Firefighter Turnout Gear SVOC Cleaning Efficiency of CO2-Based Cleaning Process Compared to Traditional Water-Based Cleaning Methods

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Firefighting is dangerous work. In the process of doing their jobs, firefighters are frequently exposed to many hazardous chemicals including metals, volatile organic compounds (VOC), Polycyclic aromatic hydrocarbons (PAH), and other semi volatile organic compounds (SVOC). Many studies have shown that substantial quantities of organic compounds can be found on the turnout gear used by firefighters after responding to a fire emergency. The exposure routes of concern for firefighters are inhalation, dermal and oral routes. These exposures have been proven to lead to a variety of cancers and other illnesses.

Firefighter turnout gear is necessarily complex, as it is designed to protect the firefighter from heat, steam, puncture, and other hazards, yet cool enough to be worn during the hottest of fire events. Turnout gear consists of three (3) distinct layers; an outer layer, moisture barrier, and thermal barrier. Typically, the turnout gear is expensive, costing $2500 or more per set.

Previous studies have shown that after a fire incident there can be substantial quantities of toxic organic compounds deposited on firefighter turnout gear. To evaluate the effectiveness of water-based cleaning methods on firefighter turnout gear, a detailed study was conducted in Finland by the Finnish Institute of Occupational Health. This study evaluated the source of contamination from numerous firefighter events. Key results from this study were:

- PAHs were found throughout the turnout gear in concentrations that exceeded safety standards;
- Substantial VOC and SVOC concentrations were found in the moisture barrier layers of the gear;
- Water washing did a poor job of removing PAHs and was responsible for transferring more contamination on the gear to less contaminated areas.
    - Washing two (2) garments yielded a washing efficiency of 40%;
    - Washing three (3) garments yielded a washing efficiency of 15%.

To address the known accumulations of products of incomplete combustion firefighters are exposed to, recent NFPA guidance recommends frequent advanced cleaning of turnout gear – at least twice per year and/or soon after significant fire events.

The typical cleaning method involves variations of industrial washers, using hot water, industrial detergents, and customized dryers. Because many studies have shown that substantial residuals of hazardous compounds remaining on the turnout equipment after water washing – including the reference cited above, alternative cleaning technologies have been introduced to improve the cleaning and reduce hazardous exposures to firefighters whose use this equipment.

Study Objective

The objective of this study is to measure the cleaning efficiency of CO2-based cleaning to removal of NFPA target SVOCs using test methodologies that follow the NFPA 1851 guidelines. The results of this study can be used by those responsible for firefighter safety to determine the best cleaning options for the firefighter turnout gear. The CO2-based cleaning systems used for these studies was developed and manufactured by CCT and has been used for over 20

years to clean a wide range of textiles and other substrates was used in this study – process schematic shown at right. This system uses an environmentally friendly cleaning solvent used in a wide range of household products to clean the materials followed by a Liquid CO2 (LCO2) wash system. The resulting process provides excellent cleaning performance without damage to the articles cleaned. At the conclusion of the CO2+ process typically 40 – 70 minutes in duration, the contents are removed – with no additional drying required.

Test Methods

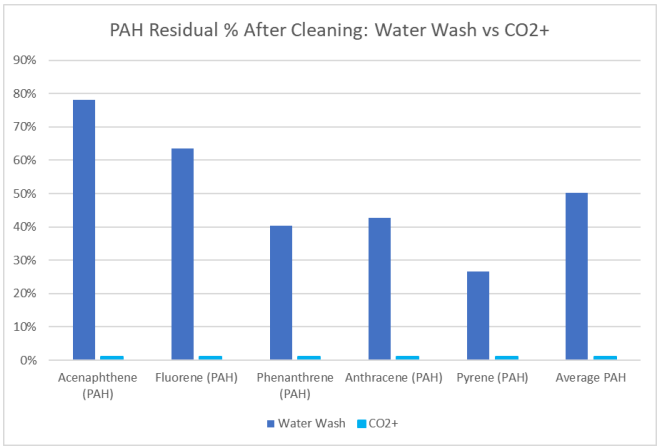
The analytical part of this test is governed entirely by the NFPA 1851 method. The method identifies a list of ten (10) target SVOC contaminants of interest. The NFPA 1851 standard details the analytical test method to be used to collect and analyze each chemical, how each test swatch is doped (quantity and concentration of each chemical), how the test swatches are to be stored, and how they are analyzed and reported. The chemical / analytical results were generated by Legend Technical Services of St. Paul, MN. The analytical test results for this study are presented below for each cleaning system evaluated. The analytical testing and analysis are specified and detailed in the NFPA 1851 Standard. The standard details not only the chemicals to examine, but also the specific analytical testing methods to be used for NFPA-1851 compliant test methodologies. The results following will provide a systematic method to compare the SVOC cleaning effectiveness of various cleaning technologies and their ultimate value to the firefighter and those charged with their health and safety.

Test Results

The results from the NFPA Water Wash Tests for SVOCs presented below show the average cleaning efficiency was 66%, but ranged from a low of only 9% Di-n-octyl phthalate to 100% for 2,4,6-Trichlorophenol, 2-Nitrophenol and Phenol, the most volatile compounds of the SVOCs tested. However, the SVOC results for the CO2-based cleaning system show samples cleaned generated 'Non-Detect' for all SVOCs tests. Hence the cleaning efficiency was 100% for all SVOCs tested.

NFPA SVOC Cleaning Efficiency		
SVOC	Water Wash	CO2+
Phenol	100%	100%
2-Nitrophenol	100%	100%
2,4,6-Trichlorophenol	100%	100%
Acenaphthene (PAH)	78%	100%
Fluorene (PAH)	63%	100%
Diethyl phthalate	90%	100%
Phenanthrene (PAH)	40%	100%
Anthracene (PAH)	43%	100%
Pyrene (PAH)	27%	100%
Di-n-octyl phthalate	9%	100%
Average SVOC	66%	100%

An examination of the SVOC results show that the phenol groups are efficiently removed by both the Water Wash and CO2+ process. However, the polycyclic aromatic hydrocarbons (PAHs) show substantial residues remaining on the test swatches after Water Wash – 50% on average of the applied PAH remaining on the test swatch, as shown in the figure below. These results are significant as the PAH compounds are the most hazardous SVOCs on the NFPA list. The implication of the results is that the CO2+ cleaning processes removed specified NFPA specified SVOCs, and in particular PAHs, to a non-detect level in all cases, demonstrating the superiority of the CO2+ process in removing hazardous SVOCs.



Summary

This report summarizes a test program which evaluates two different cleaning systems and their efficiency on removing hazardous compounds from firefighter turnout gear. The methodology used to generate these results follows the NFPA 1851 standard. Using these standards, results presented herein show that the industry standard water wash system testing left behind about 50% of the applied PAHs on the test swatches. These results support those of others which demonstrate that CO2 cleaning systems tested show superior SVOC cleaning efficiency relative to the industry standard water wash system.

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