TECHNICAL BRIEF

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A Strategic Research Initiative on the Impact of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) on Human Health

Introduction

The class of chemical compounds known as per- and polyfluoroalkyl substances (PFAS) are ubiquitous environmental contaminants commonly known as "forever chemicals."[1]

There are thousands of different PFAS with widespread usage and application across several industries. PFAS are used in a variety of consumer, industrial, agricultural, military, and commercial products including stain or water-repellant material coatings on clothing and indoor furnishings, firefighting foams, personal care products, and non-stick cookware.[2] The same properties that make PFAS chemicals attractive for these uses also make these chemicals persistent pollutants in the environment. PFAS resist typical environmental degradation and biological transformation, thus PFAS can exist in the environment and biological systems for decades in various environmental matrices. For example, fluorotelomer alcohol, or FTOH, has been observed in the atmosphere,[3] perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) have been identified at the air-water interface,[4] and organofluorine compounds were found to accumulate in water.[5,6] In addition, secondary sources of PFAS are numerous and often include large releases from aqueous film-forming foams (AFFFs) utilized by airports, firefighters, and the military in fire suppression applications.[7-10]

97% — **Approximately 97% of Americans have detectable blood levels of PFAS.[11]**

Although data from the Centers of Disease Control and Prevention (CDC) has shown that approximately 97% of Americans have detectable blood levels of PFAS,[11] the understanding of the potential health consequences of PFAS exposure is still developing. Studies examining the health impacts of PFAS exposure suggest that fetal development along with cognitive and mental capacity of young children may be altered by these pervasive chemicals.[12] Other studies have shown weak links to PFAS exposure in the development of prostate, kidney, and testicular cancer.[13] Recent evidence suggests PFAS exposure may lead to immune system disorders, where reduced vaccine response[14] and a decline in infectious disease resistance[15] have been found. Further, there is mounting evidence of the negative effects PFAS may have on male and female reproductive health.[16]

Populations vulnerable to PFAS exposure effects include adults exposed to PFAS use in industrial settings; children who inhale more air, drink more water and eat more food per pound of body weight than adults; infants and toddlers who are close to the floor or crawl on the floor and can transfer PFAS from touching consumer products like toys and interior finish materials leading to hand to mouth ingestion; and pregnant and lactating women who drink more water per pound of body weight than an average adult.

Due to the occupational hazards firefighters endure, the firefighter community has also been deemed a vulnerable population. Firefighters have higher cancer incidence rates than any other occupation.[17-19] Use of AFFFs during fire service calls contributes to the risk of PFAS exposure for firefighters. Recently, concerns about PFAS exposure from turnout gear and station uniform textiles have prompted increased research activity focused on firefighter safety and health. However, data is still limited and there is a need to study firefighter turnout gear and station uniforms for PFAS identification, quantification, and exposure levels.[20,21]

Studies within the last five years have shown that PFAS may be detected in certain consumer textiles.[22-24] In consumer wearables, like rain jackets, leggings, and shirts with performance properties, such as water repellency or wicking, PFAS have been found within the composition of the textiles and within the leachate from garments during laundering studies.[25] Studies that evaluated garments after weathering (simulating sunlight, high temperatures, and humidity exposures) found increased concentrations of volatile PFAS, suggesting that the degradation of the durable water repellant (DWR) polymers may be the reason, but further research is warranted.[25] Similar to consumer wearables, interior furnishing products may also utilize performance enhanced materials and finishes in applications such as cover textiles for upholstered furniture, window treatments, and other uses.

The products provide performance characteristics of:

- Increased water repellency
- Reduced flammability and conductivity
- Improved durability

The common link between all three types of textiles described above is the enhanced performance properties that may be inherent to the fiber or applied as a finish or coating.

Study Objectives

The overarching goals of this study are to develop methods for testing performance textiles for PFAS identification and quantification; acquire baseline data of PFAS levels in textiles from firefighter gear and uniforms, consumer wearables, and cover textiles for upholstered furniture; and determine potential routes for human exposure.

This research will be valuable in providing insight regarding PFAS exposure risks associated with the use of performance textiles in occupational wearables, consumer wearables and cover textiles for upholstered furniture by evaluating parameters that may influence exposure and impact human health outcomes.

THIS STUDY SEEKS TO ANSWER THE FOLLOWING RESEARCH QUESTIONS:

- Do performance textiles have significant PFAS chemical additives that pose a health risk from inhalation, ingestion, and/or dermal transfer exposure?
- What methods are most effective in identifying and quantifying legacy and emerging PFAS chemicals in performance textiles?
- What analytical approaches provide assessment of inhalation, ingestion, and dermal transfer exposure levels of PFAS?

Scientific Outcomes

This study will contribute to the growing scientific knowledge base and community by providing data and protocol development that will enable a standardized approacha to assess PFAS exposure. Expected results of this study will lead to:

1. Development of standard procedures/protocols for the detection of PFAS and other chemicals in textiles, air, dust, and dermal transfer.
2. Quantification of PFAS levels in various consumer and occupational textiles.
3. Evaluation and comparison of PFAS release and exposure routes from both occupational and consumer textiles.
4. Exploration of parameters that influence dermal transfer, ingestion, and inhalation PFAS exposure and uptake.

Study Plan Overview

The study objectives will be met using the following sampling and analysis plan organized into three phases.

1. **Phase 1A:** PFAS Baseline Characterization – Samples of performance textiles (both consumer and firefighter) will be evaluated for PFAS identification and quantification using analytical procedures developed specifically for this purpose. It is anticipated that liquid chromatography-tandem mass spectrometry (LC-MS/MS) will be used for medium-to long-chain neutral and ionic PFAS and that basic gas chromatography-mass spectrometry (GC/MS) will be used for short-chain, volatile, semi-volatile, and neutral PFAS measurement. Based on the measurements obtained, descriptive and inferential statistics will be applied to discern differences across textile types.
2. **Phase 1B:** Assessing PFAS Exposure Levels – Replicate material sample sets from Phase 1A will be used in evaluations for inhalation, dust release, and dermal transfer of PFAS. The products chosen will include those materials from each textile group found to have a significant presence of PFAS. To determine the level of PFAS released during normal use, various conditions will be simulated in exposure chambers. Analytical procedures will be defined to measure the amount of PFAS released into the air for inhalation, dust release available for ingestion, and dermal exposure from PFAS skin transfer. During simulations, air, dust, and dermal wipe samples will be collected for PFAS analysis. Air will be collected on specific adsorbent media and dust will be collected with a filter collection/vacuum system and/or wipe samples. Dermal transfer assessment will require a more specialized approach described in Phase 1C.
3. **Phase 1C:** A Specialized Evaluation of Release and Dermal Transfer of PFAS via Synthetic Perspiration and Porcine Skin Model - Textiles will be assessed for simulated skin absorption during dermal transfer. Prepared textile samples will be applied to porcine skin sheets, which will be saturated in research quality synthetic sweat or artificial perspiration then inserted into a diffusion cell. Various incubation parameters such as temperature, pH levels, and amount of physical movement will be utilized to evaluate how PFAS are released from textiles and transferred to the dermis during use. Levels of PFAS will be determined in the leachates (liquid portion) and tissues. Mathematical analysis using Fick's Law of Diffusion will be used to determine total amount of PFAS skin absorption. Based on the measurements obtained, descriptive and inferential statistics will be applied to examine the amount of PFAS release in relation to body temperature, pH, and movement.

Research Partners

RAD Consultants/Baylor University

Emory University Rollins School of Public Health

Fire Safety Research Institute (FSRI) of UL Research Institutes

Future Work

FUTURE RESEARCH WILL BE CONDUCTED IN ADDITIONAL PHASES TO INCLUDE:

- A traditional risk assessment of PFAS exposure to consumers and firefighters based on research data of exposure routes and levels.
- Toxicity evaluations of PFAS exposure using biological assessments.
- Comparison of PFAS exposure risks across new and decommissioned turnout gear to determine hazards across garment lifetime.
- Identification of the impact of ageing and weathering on PFAS release from turnout gear.
- Collection of environmental data in firefighter housing to assess exposure risks from housing dust and air as well as solutions for reduction.

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2211 Newmarket Parkway, Suite 106, Marietta, Georgia 30067 | **Website:** chemicalinsights.org | **Email:** chemicalinsights@ul.org