PPE Cleaning Validation
Verification of Cleaning, Decontamination and Sanitization of Fire Fighter Garments

Supplement A - Annotated Bibliography

Final Report by:

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Foreword

Fire fighter exposure to personal protective equipment (PPE) that is dirty, soiled, and contaminated is an increasing concern for long-term fire fighter health. Cancer and other diseases resulting from chronic exposures has become a leading issue and is presumed to be associated with fireground exposures related to protection/hygiene practices and persistent harmful contamination found in fire fighter PPE.

While general cleaning procedures have been established in NFPA 1851, Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting, there are no requirements that demonstrate whether current cleaning practices will adequately remove contaminants from fire fighter PPE. Many manufacturer gear cleaning recommendations are vague, and most cleaning product/process claims regarding contaminant removal effectiveness are unsubstantiated. Prior studies have identified persistent chemical and biological contaminants in structural firefighting PPE. Therefore, industry methodologies and practices are needed that can promote safe cleaning techniques so that fire fighters are not continually exposed to unclean or inadequately cleaned gear. It also important to set cleanliness criteria for the continued use of fire fighter protective clothing.

This project has established a relevant and credible procedure to validate “how clean is clean?” for fire service contaminated gear, and in doing so has addressed the primary goal of reducing fire fighter exposure to harmful contaminants in PPE. This includes the establishment of a repeatable and reproducible standardized method that can be used to determine the decontamination effectiveness of cleaning methods, the development and publication of needed fire service guidance for maintaining contaminant-free PPE, and verification that cleaning processes do not damage clothing. The project deliverables directly support efforts to update NFPA 1851 and other information that ensures consistent, effective cleaning processes are applied to fire service gear.

This report is part two of a nine-part series on this topic of “PPE Cleaning Validation”, with this part titled “Supplement A - Annotated Bibliography”. The following are all the reports in this series:
1) Master Report
2) Supplement A - Annotated Bibliography
3) Supplement B - Preliminary Work for Assessing PPE Cleaning Procedures
4) Supplement C - Investigation of Simulated Fire Ground Exposures
5) Supplement D - Evaluation of Outer Shell Liquid Retention Properties
7) Supplement F - Report of Heavy Metals Contamination, Extraction, and Analysis Procedures
8) Supplement G - Report of Biological Contamination, Extraction, and Analysis Procedures
9) Supplement H - Evaluation of Microbial Cleanliness of Selected ISP Advanced Cleaning Procedures
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The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

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Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission.

All NFPA codes and standards can be viewed online for free.

NFPA’s membership totals more than 65,000 individuals around the world.

Keywords: PPE, Personal Protective Equipment, Fire Service, Fire Fighter, Contamination, Cleaning, Validation, Verification, Garments, Gear.

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Project Manager: Casey Grant, Sreenivasan Ranganathan
ANOTATED BIBLIOGRAPHY FOR FIRE FIGHTER PPE CLEANING VALIDATION

**Format:** citation abbreviation, full APA citation, keywords, summary/summarized abstract. Some citations provided keywords which are retained, and additional keywords added as appropriate. Summaries are provided when the citation did not include an abstract. Author-provided abstracts were adapted into shorter, summarized abstracts. These include some portions of abstract used verbatim along with other portions edited or simplified for length reduction.


   **Keywords:** firefighter, occupational exposure, live fire training, PAHs, polycyclic aromatic hydrocarbons, protective clothing, deposits

   **Summarized Abstract:** This study examined the surface load in benzo[a]pyrene (BaP) on the outer surface of fire coats, personal protective equipment, and tools used by firefighters after a live fire training in a closed environment. BaP is a carcinogenic polycyclic aromatic hydrocarbon (PAH). Standard coat washing procedures for BaP contamination was assessed in this study. One training session resulted in BaP deposit of $113.75 \pm 45.03 \mu g/m^2$ on exposed fire coat material, while deposits on other PPE surfaces and tools ranged from 12 to 157 $\mu g/m^2$. After multiple training sessions, a cumulative effect became apparent. Current PPE cleaning and maintenance procedures do not seem to effectively reduce BaP contamination. To determine appropriate contamination prevention measures and improve maintenance procedures, further studies of individual French firefighters’ exposure are needed.


   **Keywords:** dermal exposure, wipes, SCBA, hoods, gloves, turnout, polycyclic aromatic hydrocarbons, PAHs, phthalates, di-(2-ethylhexyl) phthalate, DEHP, cancer

   **Summarized Abstract:** Firefighters are at risk for several cancers which may result from chemical exposure during firefighting. Wipe samples from the inside of firefighter self-contained breathing apparatus (SCBA) facepieces, and swatches from unused and used firefighter hoods, gloves, and one coat were used to characterize chemical contamination on firefighter PPE. Wipe samples and swatches were extracted with methylene chloride and analyzed by EPA method 8270 in order to find the presence of semivolatile contaminants including 6 phthalates and 20 polycyclic aromatic hydrocarbons (PAHs). For the facepieces, low levels of di-(2-ethylhexyl) Phthalate (DEHP) were consistently measured; the swatches from the used PPE showed a wide array of PAH and phthalate contamination. DEHP is linked to heart disease, cancer, and reproductive disorders, and its contamination levels were from 52 to 875 times higher than the highest level of PAH. Dermal exposure to the firefighter could be mitigated by immediate showering following fireground exposure.

**Keywords:** Di-(2-ethylhexyl) phthalate, DEHP, firefighters, exposures, phthalates, polycyclic aromatic hydrocarbons, EPA test method 8270

**Summarized Abstract:** The goal of this study was to assess the chemical exposure to firefighters by characterizing semi-volatile chemical contamination on firefighter personal protective equipment. Samples from used firefighter PPE (gloves, hoods, and one coat wristlet) were extracted with methylene chloride and analyzed by EPA method 8270 for contaminants including 20 polycyclic aromatic hydrocarbons (PAHs) and 6 phthalate diesters. Twenty-two of the chemicals of interest were found on at least one sample; plasticizer di-(2-ethylhexyl) phthalate (DEHP), a probable carcinogen, was the only one found on every sample. DEHP levels were also the highest concentration of any chemical as it was measured to be from 52 to 875 times higher than highest level of any PAH. The findings of this study suggest that firefighters are exposed to significantly higher levels of DEHP than PAHs (the most studied semivolatile combustion product in history).


**Keywords:** Exposures, flame retardants, firefighters, PBDEs

**Summarized Abstract:** Cardiovascular disease and certain cancers in firefighters may be related to exposure to hazardous substances from their personal protective equipment and direct exposure at fire scenes. This study investigated flame retardant contamination on firefighter PPE to assess exposure of firefighters to these chemicals. Samples from used and unused PPE (gloves, hoods, and a coat wristlet) were extracted with methylene chloride and analyzed by EPA method 8270D Specific Ion Method (SIM) for polybrominated diphenyl ethers (PBDEs) which used to be some of the most common flame-retardant chemicals used in the US. Fifteen out of the seventeen PBDEs of interest were found on at least one clothing sample. Every sample carried a detectable concentration of at least one PBDE. The results of this study suggest that firefighters are exposed to PBDE flame retardants at higher levels than the general public.


**Keywords:** cancer, firefighters, high reliability organizations, occupational health, qualitative methodology

**Summarized Abstract:** Although recent epidemiological research on firefighters indicates an increased incidence of specific types of cancer, little is known about how firefighters perceive their cancer risk. Participant observation (150 h, n = 100) and focus group (n = 17) data were collected
from 15 fire stations in South Florida. With a median age of 51 years, firefighters had at least 3 years of experience and the ranks included drivers, lieutenants, and specialty captains. Two major categories (direct and indirect factors) for cancer risks emerged from the qualitative analysis. These factors were based on participant notions of cancer risks and cancer prevention behaviors as they pertain to firefighting. Firefighters perceive these cancer risks as a direct result of completing essential occupational duties, and as indirect factors stemming from being a firefighter. The fact there are two categories of cancer risks implies there are different points of entry for intervention.


**Summarized Abstract:** Firefighting is one of the most dangerous occupations in terms of exposures and their proximity to occupational disaster and yet it continues to be the least studied occupation. Firefighter exposures are complex as they come with mixtures of particles and chemicals such polycyclic aromatic hydrocarbons (PAHs); as a result, firefighters face adverse health effects such as elevated risk of coronary disease and several cancers. PAHs have been detected at areas that firefighters spend most of their time including fire scenes, firehouse kitchens and rest areas, and truck bays. A partnership with the Cincinnati Fire Department was developed in aims to understand active firefighters’ airborne and dermal PAH exposures. PAHs from air and particulates were measured for number and mass concentrations of submicron (0.02–1 μm) and PM2.5 (2.5 μm diameter and less) particles during overhaul events of two firehouses and a University of Cincinnati administrative facility for comparison. Face and neck wipe samples were also collected at a domestic fire scene. Firefighters commonly remove Self-Contained Breathing Apparatus (SCBA) during overhaul to evaluate partially combusted material for re-ignition after fire extinguishment. Overhaul air samples had higher PAH concentrations than those from the firehouse, particularly the truck bay and kitchen. 17 PAHs were analyzed and only naphthalene and acenaphthylene were typically detectable. Naphthalene was detected in 7 out of 8 overhaul events, 2 out of 3 firehouse samples, and was not detected in the control site. A greater number of PAHs were found from the neck and face wipes, several of which exhibit carcinogenic activity such as benzofluoranthene which is was also found in overhaul air samples. The concentrations of naphthalene and all other individual PAHs were low; however, the culminating effect of exposure to multiple chemicals, even in small amounts, in combination with ultrafine particle exposure needs further study. It is recommended that SCBA be utilized for the entirety of the overhaul process.


**Keywords:** bioassay, PAH, firefighters, aryl hydrocarbon receptor, CALUX®
**Summarized Abstract:** Determining the effectiveness of intervention techniques to reduce firefighter exposures to toxins entails identifying new ways to monitor and assess exposure. This study assessed firefighters’ exposure to toxins by extracting dermal wipes and urine samples from before and after a controlled fire, and then analyzing the samples with the use of the polycyclic aromatic hydrocarbon (PAH) CALUX® bioassay. Post-fire neck and calf samples displayed an increased bioassay response, indicating a greater concentration of PAHs on the skin. The use of a baby wipe on the face and neck during rehab attenuated the bioassay response. Although the bioassay response and hydroxylated PAH concentrations found in the urine correlated, the increased bioassay response from post-fire urine samples was likely caused by unknown compounds. The results of this study suggest that bioassay provides an effective measure of firefighter exposure, particularly relating to the potential toxicity of contaminants.


**Keywords:** characterization of hazards during fire overhaul, fire overhaul, fire overhaul contaminants, recommended respiratory protection

**Summarized Abstract:** A comprehensive air monitoring study was conducted to characterize City of Phoenix firefighter exposures during the overhaul phase of 25 structure fires. Personal samples were collected for aldehydes; benzene; toluene; ethyl benzene; xylene; hydrochloric acid; polynuclear aromatic hydrocarbons (PNA); respirable dust; and hydrogen cyanide (HCN). Gas analyzers were employed to continuously monitor carbon monoxide (CO), HCN, nitrogen dioxide (NO₂), and sulfur dioxide (SO₂). Area samples were collected for asbestos, metals (Cd, Cr, Pb), and total dust. During overhaul, published ceiling values were exceeded for acrolein at 1 fire, CO at five fires, formaldehyde at 22 fires, and glutaraldehyde at five fires. Published short-term exposure limit values were exceeded for benzene at two fires, NO₂ at two fires, and SO₂ at five fires. On an additive effect basis, PNA concentrations exceeded the NIOSH-recommended exposure limits for coal tar pitch volatiles at two fires. Maximum concentrations of other sampled substances were below their respective permissible exposure limits. Initial 10-min average CO concentrations did not predict concentrations of other products of combustion. Findings support the use of respiratory protection during overhaul and that CO should not be used as an indicator gas for other contaminants.


**Keywords:** Environmental contamination, MRSA, VRE, Hydrogen peroxide vapour

**Summarized Abstract:** Meticillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE) can survive for days to weeks on environmental surfaces in healthcare facilities. These surfaces that are in patient rooms are frequently touched by healthcare staff and are commonly contaminated with MRSA or VRE. Several studies have shown that healthcare workers may contaminate their hands or gloves by touching these surfaces, and the workers can
then further transmit these organisms to patients. Additionally, pathogens can be directly transmitted via this route. There is growing evidence that suggests that cleaning and/or disinfection of these surfaces can mitigate transmission. Because routine cleaning of equipment and frequently touched surfaces does not always remove pathogens, improved disinfection methods are required. Preliminary studies indicate that hydrogen peroxide vapor merits continued evaluation.


**Summarized Abstract:** Exposure to combustion byproducts can cause detrimental health effects for firefighters. Members of the Buffalo Fire Department were monitored during firefighting operations with personal, portable, ambient environmental devices to assess firefighter exposures. The findings suggest that firefighters are regularly exposed to significant concentration levels of hazardous chemicals such as carbon monoxide, benzene, sulphur dioxide, hydrogen cyanide, aldehydes, hydrogen chloride, dichlorofluoromethane, and particulates. The worst exposures were most often found when respiratory protective equipment was not used. Many of these chemicals are associated cardiovascular, respiratory, and neoplastic diseases, which correlates to alleged increased risk for these illnesses for firefighters.


**Keywords:** microbial transfer, chlorine, quaternary ammonium, phenolic disinfectant, self-service laundry, wash temperature

**Summarized Abstract:** This study investigated the potential of microbial transfer in self-service laundry machines by collecting swab samples from the interior surfaces from four commercial machines and additionally water wash samples before and after disinfection treatment. Three disinfectants were used: chlorine, a quaternary ammonium product, and a phenolic product. The washers were set on a warmwater which had a range of 24 to 51°C. The quaternary product was the most the effective with an average 97% microbial kill rate, while the chlorine and the phenolic averaged 58% and 25% respectively. Chlorine and phenolic disinfectants were less effective at lower water temperatures which is common in self-service laundries. Use of disinfectants is recommended in order to avoid the interfamily cross-contamination in self-service facilities.


**Keywords:**

**Summarized Abstract:** Healthcare workers’ (HCWs) uniforms may become contaminated with bacteria during use, which can potentially contribute to hospital-acquired infections. Antimicrobial uniforms are currently used to mitigate this risk. The goal of this study is to compare the extent of
bacterial contamination of uniforms and skin when HCWs wear antimicrobial scrubs versus standard scrubs. This was carried out by a randomized and controlled investigation in a university-affiliated public safety net hospital with physicians, nurse practitioners, physician assistants, housekeeping staff and nurses (total N=105) all working on internal medicine units. Bacteria cultures were taken from staff wearing either standard or antimicrobial scrubs after an 8-hour workday. No evidence was found that determined either antimicrobial or standard scrubs deceased contamination of HCWs’ uniforms or skin after an 8-hour workday.


Keywords: kin, fabrics, microbiome, domestic, washing machine

Summarized Abstract: While household washing machines (WMs) launder clothes and textiles, they do not sterilize. This study investigated the microbe transfer in five household WM by obtaining samples from a new cotton T-shirt that was laundered with a normal laundry load. The influent water, ingoing cotton samples, greywater, and the washed cotton samples were all analyzed. The number of bacteria for WM effluent water was similar to the influent water. The WMs caused a microbial exchange of influent water bacteria, skin-related and clothes-related bacteria, and biofilm related bacteria within the WM. Biofilm-producing bacteria had a low presence in the cotton samples, however, they were enriched in the effluent water post-laundering. Almost all bacteria that was detected on the initial cotton samples survived the laundering process and were detected on the washed cotton samples. Further, malodour-causing microbes can be further distributed to other clothes. The bacteria profile of the pre-laundered textiles plays a large role in the microbiome of textiles after they have been laundered.


Keywords: contamination, firefighting, PAHs, personal protective equipment, volatile organic compounds, washing, water-only decontamination

Summarized Abstract: Firefighters conduct cleaning procedures on-scene procedures applied to the surface of firefighter turnout gear to remove hazardous chemicals including polycyclic aromatic hydrocarbons (PAHs). These procedures at the local level include using soap and water, and sometimes just water alone as it requires less time and supplies. The efficacy of these methods in removing PAHs was investigated by measuring PAH concentration levels before and after a water only decontamination, an efficiency was calculated by relating the PAH percentage of the pre-decontamination sample to that of the post-decontamination. The samples were taken from turnout gear that was used in live residential structure fires through the attack, overhaul, search and rescue, and rescue from fire operations. Water-only decontamination methods appeared to not be effective with an overall 42% increase in PAH contamination. However, it should be noted that
the unexpected increase may have been due to disparate pre- and post-decontamination sampling sites on turnout gear.


**Keywords:** Biological Monitoring, Biomarkers, 1-HYDROXYPRENE, Muconic Acid, Benzene, Polycyclic Aromatic Hydrocarbons, Firefighter

**Summarized Abstract:** Firefighters are potentially exposed to a wide range of toxic combustion and pyrolysis byproducts including benzene, carbon monoxide, acrolein, nitrogen dioxide, and polycyclic aromatic hydrocarbons. Urinary measurements of 1-hydroxypyrene and t,t -muconic acid were used to assess PAH and benzene exposures respectively. Urine samples were taken from 43 firefighters during a twenty-hour long time period following the end of exposure from a fire. Control samples were taken these firefighters after at least four days after firefighting activity. 0.32 w mol/mol creatinine is considered the 95th percentile of a normal reference population and only one control 1-hydroxypoyrene measurement exceeded this value; 38% of maximum values from all samples following exposure exceeded the reference value. None of the control t,t -muconic acid samples exceeded the limit of detection, and only 19% of post-fire samples exceeded this limit. Only six participants had concentrations exceeding 1.1 mmol/mol creatinine which is a value considered to correspond to a benzene-air concentration of 1ppm. The findings of this study suggest that firefighting activities are associated with exposure to PAHs despite the use of PPE; however, PAH exposures were relatively low compared with observations made in other studies of industrial workers. Benzene exposures were also low in this study. Low observations of both contaminants could be caused by efficiency of PPE or low contaminant concentrations during firefighting.


**Summary:** The Centers for Disease Control and Prevention (CDC) has estimated that each year in the US, at least two million illnesses and 23,000 deaths are caused by antibiotic resistant bacteria. If antibiotic effectiveness continues to dwindle, there will no longer be reliable treatments for bacterial infections. This risk will also cause surgeries, transplants, chemotherapy, and other advanced medical practices to no longer be viable due to the threat of infection. The *National Strategy for Combating Antibiotic Resistant Bacteria* aims to identify the appropriate priorities and coordinate investments to prevent, detect, and control outbreaks of antibiotic resistant bacteria such as Enterobacteriaceae (CRE), methicillin-resistant Staphylococcus aureus (MRSA), ceftriaxone-resistant Neisseria gonorrhoeae, and Clostridium difficile. The *National Strategy* lists five goals for this effort: (i) slow the emergence and prevent the spread of resistant bacteria, (ii) bolster National One Health surveillance efforts, (iii) advance development and use of rapid and
innovative tests, (iv) accelerate research and development for new antibiotics, therapeutics, and vaccines, (v) improve international collaboration.


**Keywords:** decontamination, aqueous cleaning, dry cleaning, forced ventilation, cross-contamination, cancer risk, thermal shock

**Summary:** Past studies of fire fighter contaminant exposures and cancer risks are outlined, and fire-related volatile, nonvolatile, and semi-volatile contaminants are described along with European regulations. Advantages and disadvantages are discussed for four aqueous-based processes, four dry cleaning processes, and the “thermal shock” method (forced ventilation at 42 C for 24 hours). Turnout construction to minimize cross-contamination is described. Recommended actions to reduce exposure risk are discussed.


**Summarized Abstract:** During polymicrobial infections, microbes often show synergistic interactions that can improve their colonization, virulence, and/or persistence. *Pseudomonas aeruginosa* and *Staphylococcus aureus* are the two most common causes of one of the most prevalent polymicrobial infections which occurs in chronic wounds. Despite their prevalence, little is understood about their interspecies relationship. *P. aeruginosa–S. aureus* coinfections are more virulent than infections of just one of these bacteria, however, growing these two pathogens in vitro have shown difficulties in understanding the mechanisms involved with these coinfections. This study aims to understand this coinfection better through an in vitro wound model that allows for both pathogens to grow. Antibiotic resistance was increased when the pathogens grew together in planktonic cultures, and it was further enhanced when they were grown in the wound model. This improved ability is credited to “host-derived” and “bacterium-derived” matrix components


**Keywords:** metals, cadmium, lead, mercury manganese, defluorinated chemicals, perfluorodecanoic acid, whole blood, serum, NHANES, National Health and Nutrition Examination Survey

**Summarized Abstract:** California firefighters’ blood concentrations of selected chemicals was assessed and compared with a representative US population. Samples for 101 Southern California firefighters were analyzed for cadmium, lead, mercury, and manganese in whole blood and 12 serum perfluorinated chemicals. The blood metal concentrations of the firefighters were similar to or lower than the National Health and Nutrition Examination Survey (NHANES) except for 6 participants whose mercury concentrations approached or exceeded the NHANES reporting threshold of 10 μg/L. This firefighter group had perfluorodecanoic acid concentrations that were
three times higher than the NHANES adult males; firefighters may have unknown sources of occupational exposure to perfluorinated chemicals.

**Keywords:** Bacterial Adhesion, Biofilms, Pseudomonas aeruginosa, Staphylococcus epidermidis

**Summarized Abstract:** Almost all bacteria survive through the process of surface adhesion and biofilm development, a strategy that has been refined for over millions of years. This process anchors the microorganism to nutritious environments and allows them to retreat to other environments when essential growth factors have been depleted. There are three major phases of bacterial attachment: primary and reversible, secondary and irreversible, and biofilm formation. One or more gene products control these phases. The mature bacterial biofilm contains pyramidal or mushroom-shaped microcolonies of organisms embedded in an extracellular glycocalyx that also contains channels for the transfer of nutrients and waste. This biofilm protects the inhabitants and regulates population growth and diversity through primitive cell signals. Surface bound bacteria behave significantly differently from their planktonic counterparts; this suggests that antimicrobial susceptibility tests using pure cultures and in a planktonic growth mode are questionable.


**Keywords:** contaminant, firefighter, risk assessment, turnout gear, soil, metals, arsenic, benzo(a)pyrene, PBDE-99, phthalate plasticizers, polybrominated diphenyl ether flame retardants, permeation coefficient

**Summarized Abstract:** The composition of soils on firefighter turnout gear was identified and dermal exposure risks associated with the soils were assessed by analyzing nine used Nomex hoods from the Philadelphia Fire Department for the presence of trace metals and seven sets of used turnout gear for semi-volatile organics. Samples were taken from the collar, armpit, wrist, and crotch areas of turnout gear where dermal absorption levels are known to be high. In these samples polycyclic aromatic hydrocarbon (PAH), phthalate plasticizers, and polybrominated diphenyl ether flame retardants (PBDEs) were detected. To assess dermal exposure risk, measured concentrations were converted to an estimated dermally-absorbed dose based on estimates for the permeation coefficient (Kp) and an assumed firefighting exposure scenario. Based on carcinogenic effects, benzo(a)pyrene had the highest dermal exposure risk, and for non-carcinogenic effects, PBDE-99 showed the highest dermal exposure risk. For metals, arsenic exhibited the highest dermal exposure risk in hoods.

**Summarized Abstract:** The goal of this study is to determine the prevalence and duration of methicillin-resistant *Staphylococcus aureus* (MRSA) carriage among hospital staff and the transmission from them to their respective households. This was accomplished through a point-prevalence survey (nasal swab) for MRSA of both staff and patients at a 600-bed, public tertiary care teaching hospital in France. Additionally, a MRSA prevalence survey to estimate duration in two medical wards where carriers were observed; and transmission of MRSA was assessed. Out of 965 subjects, sixty of them were identified as MRSA carriers (prevalence, 6.2%; CL, 4.7%-7.7%). Prevalence was more significant among staff in clinical wards (9.0% vs 2.1%; \(P < .0001\)). Isolate identity from staff and patients ranged from 25% in the wards to 100% in the long-term care facility. Fourteen employees and two medical ward staff were identified as MRSA carriers (prevalence, 19.4%; CIss, 10.3%-28.5%). Length of service is a factor in prevalence. Ten MRSA-positive employees’ families were investigated for transmission and MRSA was detected in four; all isolates from these families were identical. Transmission between patients and workers likely is dependent on both frequency and duration and exposure to MRSA-positive and the degree of infection control.


**Keywords:** firefighter, overhaul, products of combustion, gases, smoke, smoke particulate, inhalation, size distribution, polycyclic aromatic hydrocarbons, PAHs, metals, respiratory protection

**Summarized Abstract:** As part of a larger smoke exposure study, a study was conducted on firefighter inhalation exposure. Teams of the Chicago Fire Department were issued monitoring equipment for exposure conditions during knockdown, overhaul, and search and rescue operations. Six chemicals of interest—carbon monoxide (CO), hydrogen sulfide (H\(_2\)S), sulfur dioxide (SO\(_2\)), ammonia (NH\(_3\)), nitrogen dioxide (NO\(_2\)) and hydrogen cyanide (HCN)—were measured with direct-reading gas meters that used electrochemical sensors. The personal cascade impactors collected size-segregated particles. These particles were then analyzed by inductively coupled plasma-mass spectroscopy (ICP-MS) for smoke particle weight distribution and inorganic element content. Gloves and hoods were regularly collected for chemical evaluation of accumulated combustion residue. ICP-MS was used on the gloves and hoods for inorganic element content. Cold vapor atomic absorption spectroscopy (CVAAS) was used to analyze mercury; gas chromatography-mass spectroscopy was used to analyze polycyclic aromatic hydrocarbons (PAHs) and other organic compounds. PAHs and other organic compounds by gas chromatography-mass spectroscopy (GC-MS). Findings indicated firefighter exposure to smoke particles, especially in the submicron size range, toxic gas concentrations that exceeded NIOSH published IDLH (Immediately Dangerous to Life or Health) and STEL (Short Term Exposure Limit) levels, and known or suspected carcinogenic chemical species.

**Keywords:** building material combustion, residential structure fire, automobile fire, real-scale fire test, Chicago Fire Department, personal gas monitoring, personal aerosol smoke sampling, particulates, heavy metals

**Summary:** This study investigated the resultant combustion gases and particulates from three scales of fires which includes automobile fires, simulated real-scale fire tests, and material based small-scale fire tests. The material level tests studied the following: combustion of forty-three commonly used residential building, residential room contents and furnishings, and automobile components that were under consistent radiant heating conditions. UL’s large-scale fire test laboratory conducted nine real-scale fire tests representing individual room fires, an attic fire, deck fires, and automobile fires in order to collect and analyze the gas effluents, smoke particulates, and condensed residues that result from fire growth, suppression, and overhaul. Over four months, personal aerosol smoke samples at residential fires (knockdown, ventilation and overhaul) were collected. During this period replaceable firefighter PPE (gloves and hoods) were analyzed to characterize the chemical composition of the accumulated smoke residue. This data was sent to the University of Cincinnati College of Medicine to assess the health risk associated with the gaseous effluents and smoke particulates on fire service personnel. From the material-level testing it was observed that the type and quantity of combustion products depended on the chemistry and physical form of the burning material; synthetic materials resulted in more smoke than natural materials. These toxins were confirmed by the large-scale testing which suggests that the gases generated in large scale fires arise from the individual component material contributions. Combustion generates asphyxiants, irritants, and airborne carcinogenic species that can be debilitating when combined with other gases. Additionally, smoke and gas production had an inverse relationship with ventilation; higher levels of smoke particulates and gases were observed in contained fires and higher levels of gas and particulates were observed inside structure fires rather than outside. Certain toxic gases were monitored at field events and gas exposure in excess of NIOSH IDLH (Immediately Dangerous to Life or Health), STEL (Short Term Exposure Limit), and OSHA TWA (Time Weighted Average) were repeatedly observed. Carbon monoxide (CO) was most commonly observed exceeding exposure limits, although there were instances where other gases exceeded limits when CO did not. Collected particulates contained several heavy metals including arsenic, cobalt, chromium, lead, and phosphorus. Smoke deposition and accumulated soot showed virtually the same chemical concentrations on gloves and hoods; however, glove concentrations were 100 times greater than the hoods. Health implications were also considered and discussed.


**Keywords:** firefighting, MRSA, MSSA, contact transmission, sanitizer, biofilm, didecyl dimethyl ammonium chloride

**Summarized Abstract:** Methicillin-resistant *Staphylococcus aureus* contamination on turnout coats may be from an indirect transmission source; proper disinfection is essential to reduce the risk of exposure to fire fighters. The disinfection of gear washed in commercial washer/extractors was assessed by first inoculating swatches of turnout outer shell fabrics (Gemini™, Advance™, and Pioneer™) with *S. aureus*, and then washing with an Environmental Protection Agency (EPA)-registered sanitizer commonly used to wash turnout gear. Inoculated swatches were washed in small tubes according to the American Society for Testing Materials (ASTM) E2274 Protocol for evaluating laundry sanitizers. Inoculated swatches were also pinned to turnout gear coats and washed in a Milnor commercial washer/extractor. Viable *S. aureus* that remained attached to fabric swatches after washing were recovered and quantified. Disinfection in small tubes for only 10 s reduced the viability of *S. aureus* on Gemini™, Advance™, and Pioneer™ by 73, 99, and 100%, respectively. However, disinfection of *S. aureus*-contaminated Gemini™ swatches pinned to turnout gear and washed in the washer/extractor was 99.7% effective. Scanning Electron Microscopy showed that biofilm formation begins as early as 5 hours after attachment of *S. aureus*. This sanitizer (and, likely, others containing the anti-microbial agent didecyl dimethyl ammonium chloride) was an effective disinfectant of *S. aureus*. Inclusion of contaminated outer shell swatches in the wash cycle afforded a simple and quantitative method to assess sanitization of gear by commercial gear cleaning facilities. This methodology can be extended to assess for other bacterial contaminants.


**Keywords:** workplace program, cancer risk reduction, best practices, fire fighter culture, cleaning, decontamination, cross-contamination

**Summary:** The FDNY Contamination Reduction Workgroup report summarizes dangers of fireground contaminants and describes current and evolving practical policies and procedures whose implementation reduces firefighter cancer risk. FDNY’s participation in studies related to understanding firefighter health is described. Practical and cultural barriers to implementing risk reduction factors are addressed. The document ends with a “Reduce Your Risk” pledge that encompasses practices such as cleaning and decontaminating gear.


**Keywords:** contaminants, decontamination, evaporation, firefighters, PAHs, turnout gear
The contamination of firefighters’ turnout gear and skin was characterized after controlled residential fire responses. This was done using polycyclic hydrocarbons (PAHs) and volatile organic compounds (VOCs) as respective markers for non-volatile and volatile substances. Wipe samples were taken pre- and post-fire from the exterior of the turnout gear as well as some gear after field decontamination. VOCs off-gassing from gear were also measured pre- and post-fire and after decontamination. Wipe samples were also taken off of firefighters’ hands and neck pre- and post-fire and after cleaning neck skin. PAH levels on turnout gear were increased with each operation. Firefighters that were assigned to fire attack and search and rescue operations recorded the highest PAH levels on their turnout gear. Field decontamination by scrubbing with dish soap and water resulted in an 85% percent median decrease in contamination. However, off-gassing VOC levels increased post-fire and then decreased 17-36 minutes later regardless of field decontamination. Post-fire median PAH levels on the neck were near or below the limit of detection for all positions. The 75th percentile values for firefighters assigned to attack, search and rescue, and outside ventilation were 152, 71.7, and 39.3 μg/m², respectively. Firefighters had higher post-fire median hand contamination during attack and search and rescue (135 and 226 μg/m², respectively).


Keywords: controlled structure burns, airborne polycyclic aromatic hydrocarbons, PAHs, breath, urine, dermal, wipe sampling, volatile organic compounds, VOCs, benzene, SCBA

Summary: A study of controlled structure burns at a fire service training facility investigated the ability of airborne polycyclic aromatic hydrocarbons (PAHs) and other aromatic hydrocarbons generated during live fire training to contaminate and pass through the skin of fire fighters. Breath and urine samples were obtained before and after each burn. Breath samples were analyzed for aromatic hydrocarbons and the urine samples for PAH breakdown products. Wipe samples on fire fighters’ skin were used to measure PAH contamination before and after each burn. Breath samples were analyzed for aromatic hydrocarbons and the urine samples for PAH breakdown products. Wipe samples on fire fighters’ skin were used to measure PAH contamination before and after each burn. VOCs released from turnout gear were measured before and after each burn. Possible cancer-causing PAHs and VOCs were found in air, with some PAH air levels were above occupational exposure limits during overhaul. While all VOC air levels were below occupational exposure limits during overhaul, some VOCs were released from the fire fighters’ gear after the fire response. The PAH levels on fire fighters’ necks were higher right after the burns than before; PAHs were not found on other areas of fire fighters’ skin. Levels of benzene in fire fighters’ breath were higher right after the burns than before. However, fire fighters did not have elevated levels of benzene breakdown products in their urine. In the first round of the study, levels of PAH breakdown products were higher in urine samples collected 3 hours after the burns than in samples collected before the burns. The levels of PAHs and benzene in fire fighters’ bodies were similar to levels in occupational groups with low exposures to these compounds. Because fire fighters wore properly working SCBA, the PAHs and benzene likely entered their bodies through their skin. Recommendations included wearing full
protective ensembles during all stages of a fire response and washing hands and showering soon afterwards.


**Keywords:** firefighters, HCN, overhaul, PAHs, particulate, VOCs

**Summarized Abstract:** During 12 controlled residential fires, area air measurements were collected from the structure during active fire and overhaul and on the fireground where personnel were operating without any respiratory protection. Personal air measurements were taken from firefighters assigned to fire attack, victim search, overhaul, outside ventilation, and command/pump operator operations. There were two different tactics for fire attack, six interior and six transitional, and the exposures were compared between the two. For the twelve fires, firefighters were paired up to complete the operations except for overhaul which was completed by four firefighters. From the samples, detected compounds included polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs, e.g., benzene), hydrogen cyanide (HCN), and particulate (area air sampling only). Attack and search and rescue generally exhibited median personal air concentrations that were well above applicable occupational exposure limits except for HCN measured from search and rescue. All area air concentrations of the measured compounds decreased after suppression. Personal air concentrations of total PAHs and benzene exceeded exposure limits for some overhaul firefighters. For outside ventilation firefighters, median personal air concentrations of HCN (16,300 ppb) exceeded exposure limits, and maximum levels (72,900 ppb) were higher than the immediately dangerous to life and health (IDLH) level. Fireground median air concentrations (including particle count) were above background level and was highest when collected downwind of the structure and when ground-level smoke was the heaviest. The results highlight the importance of wearing self-contained breathing apparatus (SCBA) when performing overhaul or outside ventilation operations. Furthermore, it is recommended that firefighters should try to establish command upwind of the structure fire, if not possible, respiratory protections should be considered.


**Keywords:** PBDE, organophosphate flame retardants, brominated dioxins, chlorinated dioxins, air sampling, wipe sampling

**Summarized Abstract:** When modern furnishings are involved, structure fires may emit brominated flame retardants (BFRs), organophosphate flame retardants (OPFRs), and brominated and chlorinated dioxins and furans. This study quantified the contamination of these compounds in the air and on personal protective equipment (PPE) and evaluated gross-decontamination
measures during 12 controlled residential fires in the U.S. Bulk-sampling confirmed that the furnishings contained flame-retardants (FRs). Area air samples were taken during the fires, and wipe samples were taken from turnout coats and gloves after the fire. For each fire, only half of the coats were decontaminated. Of the BFRs and OPFRs that were measured in the air during fires, decabromodiphenyl ether (BDE-209) and triphenyl phosphate (TPP) had the highest levels with medians of 15.6 and 408 µg/m³ respectively; they were also detected during overhaul. These compounds and several other BFRs and OPFRs were detected on PPE. Gloves were typically more contaminated more than jackets, with some gloves having contamination levels over 100 ng/cm². Brominated furan concentrations from the air and surfaces tended to be higher than concentrations of chlorinated dioxins and furans. Routine gross decontamination showed reductions in BFR contaminants but gave mixed results or OPFRs. Firefighters should wear self-contained breathing apparatus (SCBA) during all phases of fire response, they also should launder/decontaminate their PPE (including gloves) after all fire events.


*Keywords*: firefighters, HCN, isocyanates, PAHs, particulates, VOCs, fire training exposure, training fuel, oriented strand board, pallet and straw, simulated smoke

*Summarized Abstract*: Exposure of firefighters and instructors to hazardous airborne chemicals in training fires vary based on the training fuel used. Area and personal air samples were collected during three instructional scenarios each day for five days. The scenarios involved burning two types (designated as alpha and bravo) of oriented strand board (OSB) or pallet and straw, or used simulated smoke. Firefighters participated in each scenario once (separated by roughly 2 days); instructors supervised three training exercises per scenario (completed in one day). During the live fire scenarios, except when simulated smoke was used, personal air samples were analyzed for polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and hydrogen cyanide. For the live fire scenarios, median personal air concentrations of benzene and PAHs exceeded applicable short-term exposure limits and were higher among firefighters than instructors. Regarding fuel type, benzene and PAH concentrations were higher for bravo OSB. For all scenarios, area air samples were analyzed for acid gases, aldehydes, isocyanates, and VOCs. Median air concentrations of aldehydes and isocyanates were highest for bravo OSB; pallet and straw resulted in the highest median concentration of certain VOCs and acid gases. The findings of this study suggest that both instructors and firefighters should use self-contained breathing apparatus (SCBA) during training exercise to reduce potential inhalation exposure.

Keywords: breath, urine, biomarker, occupational exposure, fire, combustion products

Summary: Biological monitoring was conducted during exercises involving combustion of oriented strand board (OSB), pallet and straw, or the use of simulated smoke in order to better understand how fire training contributes to firefighters’ and instructors’ select chemical exposures. Polycyclic aromatic hydrocarbons (PAHs) were tested for by analyzing metabolites in urine. Volatile organic compounds (VOCs) including benzene was tested for by analyzing breath. PAH metabolites median concentrations increased from pre- to 3-hour post-training for each scenario; OSB was the highest which was followed by pallet and straw, and third, simulated smoke. Instructors who supervised three trainings per day exhibited increased median concentrations at each collection with a full day of OSB exercises; which resulted in a 30-fold increase in 1-hydroxypyrene for instructors with a median end-of-shift concentration and 3.5-fold greater than median levels measured from firefighters in a previous controlled-residential fire study. With the exception of simulated smoke training, breath concentrations of benzene increased 2 to 7 times immediately after the training exercise. The OSB scenario resulted in both the highest exposures and PAHs accumulated for instructors completing repeated daily exercises. With the respiratory route well protected, dermal absorption likely contributed to the biological levels. Training academies should consider instructional objectives with exposure risks when planning training exercises.


Keywords: breath, urine, biomarker, firefighter, PAH, benzene

Summarized Abstract: Biological monitoring was performed on firefighters who responded to controlled residential fires to better understand the absorption of combustion byproducts; the results were analyzed by job assignment and fire attack tactic. Polycyclic aromatic hydrocarbons (PAHs) were tested for by analyzing metabolites in urine. Volatile organic compounds (VOCs) including benzene were tested for by analyzing breath. For all job assignments, median concentrations of PAH metabolites in urine increased from pre- to 3-hour post-firefighting. Firefighters performing attack and search had the greatest change with increases in pyrene, phenanthrene, naphthalene, and fluorene metabolites. Attack and search firefighters saw a 2-fold increase median exhaled breath concentration of benzene and outside vent firefighters had a 1.4-fold increase. Interior and transitional attack firefighters exhibited 50% less uptake of pyrene, 36% less uptake phenanthrene, and 20% less uptake of fluorene. Dermal absorption was likely a factor in firefighters’ exposures. Exposure will vary with job assignment and can be mitigated by employing a transitional fire attack when feasible.

Protective Equipment Ensembles after Use. *Journal of Occupational and Environmental Hygiene*, 12 (6), 404–14.10.1080/15459624.2015.1025135

**Summarized Abstract:** Firefighters’ personal protective equipment (PPE) becomes contaminated during firefighting. Some compounds in the contamination can off-gas and can then be potentially inhaled. This study sought to determine the magnitude and composition of inhalation exposure resulting from volatile organic compounds (VOCs) off-gassing during controlled structure fires. During these burns, three teams of five firefighters executed entry, suppression, and overhaul; evacuated canisters were used to sample the air inside the structure during active fire and overhaul. These canisters were also used to measure the air for 15 minutes in clean enclosures used for containing used PPE from two firefighters after each controlled fire. Firefighters’ exhaled breath was also sampled approximately 1 hour before and 4-14 minutes after each fire. The canister samples were analyzed for 64 VOCs and the exhaled breath was analyzed for benzene, toluene, ethylbenzene, xylene, and styrene (BTEXS) using gas chromatography/mass spectroscopy. At least 50% of the samples exhibited off-gassing from PPE for fourteen of the same VOCs. There were >5-fold increases in mean off-gas concentrations styrene, benzene, 1,4-dichlorobenzene, acetone, and cyclohexane compared to background levels. Additionally, several of the off-gassing compounds including benzene, propene, and styrene, were detected above background concentrations during active fire and overhaul. There was a >2-fold increase in mean breath concentrations of benzene, toluene, and styrene after the burns compared to their respective pre-burn levels. BTEXS air concentrations measured off-gassing from used PPE significantly correlated with concentrations of firefighters’ post-fire exhaled breath. BTEXS could be absorbed through both inhalation (off-gassing PPE post-fire) and dermal routes (during firefighting). To mitigate exposure from inhalation, firefighters should be made aware of the potential for this exposure medium when doffing PPE and traveling in confined vehicles with contaminated PPE.


**Summarized Abstract:** This study assessed the exposure of firefighting trainers to polycyclic aromatic hydrocarbons (PAHs) by taking personal air samples. PAH uptake was determined using biological monitoring which measured a metabolite of pyrene, 1-hydroxypyrene, in urine. Benzo(a)pyrene eight-hour time-weighted average concentrations were found to be 0.029 ug/m³ (instructor), 0.045 ug/m³ (safety officer), and 0.16 ug/m³ (fire assistant). Tobacco smoking and exposure to fire smoke were both factors contributing to the increased 1-hydroxypyrene concentrations in fire-fighting trainers. Despite the short time periods of effective exposure and routine use of respirators and protective clothing, there was evidence of PAH uptake among the instructors. The PAH uptake was substantially lower than coke-oven workers (who are known to have increased relative cancer risk), however, long-term health risk for firefighting instructors cannot be ignored. Tracing highly exposed persons and monitoring the effectiveness of control measures can be accomplished by biological monitoring with urinary 1-hydroxypyrene.

**Keywords:** fire, fire service, firefighting, personal protective equipment, PPE, gear, care, maintenance, inspection, cleaning, retirement

**Summary:** A data collection summary of current practices and policies for fire service PPE care and maintenance is provided as background information to help guide standards revisions and support future research addressing cleaning, decontamination, retirement, and related care and maintenance issues. While NFPA 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting* provides requirements for the selection, care, and maintenance of structural and proximity firefighting PPE, it lacks specificity in certain key technical areas. Data collected by this effort is intended to assist with the on-going assessment and revision of these requirements and to provide helpful baseline information to better guide future research. This extensive information collection effort used online survey tools, supported by a brief review of the applicable literature, and a compilation of typical practices within this community. Survey questions targeted distinguishing characteristics of each of the three key stakeholder groups: the fire service, independent service providers (ISPs), and manufacturers.


**Keywords:** heavy metals, cadmium, chromium, copper, lead, bunker gear, structural fire

**Summarized Abstract:** To measure heavy metals (cadmium, chromium, copper, and lead) on the surface of bunker gear following a structure fire, wipe samples were collected from the knee, elbow, and chest areas. Analysis showed varying amounts of cadmium, chromium, copper, and lead in all sample locations following a fire. Some lead concentrations exceeded Environmental Protection Agency (EPA) and Housing and Urban Development (HUD) standards for clearance in residential homes. While there are no surface standards for cadmium, chromium, and copper, if the same levels were found using air monitoring, they could potentially exceed ACGIH (American Conference of Governmental Industrial Hygienists) recommendations and NIOSH standards for an 8-hour time weighted average requiring continuous protection.


**Keywords:** Dermal exposure, phthalates, skin sampling, clothing sampling

**Summarized Abstract:** Clothing can either mitigate or exacerbate dermal exposure to phthalates. The impact of clothing on dermal uptake in real environments was investigated, with these six phthalates of interest: DMP, DEP, DiBP, DnBP, BBzP, DEHP. Two sets of experiments were conducted: skin wipes were taken from eleven adults to measure phthalate levels on bare skin (hand/forehead) and clothing covered skin (arm/back/calf); five adults wore just-washed jeans for
the durations of one day, five days, and ten days. Phthalate levels were measured from their legs on selected days during the wearing period; phthalate levels in the jeans were measured at the end of each experiment and again after washing. Although clothing-covered areas of the skin had lower phthalate levels than areas of bare skin, phthalate levels were still significant. If clothing-covered skin was neglected, dermal uptake estimation would be off by a factor of two to five. Phthalate levels in jeans and on the legs increased with wearing time; however, the levels did not exactly correlate with each other. These findings suggest that other pathways were a contributing factor to phthalate levels on the legs, including contact with bedding and bedclothes. The laundering efficiency in removing phthalates increased with decreasing $K_{ow}$; median values ranged from as low as 5% for DEHP to around 75% for DMP.


Keywords: firefighter, cancer, decontamination, personal protective equipment, health campaign

Summarized Abstract: Recent research has shown that decontamination processes can reduce contamination from carcinogenic volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) on both gear and skin of firefighters. Little is known about firefighters’ current attitudes and behaviors toward decontamination. A survey was conducted on four hundred eighty-five firefighters from four departments, and it revealed positive attitudes, beliefs, and perceived norms about decontamination. However, showering was the only decontamination procedure that occurred regularly; field decontamination involving the use of wipes, routine gear cleaning, and other behaviors all occurred less frequently. Firefighters reported time and wet gear as the major barrier to decontamination.


Keywords: hydrocyanic acid, polycyclic aromatic hydrocarbon, benzo(a)pyrene, skin absorption, washing, cross-contamination

Summarized Abstract: Despite the fact that a number of studies have shown some cancers among firefighters occur more often than in the rest of the population, a previously performed literature study of what toxic substances in smoke might be absorbed by firefighters established no causal relationship between exposure to toxic substances in smoke and incidences of cancer. This project investigated how to minimize the exposure to toxic substances before, during, and after firefighting activities to minimize the chance of any (later) health damage. The results of the model and literature study demonstrate that inhalation is the most significant absorption route for many of the 32 most common toxic substances in smoke. Skin is a probable route for absorption of hydrocyanic acid and the polycyclic aromatic hydrocarbon (PAH), benzo(a)pyrene, a carcinogen. The increased moisture of the skin under protective turnout clothing reduces the barrier function of the skin. Although the effect of this reduction on the absorption of benzo(a)pyrene has not been investigated, previous research did not show that people with a severely reduced skin barrier
develop more cancer by the absorption of benzo(a)pyrene. Also, a (sub-)study showed that most of the contamination did not pass the middle layer of 3-layer turnout gear; substances toxic to skin were hardly found on the inner layer and therefore not of any danger. However, European Union standards for skin contact with PAHs in new clothing were sometimes exceeded for the middle layer of the tested turnout gear, although that result was mainly attributable to one strongly contaminated turnout suit of a training center. After cleaning the turnout gear, the contamination spread partly over simultaneously washed suits. Larger numbers of suits per wash resulted in more contamination remaining in the turnout gear. A possible approach to prevent the relatively clean inner layer of the turnout gear from being contaminated during the cleaning process might be to clean the dirty outer layers separately from the inner layer. Based on the results of the (sub-)studies and the various occupational hygiene guidelines applied by the Safety Regions in firefighting activities, it was concluded that there is a great awareness within the Netherlands Fire Services regarding the hazards of exposure to smoke.


Keywords: laundry, hygiene, Virucidal efficacy test, Poliovirus

Summarized Abstract: Laundering is one of the essential methods to ensure a sufficient hygiene standard. This study aims to evaluate the performance of this process, in doing so, it is ideal to have methods that mimic real-life situations. Even though there are available methods to evaluate the antibacterial and antifungal efficacy of domestic laundering processes, antiviral efficacy is unclear. A new in situ test method allowing virus simulation tests inside washing machines has been developed as suspension assays cannot simulate in vitro the influence of parameters such as mechanical actions, temperature dynamics, and liquid ratios. With the new method, it was demonstrated that conventional household washing detergents have a full virucidal efficiency at 40°C, additionally they are effective against non-enveloped surrogate viruses.


Keywords: activated oxygen bleach, domestic laundry, laundry hygiene, wash cycle time, washing process, washing temperature.

Summarized Abstract: This study investigated the laundering process with and without activated oxygenated bleach (AOB) and the effects of temperature and duration of the process. Cotton test swatches were contaminated with Staphylococcus aureus, Enterococcus hirae, Pseudomonas aeruginosa, Candida albicans and Trichophyton mentagrophytes and were washed in a household washing machine with temperatures ranging between 20° and 60°C and with a variety of wash cycle times. Hygienic effectiveness of the washing process was determined by the logarithmic microbial reduction factor and cross-contamination (i.e., transfer from contaminated to sterile swatches). For all tested micro-organisms, the appropriate temperature for decontamination was dependent wash duration and detergent type. The inclusion of AOB enhanced the hygiene
effectiveness of laundering at all temperatures, with the exception of C. albicans. Cross-contamination to sterile swatches included in wash load was reduced with the use of AOB-containing detergents and high temperature. The findings of this study suggest that longer wash times and the use of AOB-containing detergents can enhance the hygiene effectiveness for lower temperatures, depending on the organism.


**Keywords:** Personal protective equipment, NFPA standards, Firefighting, Durability, Laundering

**Summarized Abstract:** The US fire service is aware of the importance of cleaning PPE after fires, but there remains a concern that damage from routine cleaning may negatively impact critical protection from fireground risk. This study found that several important protective properties of NFPA 1971-compliant (Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting) turnout gear are significantly altered by using a protocol that included repeated simulated fireground exposure (0-40 cycles) and/or repeated cleaning with common fire service techniques. Tear strength of the outer shell and thermal liner was greatly reduced when laundered as compared with wet or dry decontamination. Greater changes in the outer shell tear strength resulted from coats that used hook & dee clasps rather than zippered closures. All samples that underwent any form of cleaning showed a reduction in Total Heat Loss; gear that was laundered showed in an increase of Thermal Protective Performance. These results suggest that after repeated exposure/cleaning cycles, bunker gear can experience diminished performance of some important protective properties relative to their levels when tested in a new condition. After 40 cycles, the outer shell trap tear strength in the fill direction and the seam strength dropped below NFPA 1971 requirements. The results of this study may be useful for future editions of NFPA 1971 in setting preconditions for the measurement of certain performance properties.


**Keywords:** turnout Gear, firefighter, soils, hazardous materials, Philadelphia

**Summarized Abstract:** Soil on firefighter turnout gear from the Philadelphia Fire Department was characterized and the composition of hazardous materials remaining after cleaning was determined. A pilot study evaluated the test methods used to identify the composition soils by analyzing hoods from the Philadelphia Fire Department. Soils identified in previous studies were targeted. Samples were extracted from the coat and pants in areas that dermal absorption is reported highest including the neck, armpit, crotch, and wrist locations.

**Keywords:** IARC, cancer research candidate agents

**Summary:** An Advisory Group of 29 scientists from 18 countries recommend priorities for the International Agency for Research on Cancer (IARC) Monographs programmed during 2020–24. Included are tables that list cancer research candidate agents with high, low, and medium priority designations along with the rationale for the inclusion of each.


**Keywords:** influenza virus, virus inactivation, contaminated clothes, indirect transmission, viral epidemics

**Summarized Abstract:** This study investigated the role of contaminated clothing in the transmission of influenza A virus during an epidemic period. This was done by examining the recovery of the infectious influenza virus from experimentally virus-contaminated clothing that has been through routine wearing and washing for several months or years. With nine types of clothing, the amount of virus recovered decreased with time, and significantly varied with clothing type when the contaminated clothing was maintained in uncovered glass Petri dishes in a safety cabinet under blowing air. The findings suggest that virus transmissibility is dependent on the nature of the contaminated clothes. Thickness of the clothing material seemed not to influence differences in recovery, however, there was a correlation with the amount of residual amount of water in the deposited virus preparation on the test clothing.


**Keywords:** Quaternary ammonium compound, Staphylococcus aureus, nano scanning electron microscopy.

**Summarized Abstract:** Didecyldimethylammonium chloride (DDAC) is a Quaternary Ammonium Compound (QAC) that is used to disinfect hard surfaces in the poultry industry. DDAC is membrane active agent that operates by disrupting cell membranes to allow the leakage of important intracellular material. When DDAC is applied to Staphylococcus aureus strain ATCC2357, protuberances and bleb formations on cell walls were detected with scanning electron microscopy. These cells were also further analyzed with NanoSAM, which showed morphological changes and structural details on the cells. This technology also demonstrated that a decrease in the elemental intensities, which proves that QAC is effective.

**Keywords:** Ottawa Fire Service, combustion emission exposure, dermal wipe, urine, metabolites, organic mutagens, personal air sampling, PAH, polycyclic aromatic hydrocarbons

**Summarized Abstract:** Occupational exposures to combustion emissions were examined in pre- and post-event urine and dermal wipe samples (i.e., pre- and post-event), personal air samples, and through fire event questionnaires collected from 27 male Ottawa Fire Service (OFS) firefighters. OFS office workers served as controls. Exposure to polycyclic aromatic hydrocarbons (PAHs) and other organic mutagens were characterized by three methods: quantification of PAH metabolite levels in urine, PAH concentration levels in dermal wipes and personal air samples, and urinary mutagenicity using the Salmonella mutagenicity assay (Ames test). Lung injury and overall oxidative stress were assessed by Urinary Clara Cell 16 (CC16) and 15-isoprostane F2t(8-iso-PGF2α) respectively. There were significant increases in average post-event levels of PAH metabolite levels, post-event levels in urinary mutagenicity; Urinary CC16 and 8-iso-PGF2α did not increase. 54% of the variation in fold changes of urinary PAH metabolites were accounted for by PAH concentrations on personal air and on skin. Findings suggest a correlation of emergency on-shift fire suppression and significantly elevated exposures to combustion emissions.


**Keywords:** firefighters, polycyclic aromatic hydrocarbons (PAHs), cadmium, antimony, lead

**Summarized Abstract:** Occupational exposures of Ottawa firefighters to polycyclic aromatic hydrocarbons (PAHs), antimony, cadmium, and lead were assessed using (1) personal air samplers worn by firefighters during emergency fire suppression; (2) wipe samples from skin, personal clothing, and personal protective equipment (PPE) collected before and after emergency firefighting; and (3) air samples collected in three fire stations from vehicle bays, truck cabs, and one administration office. OFS (Ottawa Fire Services) PPE decontamination procedures were assessed using wipe samples collected before and after laundering. Lead and PAH air concentration levels exceeded occupational exposure limits at two and nine fire events, respectively. After fire suppression, concentrations were significantly higher on skin and PPE for PAHs; on skin, clothing, and PPE for antimony; and on skin and PPE for lead. PAH and antimony air concentrations were significantly higher in vehicle bays than the office, but significantly lower than fire truck cabs. Washing PPE removed, on average, 61% of PAHs, 55% of antimony, 97% of lead, and 90% of cadmium. These results indicate that firefighters are significantly exposed, via multiple routes, to combustion by-products during on-shift fire suppression.


**Keywords:** soil removal, firefighting, turnout gear, decontamination, cleaning
Summarized Abstract: Turnout gear from nine fire departments was chemically extracted to characterize type and concentration of soils, and the effectiveness of fire departments' current laundry practices was examined by analyzing samples of the gear after being subjected to routine cleaning methods. It was determined that the practices used by fire departments to remove these soils are not completely effective. Detergent type, wash temperature, and wash time were analyzed using 225 hand-dosed samples. Tide® removed more soil than the three detergents designed to clean turnout gear. Washing was more effective in removing soil when the water temperature was increased by 20° F, and it was shown that a 9-minute wash was more efficient than a 12-minute wash.


Summarized Abstract: The goal of this study was to determine the bacterial profile of both used and unused resident scrubs. Thirty pairs of scrubs were cultured before and after use from on-call residents. Swabs were tested for both aerobic gram-positive and gram-negative bacteria. Pulsed-field gel electrophoresis was used to test bacteria for antimicrobial resistance and genetic relatedness. 123 (41%) of unworn scrub samples contained bacteria, while 268 (89%) of used scrubs contained bacteria. Coagulase-negative staphylococcus (CNS; 94), gram positive rods (GPR; 34) and Streptococcus viridians (8) were the most common organisms found on unworn scrubs; the most common bacteria found on worn scrubs were CNS (271), micrococcus (51), Staphylococcus aureus (33), and GPR (28). All S aureus were methicillin susceptible; among the CNS identified, there were different species, pulsed-field types and antibiotic resistant profiles. Multidrug-resistant (MD) organism were not found on any sample


Keywords: rota virus, nosocomial infection, hand hygiene, clostridium difficile, serratia marcescens

Summarized Abstract: Inanimate surfaces have been known to be a source for outbreaks of nosocomial infections. The goal of this study is to summarize data pertaining to the persistence of a nosocomial pathogens on these surfaces. Medline was used without language restrictions to systemically review the relevant literature. Additionally, the cited articles in reports was assessed and textbooks covering the topic were reviewed. All reports that contained experimental evidence on the duration of persistence of nosocomial pathogens on any surface were included. Several types of bacteria were able to survive on dry surfaces for months, including: Most gram-positive bacteria, such as Enterococcus spp. (including VRE), Staphylococcus aureus (including MRSA), or Streptococcus pyogenes; many gram-negative species, such as Acinetobacter spp., Escherichia coli, Klebsiella spp., Pseudomonas aeruginosa, Serratia marcescens, or Shigella spp; Mycobacteria, including Mycobacterium tuberculosis, and spore-forming bacteria, including Clostridium difficile, Bordetella pertussis, Haemophilus influenzae, Proteus vulgaris, or Vibrio cholerae are gram-negative bacteria that can only survive for a few days. Candida
*albicans* is one the most important nosocomial fungal pathogens, and it can survive up to four months. Other yeasts, such as *Torulopsis glabrata*, were reported to have similar durations. Most respiratory tract viruses, *corona*, *coxsackie*, *influenza*, *SARS* or *rhino* virus, can only survive for a few days. Gastrointestinal tract viruses including *stro* virus, *HAV*, *polio-* or *rota* virus, can survive for a couple months. HBV, HIV, and other blood-borne viruses can survive for more than a week. Herpes viruses have been reported to survive for a few hours up to a week.


*Keywords*: firefighters, flame retardants, hoods, laundering, PAHs, PBDEs  
*Summarized Abstract*: Firefighters endure systemic doses of contaminants including polycyclic aromatic hydrocarbons (PAHs) and three classes of flame retardants (FRs): polybrominated diphenyl ethers (PBDEs), non-PBDE flame retardants (NPBFRs), and organophosphate flame retardants (OPFRs); over time, protective hoods can retain some contamination and contribute to this problem. This study evaluated the efficacy of laundering hoods to reduce or remove contamination. Firefighters were paired up by job assignment and they responded to controlled fires in a single-family residential structure; for each pair, one hood was laundered after each operation while the other was not. Bulk samples of both the laundered and unlaundered hoods were analyzed. The laundered hoods showed 58-81% lower total levels of each class of chemicals and lower residual levels of OPFRs, NPBFRs, and PAHs; however, PBDEs were 43% higher on average in the laundered hoods, which was likely caused by cross-contamination. After this initial testing, unlaundered exposed hoods were laundered with other unlaundered highly exposed hoods and unexposed (new) hoods. Post-laundering evaluation indicated cross-contamination as there were increased levels of PBDEs, NPBFRs, and OPFRs in both previously exposed and unexposed hoods. However, PAHs did not show any evidence of cross-contamination, the exposed hoods were significantly decontaminated after laundering (76% reduction). Further research is required to better understand how residual hood contamination can contribute to firefighter exposures.


*Keywords*: firefighters, safety gear, decontamination, occupational exposure, occupational health practice, text survey  
*Summarized Abstract*: A mobile phone text survey was conducted with 259 Florida firefighters to study cleaning practices for bunker gear. The survey response showed 65% of the participants cleaned their bunker gear in the past 12 months and approximately 32% reported that they had above average confidence in gear cleaning procedures. Arriving at a fire incident response served as a major predictor of gear cleaning in the 12 months preceding the survey. Decontamination
procedure frequency by firefighters can be increased using phone-based texting for periodic queries on adherence to NFPA cleaning guidelines.


**Keywords:** absorption, exposure, fabric, model, skin, semivolatile organic compounds, SVOC

**Summarized Abstract:** A model of transdermal uptake of phthalates was extended to include a layer of clothing and provides a better estimate of dermal uptake of diethylphthalate and di-n-butylphthalate (DnBP). Experimental observation had shown previously-exposed clothing can increase dermal absorption, and this is consistent with the model predictions. The model predicts that dermal uptake of DnBP from clothing is a substantial fraction of the total uptake of all exposures. Compounds that have a high dermal permeability coefficient have a faster rate of dermal uptake when the subject is wearing thinner clothing, has a narrower gap between clothing and skin, and experiences longer time intervals between laundering and wearing. Compounds that have clothing-air partition coefficients between 10^4 and 10^7 have the most enhanced dermal uptake. In the absence of direct measurements, dermal exposure may be predicted by using a combination of equilibrium data for compounds in equilibrium with cellulose and water with computational methods.


**Keywords:** SVOC, Phthalate, Clothing, Exposure, Adsorption, Partitioning

**Summarized Abstract:** Dermal uptake and non-dietary ingestion of semi-volatile organic compounds can be increased by accumulation on indoor surfaces and fabrics. This study aimed to better understand the potential of dermal uptake of phthalates by measuring mass accumulation on cotton fabrics of two phthalate esters that are commonly found indoors: diethylphthalate (DEP) and di-n-butyl phthalate (DnBP). Through 10-day chamber experiments, a strong air-to-cloth partitioning of these phthalates to shirts and jean material was observed. Area-normalized partition coefficients for DEP and DnBP ranged from 209 to 411 (mg/m^2)/(mg/m^3) and from 2850 to 6580 (mg/m^2)/(mg/m^3) respectively. Clothing volume-normalized partition coefficient of DEP averaged 2.6 x 10^5 (mg/m^3)/(mg/m^3) and DnBP averaged 3.9x10^6 (mg/m3)/(mg/m3). It has been estimated that a typical set of cotton clothing can absorb DnBP from the equivalent >10,000 m^3 of indoor air at equilibrium, therefore significantly decreasing external mass transfer barriers to dermal uptake. Related to a child’s body burden of DnBP, it has been estimated that mouthing fabric that has been equilibrated with indoor air may cause a substantial portion of a child’s body burden of DnBP.

Keywords: Hand contamination, *Acinetobacter*

Summarized Abstract: The goal of this study is to determine the link between the bacterial contamination of health care workers’ (HCWs) hands and uniforms (white coats and scrubs). Cultures were taken from the hands and uniforms of HCWs working in five intensive care units (ICUs). Tested pathogens included any gram-negative bacilli, *Staphylococcus aureus*, and *enterococci*. 103 hands (86%) had bacterial growth detected, with the following profile: 13 (11%) grew *S aureus*, seven (6%) grew *Acinetobacter* spp, two (2%) grew enterococci, and 83 (70%) grew only skin flora. The pathogenic presence on hands correlated with greater likelihood of the pathogenic presence on white coats ($\kappa = 0.81; P < .001$), but not on scrubs ($\kappa = 0.31; P = .036$). Similarly, *Acinetobacter* presence on HCWs’ hands was linked with a greater probability of *Acinetobacter* contamination of white coats ($\kappa = 0.70; P < .001$), but not of scrubs ($\kappa = 0.36; P = .024$).


Keywords: Enterococcus, Hospitals, Plastics, Staphylococcus. Textiles

Summarized Abstract: There has been an increasing concern of patient transfer of gram-positive bacteria, including multi-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE). One significant attribute of these bacteria is their ability to survive on hospital surfaces for extended durations. The goal of this study is to investigate the survival of 22 gram-positive bacteria (vancomycin-sensitive and -resistant enterococci and methicillin-sensitive and -resistant staphylococci) on five hospital surfaces: smooth 100% cotton (clothing), 100% cotton terry (towels), 60% cotton–40% polyester blend (scrub suits and lab coats), 100% polyester (privacy drapes), and 100% polypropylene plastic (splash aprons). This was executed by inoculating swatches with $10^4$-$10^5$ CFU of each organism and then performing daily assaying of the swatches by placing them in nutritive media. The bacteria growth was examined after 48 hours. All types of bacteria survived at least a day with some surviving up to 90 days. Antibiotic sensitivity did not display any consistent effect. The long survival of MRSA and VRE on these common hospital surfaces emphasizes the need for careful contact control procedures and disinfection.


Summarized Abstract: From the months of July to September 1997, there was an outbreak of methicillin-resistant *Staphylococcus aureus* (MRSA) in two wards of a medical school teaching hospital. In effort to determine if these MRSA clinical isolates were related to environmental factors, two sequential MRSA surveys of the hospital staff and surroundings of the two wards that experienced the outbreak (Wards 1 and 2) and one ward that did not have an outbreak (Ward 3). The survey was conducted in April 1998 for Ward 1 and in March 1999 for all three wards. From these surveys, MRSA strains were detected mainly from white coats. MRSA strains that were isolated from fingers in the first survey decreased in the second survey. The MRSA strains were classified into five types (A-E) per the patterns from the pulsed-field gel electrophoresis (PFGE).
Type D which includes the MRSA outbreak pattern of the MRSA from Ward 1 in 1997 decreased in the second survey by managing microbial hygiene, which indicates the Ward 1 outbreak was controlled. Ward 2 strains from the second survey were mostly type E, which was also common among Ward 2 clinical isolates in the later part of 1998-1999. The results of these surveys indicate that a high probability of cross-infection exists between patients and staff. It is recommended that staff be cognizant of the potential that their coats might be contaminated with prevailing strains of MRSA. Furthermore, these results are helpful for successful management of MRSA infections.


**Keywords:** temperature, detergent, phosphate, fabric finish, bacterial survival, strength retention, elongation, fabric

**Summarized Abstract:** This study investigated the impact of temperature, detergent type, and fabric finish on bacterial survival, and both strength retention and elongation of fabrics. Temperature was a significant factor in reducing bacterial survival, breaking strength, and elongation. Fabric finish did not significantly affect bacterial survival, but it did impact strength retention and breaking elongation. Detergent type, especially a phosphate detergent, is important in diminishing bacterial survival during laundering.


[https://doi.org/10.1093/jaoac/52.4.836](https://doi.org/10.1093/jaoac/52.4.836)

**Keywords:** Disinfectants, laundering process

**Summarized Abstract:** This study proposed a laboratory model to test chemicals for efficacy as laundry disinfectants or sanitizers. This model also aims to determine the residual bacteriostatic effects on finished fabrics. The model is versatile in its ability to accommodate a variety of variables that can be encountered during laundry processes. The data from these investigations are presented, and further research is recommended


**Keywords:** PAHs, polycyclic aromatic hydrocarbons, VOCs, volatile organic compounds, benzene, formaldehyde, cyanide

**Summarized Abstract:** The exposure of firefighters to various fireground contaminants during extinguishment of simulated room fires was characterized. Contaminants of interest included polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and simple inorganic compounds such as cyanide. Samples were taken outside and inside the protective clothing. PAH deposition was characterized both on the outer surface of firefighting protective clothing and on skin simulant patches attached to the firefighter. Findings indicated firefighter
exposure to airborne contaminants outside their protective clothing during simulated residential room fires. They included aromatic hydrocarbons like benzene, oxygenated hydrocarbons like formaldehyde and PAHs, primarily naphthalene; the concentrations inside the protective clothing were 50% to more than 99% lower than the external concentrations. Deposition of PAHs also occurred on the swatches attached to the protective clothing. Swatches had deposition of PAHs, the concentration and distribution were comparable to the measurements outside the protective clothing excepting naphthalene and acenaphthylene. Benzo[a]pyrene, a known carcinogen, was also detected on the swatches. The results suggest the PAHs within the air are readily deposited onto protective clothing during extinguishment and that direct deposition of PAHs onto the skin from the airborne contaminants occurred at low concentrations. Naphthalene, phenanthrene and pyrene were detected, although values varied significantly across the simulated residential room fires and deposition was not observed in all instances. The results show the skin is a route of entry that cannot be discounted. Recommendations are provided to reduce the opportunities for exposure and hence reduce the cumulative dose to a firefighter.

63. Queensland Fire and Rescue Service Scientific Branch. (2011). **Firefighter Exposures to Airborne Contaminants During Extinguishment of Simulated Liquified Petroleum Gas (LPG) Fires.**

**Keywords:** LPG, liquified petroleum gas, petrochemical training, VOCs, PAHs, acid gases, carbonyl, hydrogen cyanide, surface deposition, air sampling

**Summary:** Exposure of firefighters to combustion products in liquid petroleum gas-fed fires was characterized by taking measurements during five petrochemical training scenarios. Active air sampling was conducted both inside and outside the structural firefighting ensemble for volatile organic compounds (VOCs), carbonyl compounds, acid gases, hydrogen cyanide, and polycyclic aromatic hydrocarbons (PAHs). Surface deposition of PAHs was evaluated with swatches on the structural firefighting ensemble and dermal (surrogate skin) patches. Overall results showed firefighter exposure to PAHs outside their protective clothing. While firefighter PAH exposures exceeded PAH exposures typical in urban environments, firefighters’ exposures were less than the reported mean PAH exposures for workplaces and they were significantly less than exposures from the simulated residence of office fires.

In addition, PAH exposure results varied between the burns, despite the similar fuels and tactics applied to extinguish the fires. The results showed that firefighters were not exposed to any significant concentration of VOC - oxygenated hydrocarbons or VOC – hydrocarbons in or on their protective equipment. The concentrations were comparable to those found in the urban environment. For the acid gases, sulfuriac acid was the only one that exceeded the established Australian National Exposure Standard (NES) value; however, it was still below the Short-Term Exposure Limit (STEL). The measurements for the acid gases, VOC – oxygenated hydrocarbons and VOC – hydrocarbons were significantly less than the measurements from simulated office and room fires.
Study results clearly showed the concentration of PAHs deposited directly onto the protective clothing the firefighter activities during the extinguishment of the LPG fed fire was less than the limit of reporting.

64. Queensland Fire and Rescue Service Scientific Branch. (2011). **Firefighter Exposures to Airborne Contaminants During Extinguishment of Simulated Office Room Fires.**

**Keywords:** simulated office fire, PAHs, polycyclic aromatic hydrocarbons (PAHs), VOCs, volatile organic compounds, benzene, formaldehyde, acid gases, hydrogen chloride, hydrogen cyanide, naphthalene, deposition, air sampling, skin absorption

**Summarized Abstract:** The exposure of firefighters to contaminants during extinguishment of simulated office fires was characterized. Contaminants evaluated included polycyclic aromatic hydrocarbons (PAHs); volatile organic compounds (VOCs) such as benzene and formaldehyde, and acid gases such as hydrogen chloride and hydrogen cyanide. Samples were taken outside and inside the protective clothing. PAH deposition was characterized both on the outer surface of firefighting protective clothing and on skin simulant patches attached to the firefighter. The results showed the firefighters were exposed to a variety of airborne contaminants outside their protective clothing. The contaminant distribution included aromatic hydrocarbons like benzene, oxygenated hydrocarbons like formaldehyde and PAHs, such as naphthalene. The concentrations of airborne contaminants were typically lower inside the protective clothing than outside, however there was no observed protective effect for some chemicals. Naphthalene was the primary PAH inside the clothing. PAHs also deposited onto the swatches attached to protective clothing. Swatches had deposition of PAHs, the concentration and distribution were comparable to the measurements outside the protective clothing excepting naphthalene and acenaphthylenes. Benzo[a]pyrene, a known carcinogen, was detected on the swatches. The results suggest that the during extinguishment, airborne PAHs are readily deposited onto protective clothing. No measurable PAH direct deposition onto protective clothing was observed in this study. Recommendations have been provided to reduce exposure and hence the cumulative dose to a firefighter.


**Keywords:** NFPA 1851, advanced cleaning, preliminary exposure reduction, decontamination, firefighter culture, structural firefighting PPE, care and maintenance of structural firefighting PPE

**Summary:** A cultural shift that recognizes safety issues related to the cleaning and care of bunker gear are discussed and changes to NFPA 1851 are described. Preliminary Exposure Reduction, cleaning, advanced cleaning, contamination, and inspection are defined and explained, and a decision-making flowchart is presented.

**Keywords:** MRSA, *S. aureus*, PCR, environmental surfaces, nasal carriage, fire stations

**Summarized Abstract:** MRSA strains from environmental surfaces of two Northwest fire stations from two independent districts were collected and analyzed. Changes in education, signage, and disinfection protocols were implemented after the first sampling. The second sampling determined the nasal carriage of MRSA. SANICULTTTM swabs and RODACTM plates were used to collect environmental samples. MRSA isolates were confirmed with biochemical tests and 16S RNA sequencing. Antimicrobial susceptibility testing was conducted; PCR, sequencing, and PFGE analysis determined the mecA gene, MLST typing and SCCmec typing. For 44 (4.2%) of 1,064 samples, MRSA was isolated and included USA300 isolates. The same strains that were found in the garage (vehicles and protective clothing) were also found in the living quarters. One fire district found MRSA nasal carriage to be 22.5%. Community and hospital-like MRSA were isolated from the environmental samples. Environmental MRSA was genetically related to the majority of the nasal MRSA*S. aureus* isolates. Transmission between personnel and environmental surfaces may be a factor.


**Keywords:** MRSA, MSSA, Staphylococcal sample kit, Fire station disinfection protocols

**Summarized Abstract:** This study collected isolates of Methicillin-resistant *Staphylococcus aureus* (MRSA) and methicillin-susceptible *S. aureus* (MSSA) from 33 Washington State fire stations. The isolates were collected by fire personnel. They used commercial testing swabs to sample up to six surfaces per swab, with 20 swabs at each station. MRSA and MSSA isolates were confirmed with biochemical tests. Additionally, a survey was included to collect information on cleaning procedures in the stations. Out of 653 samples, 8% contained MRSA, and 18.5% contained MSSA. Nineteen (58%) fire stations tested positive for MRSA, 27 (82%) tested positive for MSSA, and 14 (42.4%) stations tested positive for both. Only three (9.0%) stations were negative for both. Twelve (37.5%) reported fire service personnel with MRSA requiring medical care. Positive controls were detected at the >10²CFU/mL threshold.


**Keywords:** PPE, worker clothing, cleaning, standards, CDC, EPA, FDA, MSHA, NASA, NIOSH, NRC, OSHA, USCG, USDA, USN, AIHA, ANSI, ASHP, ASTM, CCOHS, NYCOSH, NFPA, NSC

**Summary:** Specific requirements and recommendations from government agencies, advisory bodies, and representative equipment manufacturers are presented for the cleaning and cleanliness of worker clothing and personal protective equipment. Rules, regulations, standards, and recommendations are included from government agencies including the Centers for Disease Control & Prevention (CDC), Environmental Protection Agency (EPA), Food and Drug Administration (FDA), Federal Emergency Management Agency (FEMA), Mine Safety and
Health Administration (MSHA), National Aeronautics and Space Administration (NASA), National Institute for Occupational Safety and Health (NIOSH), Nuclear Regulatory Commission (NRC), Occupational Safety and Health Administration (OSHA), United States Coast Guard (USCG), United States Department of Agriculture (USDA), and United States Navy (USN). Advisory bodies’ standards, rules, and recommendations are included from the American Industrial Hygiene Association (AIHA), American National Standards Institute (ANSI), American Society of Health-System Pharmacists (ASHP), ASTM (American Society for Testing and Materials) International, Canadian Centre for Occupational Health & Safety (CCOHS), New York Committee for Occupational Safety and Health (NYCOSH), National Fire Protection Association (NFPA), and National Safety Council (NSC).


**Summarized Abstract:** The goal of this study was to assess the rate and risk factors of methicillin-resistant S. aureus (MRSA) and vancomycin-resistant enterococci (VRE) on the protective gowns and gloves used by healthcare workers (HCWs). This was accomplished by observing the interactions between HCWs and patients during routine clinical activities at University of Maryland Medical Center’s intensive care unit. Samples were taken from HCWs’ hands before and after entering a patient’s room, from gowns and gloves after patient care activities were completed, and from HCWs’ hands immediately after removing their gowns and gloves. Of 137 HCWs caring for patients colonized or infected with MRSA and/or VRE, 24 (17.5%; 95% confidence interval, 11.6%–24.4%) had their glove and/or gown contaminated. HCW contact with the endotracheal tube or tracheostomy site of a patient ($P < .05$), HCW contact with the head and/or neck of a patient ($P < .05$), and HCW presence in the room of a patient with a percutaneous endoscopic gastrostomy and/or jejunostomy tube ($P < .05$) were associated with an increased risk of acquiring these organisms. HCWs’ gloves and gowns were frequently contaminated with MRSA or VRE during routine care, especially when taking care of a patient’s respiratory tract and any related dwelling devices. As part of wider infection control study, a high compliance hand disinfection will mitigate antibiotic-resistant organism transmission among patients within the inpatient setting.


**Keywords:** pilot study, firefighter cancer risk, air quality, fire station, Boston, particulates, polycyclic aromatic hydrocarbons, PAHs, exhaust capture, station design

**Summarized Abstract:** Exposures at the fire station may be a contributing factor towards firefighters’ increased risk of cancer. This pilot study investigated physical and organizational factors that may contribute to levels of contaminants by characterizing the air quality in four Boston fire stations. Air sampling for particulate matter less than 2.5μm in diameter (PM2.5) and
particle-bound polycyclic aromatic hydrocarbons (PAHs) was conducted in the fire stations’ kitchens, truck bays, and areas just outside the station. The data was analyzed to assess differences between and within the stations. Truck bays exhibited higher exposures than either outdoors or kitchens, and the levels varied throughout the day. Officers from each station (n=7) were interviewed to explore the health- and safety-related organizational policies and practices. The station that had the highest exposure risk in the truck also had the lowest levels in the kitchen, this situation is likely due to the new building materials and effective separation between building zones. The implementation of exhaust capture was related to the stations’ age and layout. The levels of PM2.5 and PAH inside fire stations may be a factor in firefighter cancer risk.


Keywords: occupational exposure, cancer risk, UK, PAH, 7,12-dimethylbenzo[a]anthracene, and 3-methylcholanthrene (3-MCA)

Summarized Abstract: Wipe samples were collected from skin (jaw, neck, hands), PPE, and work environment (offices, fire stations and engines) to study the UK firefighters’ exposure to PAH carcinogens. Levels of 16 PAHs were assessed with more potent carcinogens, 7,12-dimethylbenzo[a]anthracene, and 3-methylcholanthrene (3-MCA) at 12 months post-initial testing. The cancer slope factors (which estimate cancer risk) indicate a considerably elevated risk. PAH carcinogens that were determined to be on body surfaces, PPE, and work surfaces included: benzo[a]pyrene (B[a]P), 3-MCA, and 7,12-dimethylbenzo[a]anthracene. Dermal absorption serves as the main route for exposure.


Keywords: decontamination, laundering, polycyclic aromatic hydrocarbons, PAHs, dry cleaning, forced air circulation, blood, microorganisms

Summary: This study characterized contamination levels in turnout gear from retired firefighters. The effectiveness of current laundering in decontaminating PPE in a different circumstance is evaluated. This work added to findings in the original part of this study (Contract No. EMW-92-C-3987 completed in 1996) and addressed the effects of different cleaning on selected firefighter protective clothing properties. Retired turnout coats were destructively evaluated with solvent extraction and gas chromatography with mass spectroscopy for organic chemicals and digestion with atomic absorption for inorganic materials. This evaluation showed several hazardous chemicals with some of them in relatively high concentrations. Multiple polycyclic aromatic hydrocarbons (PAHs) were found in the used clothing. The efficacy of seven laundering techniques for removing chemical contaminants was tested against five materials with six target chemicals. Dry cleaning was the most efficient procedure but is not a currently acceptable process
due its effect on the clothing. Conventional methods did not have significant differences in efficiency between them, however, subsequent forced air circulation (aeration) improved their efficacy in removing additional contamination. Further research showed that aeration can provide benefits for removing some chemicals from contaminated clothing. Similar research showed that blood removal had varied effectiveness based on material more than cleaning technique. Higher wash temperatures were more effective in removing microorganisms during testing. Multiple laundering cycles exhibited significant changes for barrier properties of the moisture barrier seams (for one material) and the water absorption of outer shell materials. NFPA used this study for development of guidelines that standardize cleaning and decontamination of structural firefighting protective clothing.

73. Tano, E., Melhus, Å. (2014). *Level of decontamination after washing textiles at 60 C or 70 C followed by tumble drying*. Infection Ecology & Epidemiology, 4(1), 24314.

**Keywords:** laundry; high temperature; tumbling; bacterial cleanliness; textiles

**Summarized Abstract:** The emergence of multi-resistant bacteria has resulted in several major outbreaks in healthcare facilities. One possible method for the spread of bacteria is the inadequate laundering of hospital textiles. The goal of this study was to develop a user-friendly method for simulating laundering processes of hospital textiles and apply the method to evaluate the decontamination efficiency of two different washing temperatures. The laundering process, including tumble drying, was investigated at two professional laundries, and used Enterococcus faecium as the bioindicator. The findings showed that decontamination efficacy is not affected by lowering washing temperature from 70°C to 60°C. The washing cycle reduced the number of bacteria 35 log10 CFU; the tumble drying further reduced the number of bacteria with an additional 34 log10 CFU. The yielded final result was independent of washing temperature. There is a large risk of adding non-fermenting gram-negative bacteria to the fabric from the washing cycle if tumble-drying is not performed. To save energy, it is possible to wash with a temperature of 60°C as long as tumble drying is done after each washing cycle and that the whole process is monitored to maintain sufficient textile hygiene.


**Summarized Abstract:** Staphylococcus aureus is a commensal bacteria of human nostrils and skin. This bacterium frequently causes soft tissue and blood infections. The most significant attribute of this bacteria is its persistence—it tends to reoccur despite treatment with antibiotics or surgical intervention; this bacterium has the ability to manipulate immune responses. This review highlights how S. aureus virulence can block and destroy phagocytic cells and alter host B cell and T cell responses. There is also a discussion how the insights to this bacterium could be useful for the development of new treatments for infections with antibiotic resistant strains.

**Summarized Abstract:** Transmission of nosocomial pathogens between patients has been linked to transient colonization of health care workers. Studies have shown that contamination of health care workers’ white coats and other clothing garments may be the route for this transmission. The goal of this study was to investigate the prevalence of contamination of white coats with important nosocomial pathogens including methicillin-sensitive *Staphylococcus aureus*, methicillin-resistant *S. aureus* (MRSA), and vancomycin-resistant enterococci (VRE). This was done by a cross-sectional study involving attendees of medical and surgical grand rounds at a large teaching hospital. Each participant completed a survey and sampled their white coat with a moistened culture swabs on lapels, pockets, and cuffs. Thirty-four of the 149 (23%) participants had contaminated white coats; six (18%) were MRSA. VRE did not contaminate any of the coats, however it was more prevalent among residents, those working in inpatient settings, and those who came in contact with an inpatient that day.


**Summarized Abstract:** The goal of this study was to assess the safety and efficacy of re-usable versus single-use scrubs and laundering machines. This was carried out by utilizing the Stomacher technique to evaluate 10 sets of surgical scrubs that were collected from several healthcare organizations in the US (n=20). The number of organisms on the garments was quantified with colony-forming units (CFUs); the average logarithmic bacterial population and the standard deviation associated with each garment was calculated. One-way analysis of variance (ANOVA) was used to compare the mean log (base 10) of CFUs versus configuration. Mean microbial populations among facility-laundered, third party-laundered, and single-use scrubs (prior to use, “clean”) were statistically similar. However, the mean microbial population among home-laundered scrubs, (prior to use, “clean”) was substantially greater than any other “clean” garment. Further, the mean population of the home-laundered scrubs was similar to the mean population after use. Facility and third-party laundries are effective and viable options for scrub cleaning, while home laundering is not recommended. Further research is merited in order determine the bacterial organisms.


**Keywords:** linens, bacteria, *Staphylococcus aureus*, wash temperature, wash cycle time, bacterial survival

**Summarized Abstract:** After testing linens collected from hospital isolation patients’ beds, and linens used by students in their homes, bacterial survival was determined in linens inoculated with *Staphylococcus aureus*. Two different washers were used with temperatures of 38°, 49°, 54°, and 60° C alongside a commercial tumbler dryer. Lines were macerated in a Waring blender and enumerated with nonselective media. The results suggest that an acceptable level of surviving bacteria for hotel and motel linens can be achieved with 54° C wash cycle for 8 to 10 minutes followed by adequate drying; a wash cycle at 60° C for 10 to 13 minutes is suggested for health care facilities.

**Summarized Abstract:** Pseudomonas aeruginosa cells have the ability to grow in presence of 770 ppm n-alkyl (50% C12, 30% C14, 17% C16, 3% C18) dimethyl dichlorobenzyl ammonium chloride (QAC) which makes it a good selection for this study. These cells displayed resistance to the germicide through tri-weekly transfers over seven months in tryptone glucose yeast extract broth containing no QAC. These resistant cells were compared to sensitive strains in order to identify the resistance mechanism and the methods of QAC. Gas chromatographic analysis detected that QAC cells produce large quantities of ethyl acetate and ethyl valerate, unlike the sensitive cells. These sensitive cells displayed two bands esterase activity through cell extracts by gel electrophoresis, the resistant cells only showed one, and only when alpha napthyl acetate was used as the substrate. Biochemical test also exhibited numerous differences between the kinds of cells; one of the most significant differences was resistant cells losing the ability to synthesize extracellular lipase and protease enzymes. Additionally, the resistant cells were more resistant to osmotic disruption. Permeability studies were also conducted, and they showed that the resistant cells have a decreased rate of glucose uptake. Lastly, growth curve investigations demonstrate a slower rate of growth of resistant cells with a 15-minute longer generation time.


(last accessed 27 December 2021)

**Keywords:** decontamination efficacy, rubber boots, leather boots

**Summarized Abstract:** The assumption that firefighters’ rubber boots both absorb fewer contaminants than leather boots and can be decontaminated more effectively than leather boots was evaluated. Decontamination procedures performed on both rubber and leather footwear samples revealed that in most instances the leather footwear samples were more effectively decontaminated than were the rubber footwear samples.


**Keywords:** Uniform, Attire, pathogenic bacteria, nosocomial infection

**Summarized Abstract:** Medical and nursing staff uniforms are typically not considered a significant risk for microorganism transmission. This study investigated the rate of potentially pathogenic bacteria present on hospital staff uniforms, and the bacteria load as well. This was executed by obtaining cultures from nurse and physician uniforms by pressing standard blood agar plates to the abdominal area, sleeve ends, and pockets; additionally, each participant completed a questionnaire. 238 samples were obtained from 75 nurses (55%) and 60 physicians (45%).
(58%) personnel indicated that they change their uniform every day and 104 (77%) claimed that their level of attire hygiene is fair to excellent. Potentially pathogenic bacteria were detected from at least one site of the uniforms from 85 participants (63%) and from 119 samples (50%). Furthermore, 21 (14%) of the samples from nurses’ gowns and six (6%) from physicians’ gowns (P=NS) contained antibiotic-resistant bacteria. Up to 60% of uniforms were contaminated with potentially pathogenic material including drug-resistant organisms, further research is required to determine in these bacteria can be transmitted patients and clinically relevant infection.


**Keywords:** airborne disease, bloodborne disease, chain of infection, first responder protection

**Summarized Abstract:** Information about communicable diseases that may affect the fire service, including both airborne and bloodborne diseases, is presented. Factors determining whether an exposure will lead to disease are reviewed with the chain of infection model used to elucidate the infection process. With a focus on the risk and protection for first responders, diseases and conditions profiled include hepatitis, HIV/Aids, influenza, avian (“bird”) flu, tuberculosis, pertussis, diphtheria, SARS, pneumonia, meningitis, clostridium difficile, MRSA, scabies, and lice.


**Keywords:** biomonitoring, firefighter, GC-MS/MS, monohydroxylated PAHs, protection factor, skin wipe, urinary metabolites

**Summarized Abstract:** Reducing the amount of time firefighters wear PPE and handle contaminated equipment was the most important factor in reducing Swedish firefighter’s exposure to combustion particles. This study assessed exposure by testing the level of protection obtained by different garment layers during a standardized smoke diving exercise. Realistic work protection factors (WPFs) were determined by comparing air concentrations of a full suite of gaseous and particle-bound polycyclic aromatic hydrocarbons (PAHs) inside and outside structural ensembles, which included jackets and thick base layers. This was done during a tough fire extinguishing exercise using wood as the fuel. During a standardized smoke diving exercise, PAH skin deposition and levels of eight urinary PAH metabolites of twenty volunteer student firefighters before and after the exercise were measured to assess exposure. The findings suggest a relatively high protective capacity with an average WPF of 146 ± 33 for the sum of 22 PAHs, but it also indicates a substantial enrichment of contaminants with a risk of prolonged dermal exposure. In the second exercise, the post-exposure median levels of skin-deposited Σ14-PAHs increased 5-fold and urinary 1-hydroxypyrene increased 8-fold. Among the PAH metabolites investigated, 1-hydroxypyrene proved to be the best indicator of exposure, as it had significantly elevated urinary levels at both 6 hours and 20 hours post-exercise and the strongest correlation to dermal exposure. Two-ring and three-ring PAH metabolites were eliminated faster and levels of 3-hydroxy-
benzo[a]pyrene did not meet detection criteria. In accordance with previous results, the findings from the correlation studies suggest that dermal uptake was a key route for exposure.


Keywords: asbestos, biological cultures, Escherichia coli, E.coli, , heavy metals, Sb, As, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li Mg, Mn, Mo, Ni, Se, Sr, Tl, Ti, V, Zn, polycyclic aromatic hydrocarbons (PAHs), phthalates, phenolics, Xeros Polymer Bead Cleaning System, decontamination efficacy, firefighting gear

Summary: The ability of the Xeros Polymer Bead Cleaning System to remove contaminants from firefighting gear was studied and the performance of the Xeros system was compared to that of conventional commercial washing machines. Fabric swatches were contaminated with asbestos, biological cultures (Escherichia coli, or E.coli), heavy metals (Sb, As, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li Mg, Mn, Mo, Ni, Se, Sr, Tl, Ti, V, Zn), and polycyclic aromatic hydrocarbons (PAHs), phthalates, and phenolics. Contaminated sample swatches were pinned to gear throughout the load to represent typical cleaning conditions. On average, the Xeros Polymer Bead Cleaning System removed all of the asbestos and 99.2 percent of the biological cultures. The Xeros Polymer Bead Cleaning System removed most of the heavy metals at least 87.5 percent. Between 26.7 and 95.0 percent of the organic contaminants were removed, with most removed at least 93.6 percent. The conventional washer also removed all of the asbestos, and it removed 99.97 percent of the biological cultures.