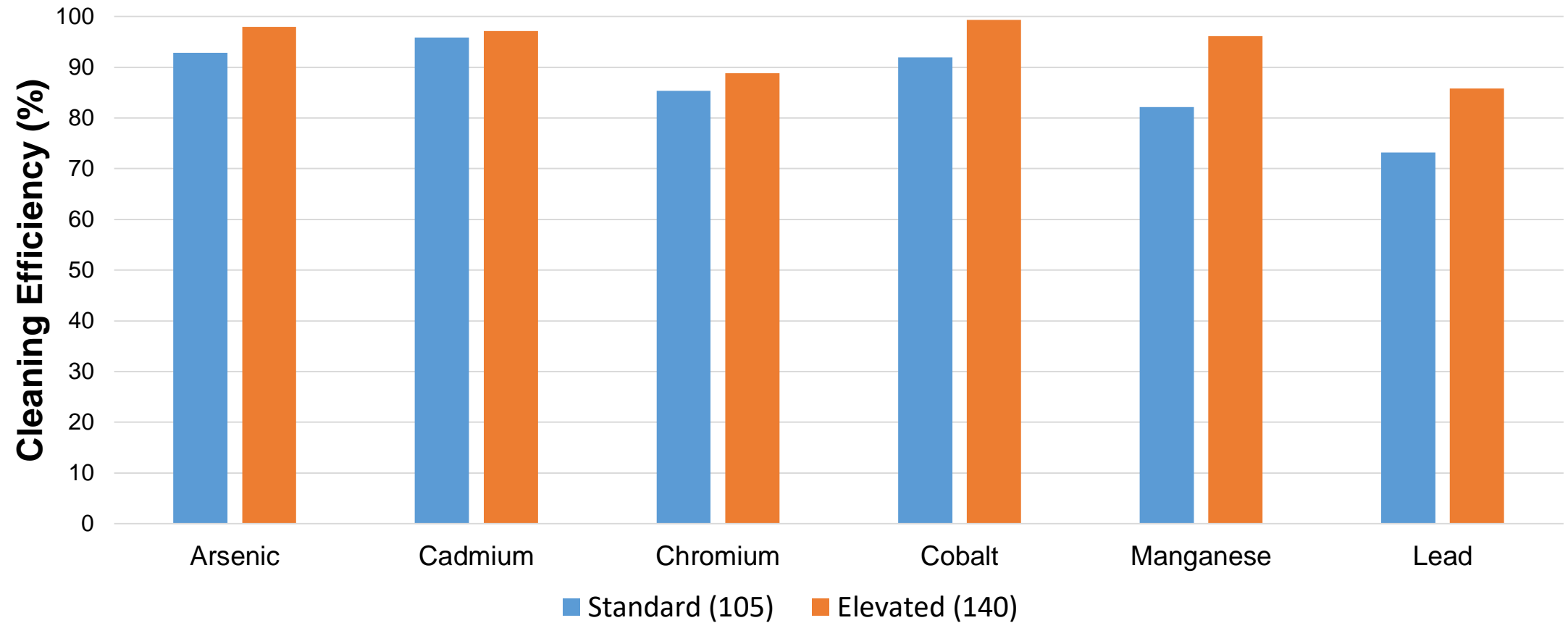
# Evaluation of Biological Contamination

- Initial results showed varying effectiveness of sanitizer on clothing samples on small scale
  - Controlled soak in sanitizer
- Results at one ISP provided log reductions of over 5 for *S. aureus*
- Results for tests at other ISPs confounded by foreign bacteria

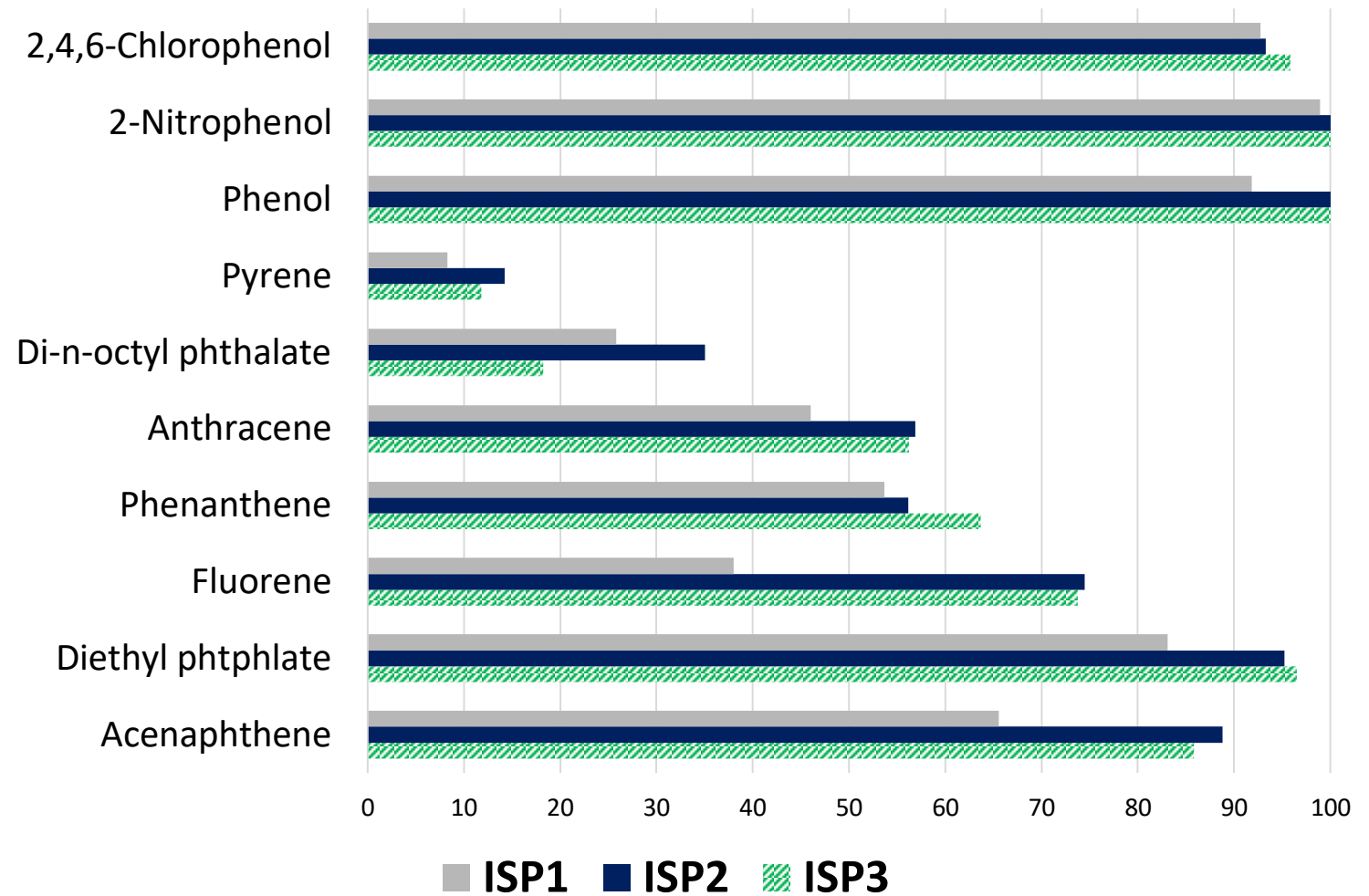




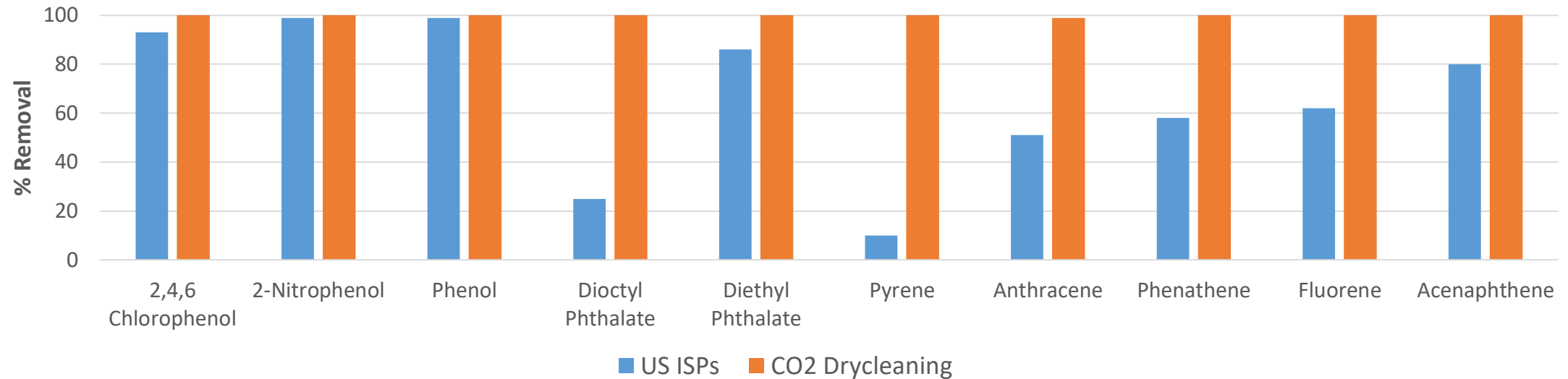
# Effect of Higher Wash Temperatures



**Decontamination  
Efficiency at  
Different ISPs**



# Implementation of Procedures



- U.S. Commercial laboratory set up with test capability
- Significant interest generated by suppliers of new agents, processes
- Work undertaken in Europe to examine unique process

# Accomplishments for the Fire Service

- “Measuring stick” provided to assess cleaning processes
- Cleaning verification of ISPs mandated
- Benchmarks performance established to encourage industry improvements
- Fire service awareness on PPE contamination increased

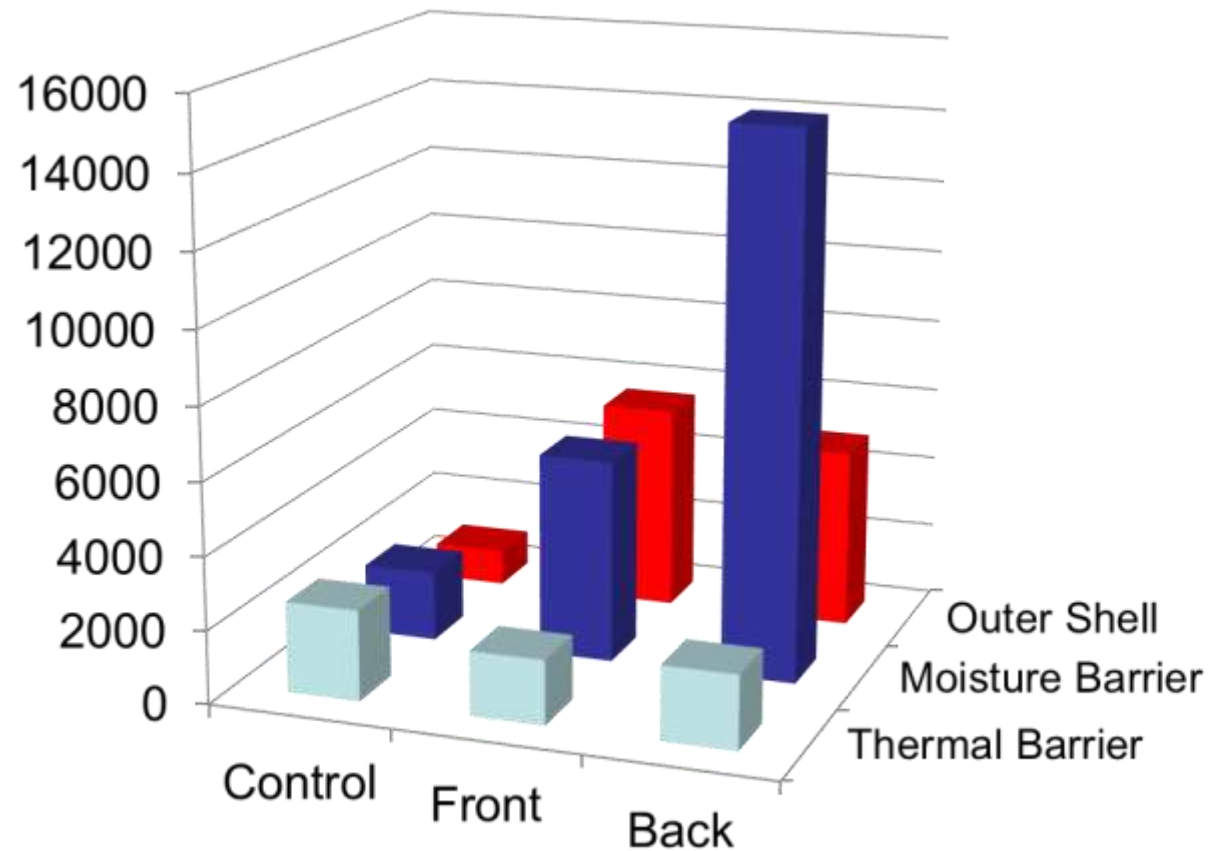


**Fire Department Cleaning Facility**



# Layer by Layer Garment Contamination

Total Petrochemical Hydrocarbons

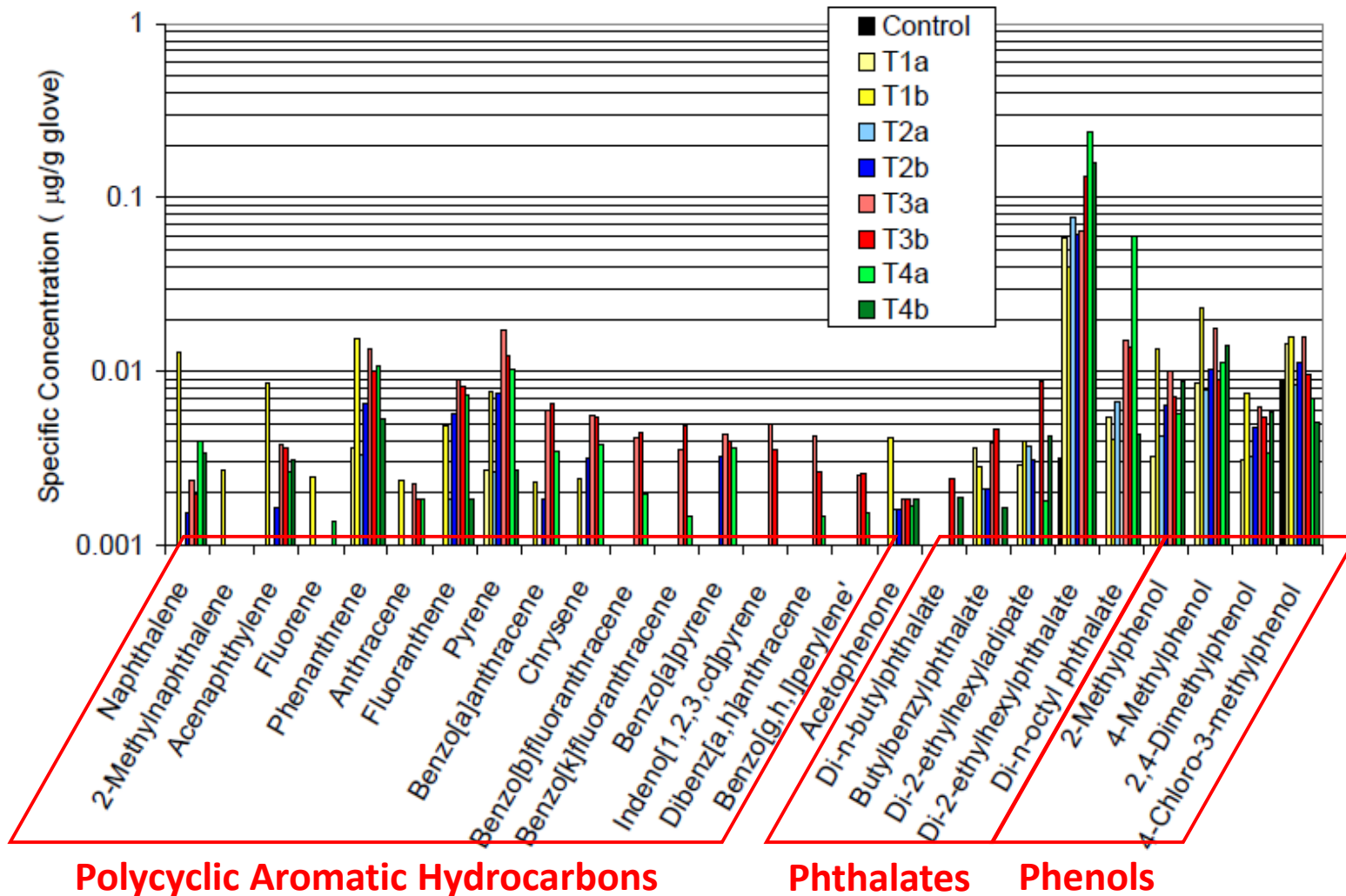


Interior side of garment outer shell



Moisture barrier side of liner

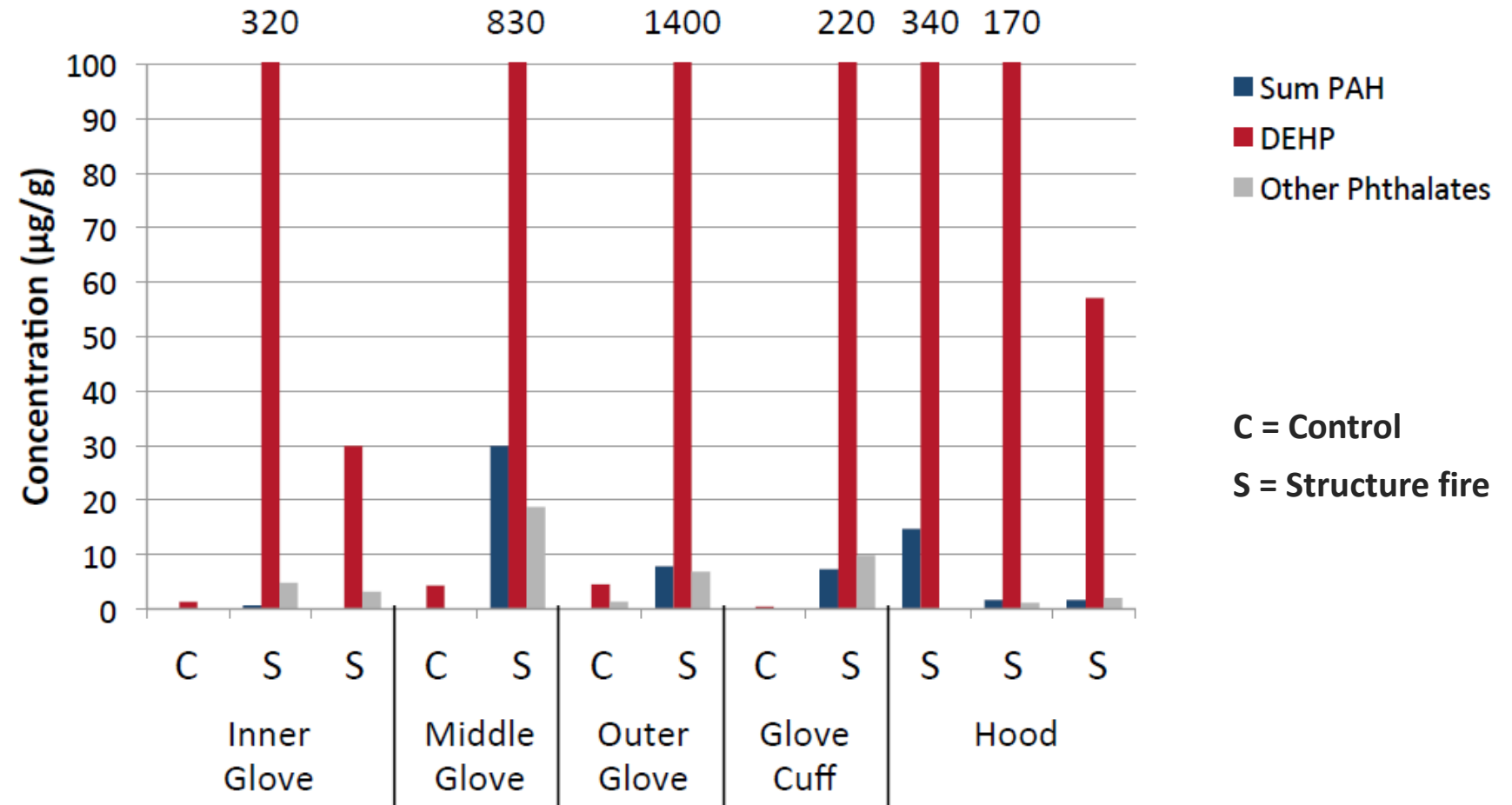
# Earlier DHS-Sponsored Research



- 2007 DHS grant to UL on contamination
  - Analyzed firefighter hoods and gloves for specific chemicals
    - PAHs
    - Phthalates
    - Phenols
  - Showed significantly high levels in gloves
    - 1000x higher in heavy metals

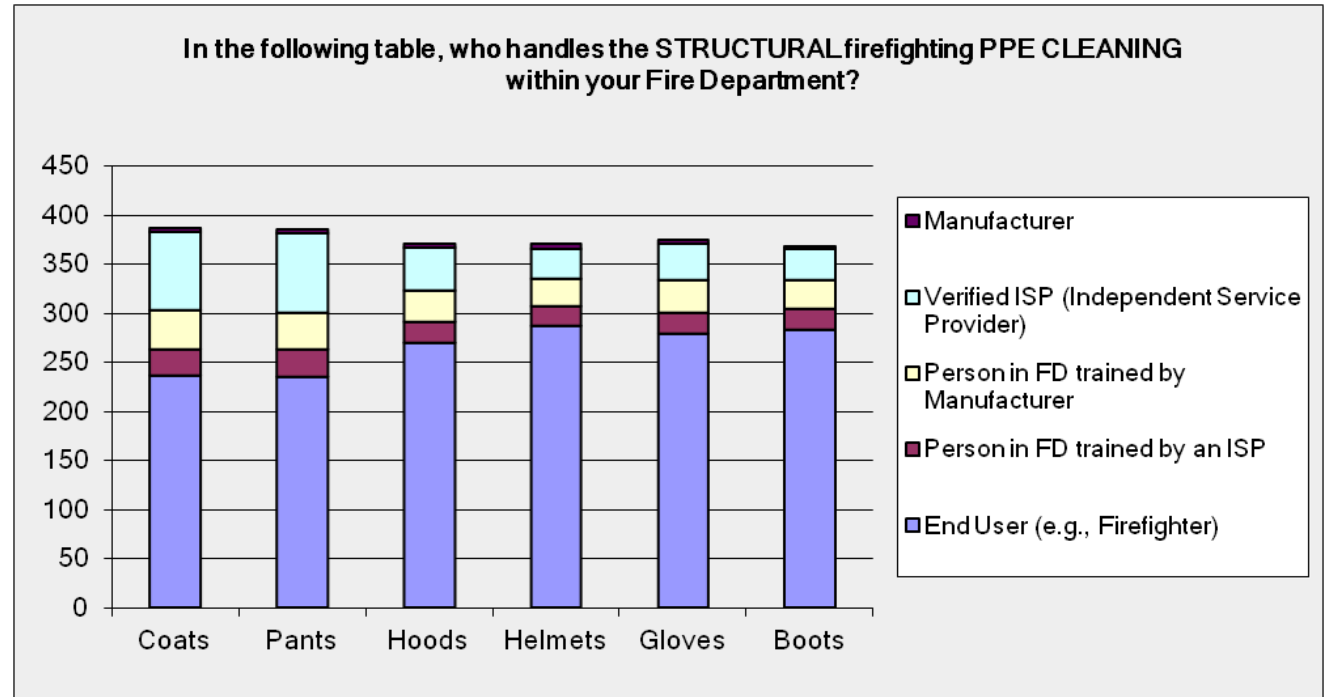
# Separate Research on Plasticizers

- Baxter & Alexander, JOEH, 2014
- DEHP levels 50-800 times higher than PAHs



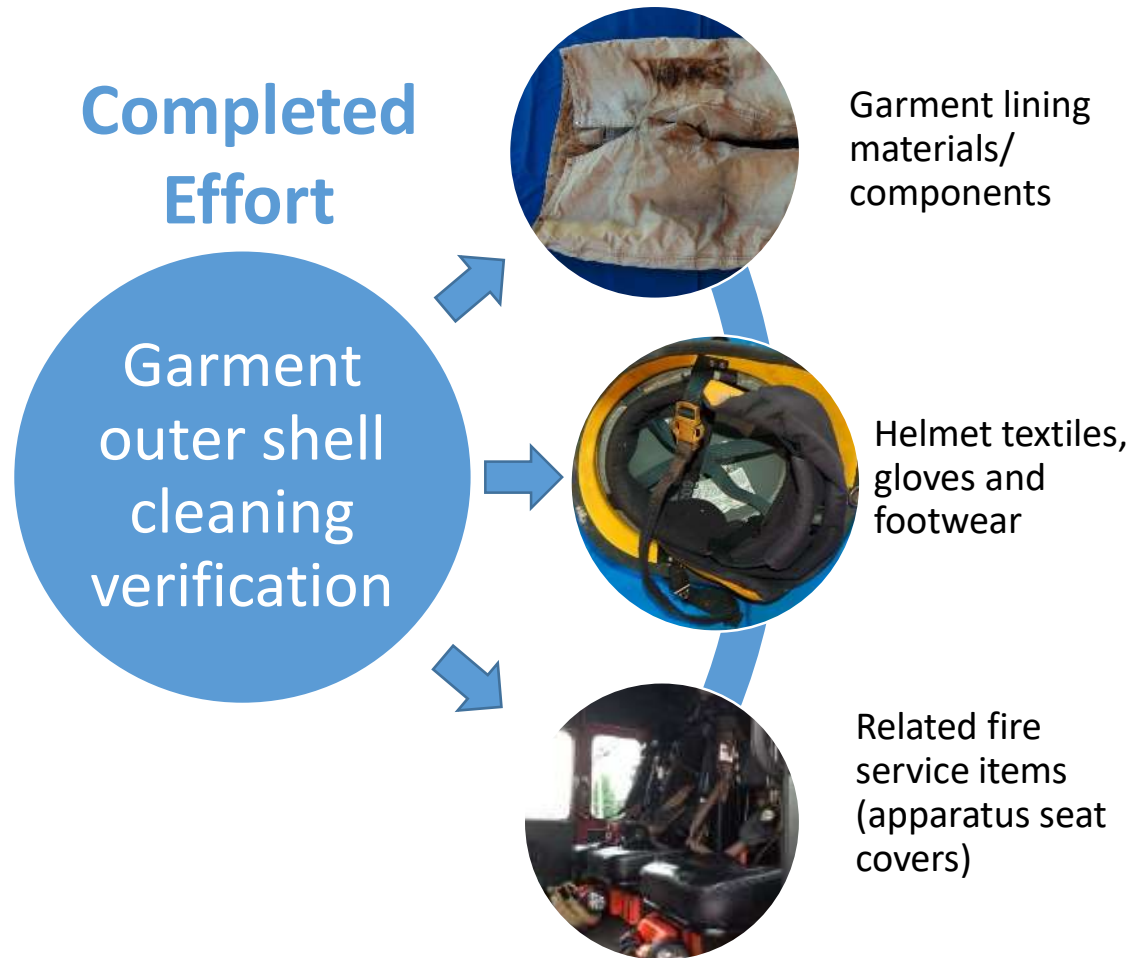
## Prior FPRF Assessment of PPE Cleaning

- 2013 survey to line and staff firefighters
- 1148 respondents
- Multiple questions on cleaning
  - Frequency
  - Where performed
  - Decisions relative to cleaning agent selection





# Existing to New Project Scope



- Examine other garment layers and components for chemical decontamination
- Investigate contamination and cleaning as applied to gloves, footwear, helmets, & SCBA
- Determine if contamination/cleaning assessments can be applied to other items (e.g., tools, seat covers, hose)

# Fundamental New Project Questions/Goal

1. How does contamination vary in different PPE and related items?
2. Are manual cleaning methods effective in removing contamination?
3. What new best practices can be transitioned to fire service?



***Extend cleaning validation procedures to other PPE***

# Specific Technical Challenges

- Current procedures were optimized for water-resistant textiles
  - Other materials (coated fabrics, leather, plastics) expected absorb contamination differently
  - Levels of contamination unknown
- Ability to apply kit-like approach will require significant adaptation of procedures
- Objectives of research likely to change with different items



# Key Research Investigations

PPE/Equipment	Cleaning Effectiveness Issues	
<b>Garments</b>	<ul style="list-style-type: none"> <li>• Detergent ingredients</li> <li>• presoak type and time</li> </ul>	<ul style="list-style-type: none"> <li>• Machine fill levels &amp; number of rinses</li> <li>• Machine cross-contamination</li> </ul>
<b>Helmets</b>	<ul style="list-style-type: none"> <li>• Hard surface vs. textiles</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to clean textiles with garments</li> </ul>
<b>Hoods</b>	<ul style="list-style-type: none"> <li>• Overall wash toleration</li> </ul>	<ul style="list-style-type: none"> <li>• Remaining contaminant levels when washed with garments</li> </ul>
<b>Gloves</b>	<ul style="list-style-type: none"> <li>• Hand vs. machine cleaning</li> <li>• Machine procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Leather vs. fabric construction</li> </ul>
<b>Footwear</b>	<ul style="list-style-type: none"> <li>• Interior contamination levels</li> </ul>	<ul style="list-style-type: none"> <li>• Leather v. rubber construction</li> </ul>
<b>SCBA</b>	<ul style="list-style-type: none"> <li>• Use of ultrasonic cleaning</li> <li>• Ease of textile cleaning</li> </ul>	<ul style="list-style-type: none"> <li>• Contamination accumulation on different SCBA parts</li> </ul>
<b>Apparatus Seats</b>	<ul style="list-style-type: none"> <li>• Cover contamination depth</li> </ul>	<ul style="list-style-type: none"> <li>• Ease of cleaning</li> </ul>

# Further Garment Cleaning Investigation



**Gear Presoaking**

- Map contamination levels through layers and on different components
  - Assess key areas of risk
  - Determine needed process differences
- Look at differences in wash processes
  - Impact of presoak / cycle times
  - Specialized detergents / machine differences
- Examine contaminant transfer in machine and from clothing





# The PFA Topic

## New Fire Service Survey

Priorities and objectives in study  
to broaden cleaning practices  
beyond turnout clothing

Two options to participate

- (1) Scan QR code to access  
survey
- (2) Send email to me at:  
[jeffstull@intlperpro.com](mailto:jeffstull@intlperpro.com)

