NIOSH NPPTL Contributions for Advancing Firefighter PPE

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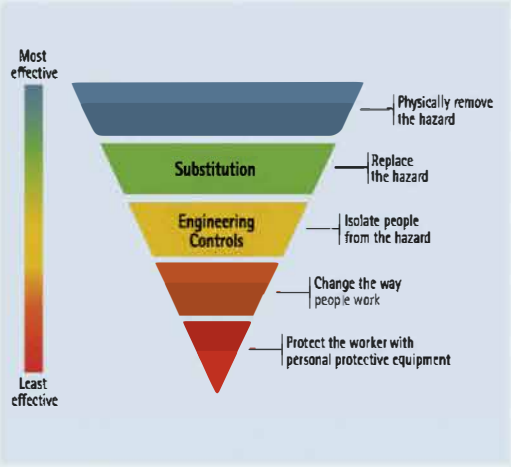
The fireground represents a dynamic work environment where operations and conditions change constantly. The National Institute for Occupational Safety and Health (NIOSH) hierarchy of controls[1] provides an approach that can be taken to control and lower worker exposures and reduce the risk of illness or injury in the workplace (see Figure D1). Although PPE can be viewed as the last line of defense because it is at the bottom of this list of controls, for the firefighter, the design and function of PPE remain critical to the safety of the wearer. Turnout gear, designed to provide the wearer protection not only from the fire itself but also against water penetration, chemical penetration, and thermal hazards, serves as important PPE for firefighters. Proper fit, care, and maintenance—including cleaning—play vital roles in maintaining these protections.

In recent years, the NIOSH National Personal Protective Technology Laboratory (NPPTL) has carried out extensive research on the cleaning of structural firefighter turnout gear and wildland gear. Specifically, NPPTL collaborated with the Fire Protection Research Foundation (FPRF) and International Personnel Protection, Inc. (IPP) on a series of FEMA-funded "How Clean Is Clean?" projects to develop laboratory certification testing procedures and minimum cleaning standards for the outer shells of turnout gear. Two outside laboratories currently use these methods to certify ISPs throughout the United States and Canada with more than 60 ISPs certified. NIOSH continues to participate in this research to develop additional certification testing methods for turnout gear multi-layered quilted thermal liners, moisture barriers within turnout gear and gloves, loose-knit hoods, and gloves. The FPRF plans to add decontamination methods developed for these types of PPE to those currently used by laboratories to certify ISPs to clean these items. All information will be included in reports that will soon be available on the FPRF Web page.[2]

Figure D1. Hierarchy of Controls



Source: NIOSH/CDC.

Through experimentation, NIOSH attempted several methods to contaminate and extract semi-volatile organic compounds (SVOCs) from leather gloves to better understand the process necessary for decontamination. Unfortunately, the chemicals applied to the surfaces of these gloves migrated deep into the leather and were retained. NIOSH tried several approaches to remove the contaminants with various solvents but could not develop a consistently effective approach. NPPTL continues to explore the cleanability of leather gloves, with the results also being information updated on the FPRF Web page.

As part of the FPRF collaborative project to determine cleaning efficiencies, current research by NIOSH includes boots and helmets. Three methods of cleaning will be used: sonication, hand washing, and cleaning in a washer qualified to decontaminate SCBA—which can also be used to clean boots and helmets. The cleaning efficiencies will be calculated, compared, and reported on the FPRF Web page.

The latest collaborative project funded by FEMA through FPRF also includes an exposure assessment project. This project aims to predict exposures by event type to result in better recommendations for decontamination strategies after the event. For this project, swatches from a "scoured" (i.e., all coatings removed) outer shell textile are used, with the swatches cut and a grommet inserted into the fabric. Individual swatches are placed in a paper pouch to minimize contamination during transport, with the pouch, a carabiner, and a self-addressed stamped return envelope placed in a manila envelope, making up a "sampling kit." Firefighters wear the swatch for one fire event in an area of their choosing (with the drag loop or SCBA strap suggested). After the event, firefighters remove the carabiner (which can be kept or discarded), insert the swatch back into the paper pouch, and check a box on the outside to indicate the type of event for which the swatch was worn (i.e., household structure fire, commercial building fire, vehicle fire, wildland or wildland-urban interface event, etc.). The pouch can then be placed in the envelope and placed in the U.S. mail. After being returned to the laboratory, swatches are extracted and analyzed to determine SVOC content. The data from each swatch and the type of event where worn are entered into data visualization software that will show patterns between contaminants and fire types.

In addition to the collaborative efforts outlined above with FEMA and FPRF, NIOSH NPPTL is also engaged in or has completed several fire service-related projects designed to inform standards develop-

Table D1. Contaminant Removal Efficiencies by Chemical, Temperature, and Pretreatment Per NFPA 1851-2020 Procedures

WATER TEMPERATURE	DIMETHYL PHTHALATE	2,4,6-TRICHLOROPHENOL	2,4,5-TRICHLOROPHENOL	PHENANTHRENE	DI-N-OCTYL PHTHALATE	PYRENE	CHRYSENE	BENZO(A) PYRENE
All Cold	96	89	84	51	41	19	18	13
105°F	96	91	87	46	38	31	18	12
125°F	96	97	95	61	45	38	26	10
140°F	96	98	95	82	47	58	20	32
105°F Soak	96	98	95	65	50	48	35	34
125°F Soak	96	98	95	77	55	55	45	34
140°F Soak	96	98	95	84	60	63	57	46
MDL%	96%	98%	95%	95%	92%	95%	95%	85%

MDL: Method Detection Limit. *Source: NIOSH/CDC.*

ment organizations (SDOs) such as the NFPA when a research gap emerges. Four such projects are described below.

First, to determine if NFPA 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*,[3] sufficiently removes chemicals from firefighting gear, NIOSH conducted a study using elevated temperatures and adding a "soak" step using a commercially available degreaser. The current version of the NFPA standard suggests advanced cleaning of gear at a temperature no higher than 105°F using a detergent with a pH between 6.5 and 10 with g-forces not to exceed 100G.[3] Based on the NPPTL study results, the heat map (Table D1) shows that cleaning efficiencies increased with increasing temperature for most chemicals. The addition of a "soak" cycle programmed into the extractor further increased the cleaning efficiencies.[4]

Second, NPPTL received funding from the NIOSH National Occupational Research Agenda (NORA) for a study called the Turnout Gear Lifecycle Project to assess the lifecycle of turnout gear. The project aims to improve confidence that firefighter turnout gear will remain protective throughout its 10-year lifecycle. This will be accomplished by providing evidence-based recommendations to support improvements to existing performance, care, and maintenance standards language. Specifically, this project will obtain turnout gear coats and trousers from multiple regionally dispersed fire departments, estimate the use history from up to 12 months of data obtained from the National Fire Operations Reporting System (NFORS), perform advanced visual inspection according to NFPA 1851 using a newly developed electronic "app based" system to store inspection findings and photographic records, and then conduct performance tests according to select NFPA 1971 test methods. These tests will use a procedure NPPTL developed to retrieve fabric samples from the coat or trouser and evaluate these samples with respect to NFPA's certification requirements, then determine the concentration of organic chemicals trapped within the fabric using advanced analytical chemistry analysis methods. These data will be analyzed, interpreted, and disseminated to the fire service community.

Third, NIOSH is involved in a pioneering project entitled Advancing Equitable PPE Protection for Women Working in Hazardous Environments. This project is informed by data collected from a Federal Register Notice (FRN) in 2021 and feedback from a dedicated PPE equity workshop conducted in 2022.[5] With a focus on female frontline workers across industries such as healthcare, emergency medical services, firefighting, mining, and construction, this project addresses the specific challenges that women face in PPE use, accessibility, acceptability, availability, and knowledge. Through extensive focus groups involving female frontline workers and management and administrative personnel, the project aims to uncover barriers and driving factors for equitable PPE protection for female workers. The results will be used to develop a methodological framework prototype for collecting information related to drivers and barriers to PPE equity. The framework will be validated with and tailored to broader underserved worker populations in the future, ensuring a safer and more inclusive work environment.

Fourth, NPPTL recently completed an effort to determine chemical contamination of wildland gear and effective decontamination and cleaning strategies. NIOSH received wildland shirts worn in various wildfires throughout the United States and analyzed them for contaminants. Polycyclic aromatic hydrocarbons (PAHs) were found to be the main contaminants, most often formed from the burning of wood or other biomass. NPPTL conducted laundering studies to determine if extractor-type laundering was required or whether similar results could be obtained from household-type machines. In addition, NIOSH developed a passive decontamination chamber to transform organic chemicals using ozone into more volatile species that could be released from the textiles into outdoor air. The results from this study will be published soon.

As the above projects demonstrate, NIOSH NPPTL continues its strong commitment to the fire service community by conducting post-market research to ensure that the PPE being used will continue to meet performance requirements and reduce occupational exposures to known or suspected carcinogens.

REFERENCES

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