NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2004-0368-3030
Bureau of Alcohol, Tobacco, Firearms and Explosives
Austin, Texas

January 2007

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Erin Snyder of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Special Agent Jośe Viegra, Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF). Analytical support was provided by Ardith Grote and Tammy Wise, Division of Applied Research and Technology (DART), and DataChem Laboratories, Inc., (Salt Lake City Utah). Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

Copies of this report have been sent to employee and management representatives at ATF and the OSHA Regional Office. The report may be viewed and printed from the following internet address: http://www.cdc.gov/niosh/hhe. Copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation (HHE) at the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) in Austin, Texas. The agent submitted the HHE request because of concerns about chemical agents encountered at fire scene investigations contaminating their clothing worn at the scene and possible cross-contamination of personal washing machines and dryers when the garments are taken home for laundering. NIOSH investigators conducted a multi-phased field and laboratory evaluation to investigate any possible contamination of the agents' uniforms.

What NIOSH Did

- NIOSH and ATF investigators designed a 5-part study to look at possible uniform contamination.
- We put known amounts of chemicals on clothing to see if they could be recovered by the laboratory.
- We analyzed uniforms worn during fire investigations to see if they contained chemical contaminants.
- We analyzed contaminated uniform patches to see if laundering removed chemicals.
- We checked the washer and dryer for cross-contamination from soiled uniforms.

What NIOSH Found

- Many of the chemicals were removed during the laundry process.
- Some chemicals remained after washing and drying.
- The washer and dryer had no chemicals remaining after laundering soiled uniforms.

What Bureau of Alcohol, Tobacco, Firearms and Explosives Managers Can Do

- Issue disposable uniforms for use in fire investigations.
- If current uniforms are used, they should be cleaned by a professional laundry service.

What Bureau of Alcohol, Tobacco, Firearms and Explosives Employees Can Do

- Use disposable uniforms when supplied.
- Agents should not take uniforms home for laundering.
- Remove uniforms before entering personal or official vehicles.
- If disposable uniforms are not supplied, a professional laundry service should be used.

What To Do For More Information:

We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2004-0368-3030

Health Hazard Evaluation Report 2004-0368-3030
Bureau of Alcohol, Tobacco, Firearms and Explosives
Austin, Texas
January 2007

Erin Snyder, M.S.

SUMMARY

On August 19, 2004, the National Institute for Occupational Safety and Health (NIOSH) received a request from an agent at the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) regarding potential exposures during fire scene investigations. Concerns were raised about the presence of contamination on uniforms upon completion of an investigation, removal of the contamination following home laundering, and contamination of home washing machines from contaminated uniforms. At the time of the request, employees had not reported health effects associated with chemical exposures during fire scene investigations.

In response to the request, a study protocol was developed using polynuclear aromatic hydrocarbons (PAHs) as a marker for contamination. The goals of the study were to determine whether PAHs were present in clothing worn at a fire scene and if home laundering would remove such contaminants from the ATF uniform.

Results from the study showed that PAHs were present at fire scenes; however, contamination of a washing machine/dryer used by an ATF fire scene investigator to launder his/her uniform is unlikely. The contamination of subsequent loads of laundry is also unlikely. However, there is a potential for contamination of other clothing laundered with soiled uniforms. Due to the number of uncontrolled variables in this study, definitive conclusions cannot be made as to whether a significant amount of PAH contamination was removed during the laundering of soiled field uniforms.

Due to the potential for exposure to PAHs, some of which may be carcinogenic, NIOSH investigators recommend the use of protective clothing for ATF agents involved in fire scene investigation. To reduce the potential for carrying these contaminants home, disposable coveralls should be worn at the fire scene then discarded when the investigation is finished or a professional laundry service should be used to launder the uniforms currently worn by fire scene investigators.

Keywords: NAICS 922120, Bureau of Alcohol, Tobacco, Firearms, and Explosives, ATF, fire scene investigation, arson investigation, polynuclear aromatic hydrocarbons, PAHs, protective clothing, laundering

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INTRODUCTION

On August 19, 2004, the National Institute for Occupational Safety and Health (NIOSH) received a request from an agent at the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) regarding potential chemical exposures during fire scene investigations. The ATF trains a select number of special agents as fire investigators as part of the Certified Fire Investigator (CFI) program. These special agents work with counterparts in state and local fire departments to investigate the origin and cause of fires. Currently, the agents wear ATF-issued uniforms consisting of cotton pants and either a long-sleeved or short-sleeved polyester/cotton blend shirt. These uniforms are then worn home and laundered by agents. Concerns were raised about the presence of chemical contamination on uniforms upon completion of an investigation, removal of the contamination following home laundering, and contamination of home washing machines from contaminated uniforms. At the time of the request, employees had not reported health effects associated with chemical exposures during fire scene investigations.

BACKGROUND

The ATF's involvement in an investigation occurs after the fire scene has been suppressed and overhauled by local fire fighters. Fire scene investigation involves the determination of the origin and cause of the fire; investigators also determine whether the fire was accidental or incendiary.

In a typical structure fire, products containing plastics, foams, insulation, paints, and fibers are nearly always present. When these materials are involved in a fire, they can release gases, vapors, and particulates (aerosols, fibers, metal fumes, and other particulate).

In previous NIOSH studies, investigators worked in conjunction with the ATF and state police fire investigators to determine the potential respiratory health effects from exposures of fire and arson investigators to environmental contaminants including dust, metals, hydrogen cyanide, inorganic acids, and polynuclear aromatic hydrocarbons (PAHs).[1, 2] Environmental air sampling conducted at numerous fire scenes indicated low or trace concentrations of most analytes. However, formaldehyde, acetaldehyde, and several PAHs were detected, all of which NIOSH considers potential occupational carcinogens. These findings indicate both acute and chronic airborne respiratory exposures to such compounds are of concern to the health of fire scene investigators. Recommendations in the NIOSH reports included using protective clothing to reduce the potential for carrying contaminants home by the fire scene investigator. Disposable coveralls or a professional laundry service for reusable clothing were suggested as a means of controlling exposure.

Studies by other researchers have used biological monitoring to determine the extent to which fire fighters and others involved at fire scenes are exposed to PAHs. Results from these studies showed clear evidence that PAHs can penetrate the skin and that PAH exposures were associated with fire fighting activities.[3, 4]

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general

environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[5] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[6] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[7] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

During the investigation of a fire scene, agents from the ATF are exposed to a variety of environmental agents. Perhaps the most common contaminants present at a fire scene are PAHs, a group of over 100 chemicals formed during the incomplete burning of coal, oil, gas, or organic substances. Potential routes of exposure include inhalation, dermal contact, and ingestion. Oftentimes, PAHs are found as a mixture of two or more compounds, such as soot.[8] The International Agency for Research on Cancer has classified soot as carcinogenic to humans, and the Department of Health and Human Services has determined that some PAHs may reasonably be expected to be carcinogens.[8,9] As a class, there are no established occupational safety and health exposure limits for PAHs, although NIOSH recommends that exposure to any potential cancer-causing agent be kept as low as feasibly possible.[10]

METHOD AND RESULTS

Phase 1: Spiking and Recovery Analysis of New Uniforms

Based upon previous research conducted at fire scenes, PAHs were selected as markers for contamination. To determine whether PAHs could be detected in the uniform clothing, three pairs of new uniform pants and six new uniform shirts were mailed to DataChem Laboratories in Salt Lake City, Utah. Interferences in the PAH analysis could exist from compounds that are added to the clothing during production such as dyes, fixers, and elasticizers. To minimize the potential impact of interferences from manufacturing additives, the garments were pre-washed before the spiking study. This likely represents a real-life situation because it can be assumed that fire investigators would wash the new uniform before wearing it in the field. The clothing was washed alone per manufacturer's instructions in a warm cycle with Tide® Unscented (free of perfumes and dyes) household laundry detergent, and then dried on medium heat without fabric softener. The uniforms were then cut into 3-inch x 3-inch patches. Six patches of shirts and six patches of

pants were used as media blanks. Eighteen patches from both shirts and pants were divided into three groups, and each one was placed into a 40-milliliter (mL) amber vial. Each patch was then spiked with a known amount of Supelco PAH standard mix at one of three levels: six of each clothing type were spiked at 1.5 micrograms (µg)/sample, six of each at 7.5 µg/sample, and six of each at 15 µg/sample. Fifteen mL of methylene chloride were added to each vial, and the samples were desorbed by agitation and sonnication. The resulting desorbate was then analyzed against a liquid standard of an Environmental Protection Agency (EPA) 610 PAH standard mix using a gas chromatography/mass spectrometry (GC/MS) system.[11]

Although the dyes from the clothing were present in the desorption solvent, all media blanks were free of PAH analytes. The recovery levels were within expected ranges near the spiked levels; however, the results from the 1.5 µg/sample level were too near the anticipated level of detection to be considered reliable. It was recommended that spiking levels in the range of 7.5 to 200 µg/sample be used in subsequent studies. The percent recoveries from the pants were nearly identical to those from the shirts.

Phase 2: Field Sample Collection and Analysis of Cotton Patches

Once it was resolved that there were no substantial interferences to PAH analysis from chemicals present in the uniforms, the next step was to determine that PAHs were indeed present in clothing worn at a fire scene. A plan was developed to collect samples from one ATF agent's clothing at each of three fire scene investigations. Cotton gauze patches (4 inches x 4 inches) were affixed to flexible cardboard holders and either taped or pinned to the agents' uniforms in eight locations (right arm, left arm, right side of stomach, left side of stomach, right thigh, left thigh, right shin, and left shin), allowing for unhindered movement of the agent during the investigation. Once the investigation was complete, the patches were removed, wrapped in aluminum foil, and shipped to the NIOSH laboratory for analysis. Upon receipt, the patches were removed from the cardboard holders and each placed in a 40-mL amber vial. Thirty mL of methylene chloride solvent was added to the vial and tumbled overnight to ensure saturation of the patch. A 1 mL liquid aliquot of each was then extracted from the vial, 2 microliter (µL) of which was injected into a GC/MS for identification. A 10 mL aliquot was also removed from each sample and concentrated by evaporation. The final volume was analyzed by GC/MS (full scan) and by GC/MS single ion monitoring (SIM) mode for 16 PAHs: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a) anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz (a,h)anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene. SIM is a more sensitive and selective analysis by GC/MS, whereby only selective ions, known to be present in the compounds of interest, are scanned.

A PAH standard solution was also analyzed with each set of patches. The solution was a 1:10 dilution of an EPA 610 PAH standard mix. This mix contained 16 individual PAH compounds at concentrations ranging from 100-2000 µg/mL (10-200 µg/mL for the 1:10 dilution).

Several of the patch-methylene chloride extractions were yellow to dark brown in color, notably the left and right shins and left arm samples. However, no peaks were detected in the original 30 mL extraction solutions. In addition, no major contaminants were detected in any of the concentrated solutions analyzed by GC/MS. Small amounts of PAHs (estimated concentrations <0.2 µg/sample) were detected on some of the concentrated gauze samples analyzed by GC/MC-SIM. Results are shown in Table 1. Dibenz(a,h)anthracene, benzo(g,h,i) perylene, and indeno(1,2,3-cd)pyrene were not detected in any of the samples. No large amount of any other compound was found in initial GC/MS screening that would have been a better marker than PAHs for this study.

Phase 3: Spiking and Washing of New Uniform Patches

Upon determining that not only were PAHs present on clothing patches worn at a fire scene, but that they could also be successfully recovered from the uniform clothing, the third phase of the project involved spiking new uniform patches with known amounts of PAHs and then laundering them in a washing machine. One new set of uniforms was washed prior to the patches being laundered, then the uniforms were added to each load of patches to simulate a load of laundry. Individual sets of patches were placed in pre-washed lingerie bags (purchased specifically for this project) to keep all patches contained. Thirty-six patches were spiked with a Supelco PAH standard mix at 20 µg and 200 µg levels. An equal number of patches were also spiked with 100 µL of an EPA 610 PAH standard mix resulting in spiked levels of individual PAHs ranging from 10 to 200 µg. This yielded a total of 108 spiked patches. The patches were washed per the uniform label instructions in warm tap water using Tide® Unscented (free of perfumes and dyes) household laundry detergent. They were then dried on medium heat without fabric softener. Of the 36 patches at each level, 12 were not washed (controls), 12 were washed and line-dried (referred to in Table 2 as wash only), and 12 were washed and machine-dried. In addition, six shirt patches served as environmental blanks as they were not machine washed, but were hung on a clothes line only. Once the patches were dry (either by machine or on a clothes line), they were placed in a 40 mL amber glass vial using clean forceps and sent to DataChem Laboratories for analysis. The laboratory was blind as to which samples were controls and which had been spiked and at what levels. Fifteen mL of methylene chloride were added to each vial containing a clothing patch. The samples were then desorbed in an ultrasonic bath for at least 30 minutes. The resulting desorbates were analyzed by GC/MS-SIM. Calibration standards were prepared by spiking the appropriate amount of a Supelco PAH standard mix onto a clean clothing patch and desorbing in the same manner as the samples.[11]

Results including limit of detection (LOD) and limit of quantification (LOQ) data from the third phase of this project are presented in Table 2. GC/MS-SIM analysis indicated the patches that were spiked with 20 µg and washed and line-dried showed a reduction in the concentration of the first eight PAHs as listed in Table 2 by one half or more. The remaining eight as listed in Table 2 showed little if any change. The first eight PAH levels were further reduced for the 20 µg samples that were both washed and machine dried. In addition, the samples spiked at 200 µg yielded similar results, with the exception of benzo(b)fluoranthene.

The results of those patch samples spiked with 100 µL during this phase showed a lower level of contamination at all 16 PAH levels. All the patches at the 100 µL level were taken from uniform shirts while patches at the 20 µg and 200 µg levels were taken from uniform pants. The question was then asked whether the reduction in PAHs at the 100 µL level was due to the difference in the material used in the shirts versus the pants or a problem with the spiking solution. The ATF uniform consisted of pants made of 100% cotton, while shirts were a 65% polyester and 35% cotton blend. To examine this issue further, phase three of the protocol was repeated with two changes: only shirt patches were used and only the 20 µg and 200 µg levels were tested. The results from this phase (Table 3) are similar to those reported from the initial test: the patches spiked at both the 20 µg and 200 µg levels showed a reduction in the first eight PAH levels as shown in Table 3 by nearly one half, but little change in the remaining PAHs as shown in Table 3. The results were similar for washing only and washing/drying. The second round of spiking tests indicated that there was no significant difference between patches from shirts versus those from the pants. The lower PAH results in the 100 µL initially seen are more likely due to an error in the preparation of the concentration levels. In addition, the environmental blanks that were hung on a clothes line, but not washed, did not have any detectable levels of PAHs present.

Phase 4: Analysis of Field Uniform Patches

This phase of the project involved obtaining field samples from fire scene investigators' uniforms upon completion of an investigation. The ATF field agent cut patches from those areas deemed most soiled on the uniforms of two fire scene investigators, then wrapped the patches in aluminum foil and shipped them to the NIOSH laboratory. Upon receipt of the field patches, the patches were cut in half, attempting to keep the two portions as evenly soiled as possible. Once labeled, one half of each patch was laundered using the same method as described in previous phases, while the other half was not laundered. The patches were sent to DataChem laboratories for analysis; the laboratory was blind to this phase of the evaluation. Dividing each patch in two gave a comparison of the PAH levels from the portion that was laundered and the portion that was unwashed, indicating how much of the PAHs were removed during laundering. Six samples were taken from Investigator #664 (a total of 12 patches) and 20 samples were taken from the uniform of Investigator # 659 (a total of 40 patches). Six blanks and eight spikes for comparison to phase 3 results were included, which yielded a total of 66 patches for analysis. Fifteen mL of methylene chloride were added to each clothing patch. The samples were then desorbed in an ultrasonic bath for at least 30 minutes. The resulting desorbates were analyzed by GC/MS-SIM. Calibration standards were prepared by spiking the appropriate amount of a Supelco PAH standard mix onto a clean clothing patch and desorbing in the same manner as the samples.[11]

Results from this phase are presented in Table 4; LOD and LOQ data are also included. As many as half of the sample sets showed a lower level of contamination in PAH levels (such as F-12, F-51) when comparing the unwashed patch to its partner that was both washed and dried. Several sets (such as F-6, F-64) showed a lower level of contamination in the first eight to ten PAHs tested as listed in Table 4, but little to no change in the remainder. However, in several sets (such as F-18, F-49) half of the PAH levels were actually higher after being laundered. It is worth noting that the patch sets were not necessarily equal in size, and PAH content could vary from different locations in the garment, even within a realatively small area (e.g., pant front, thigh).

Phase 5: Washing Machine/Dryer Contamination

One of the original concerns of the HHE request was that the washing machine used to launder an agent's uniform may become contaminated and thus further contaminate subsequent loads of laundry belonging to other family members. To determine whether contamination was present, clean cotton gauze patches dampened with tap water were used to wipe the tub and the door of the washing machine both before and after washing a load of spiked PAH patch samples only from Phase 3: Spiking and Washing of New Uniform Patches. The same collection method was used for the dryer. In addition, bulk lint from the dryer was also collected for analysis after each load.

All wipe samples collected from the washing machine and dryer both before and after use in Phase 3: Spiking and Washing of New Uniform Patches did not contain detectable levels of PAHs. However, the bulk lint collected from the dryer did show trace levels of nearly all the PAHs tested, except for anthracene and chrysene.

DISCUSSION

The results from the laboratory portion of this study in which patches of uniforms were spiked with 20 µg and 200 µg levels of a PAH spiking solution indicate that washing of the patches was successful in removing some PAH contamination. Subsequent machine drying of the patches further reduced PAH levels. In this study, an error occurred in the preparation of the 100 µL spiking solution, yet the discrepancy in the results it produced led to the discovery that there was no significant difference in PAH retention on a cotton versus a poly/cotton blend fabric.

The field sample portion of this study was uncontrolled. Each fire scene is unique in the types of materials that are present and consequently in the PAHs produced by the burning of these materials. Every effort was made to keep the sets of uniform patches as similar as possible when cut in half for analysis; however, the two cannot be compared directly because they were not equal in size or weight, and uniform contamination of the fabric sections cannot be ensured. In the laboratory, the PAH spike was applied directly to the fabric. In the field samples, the PAH may have been on debris or dirt present on the uniform, which would thus make the uniform appear cleaner after laundering. In addition, it was later learned that an accelerant was used to start the fire being investigated by Investigator #664; thus the types and amounts of PAHs present on these patches may vary significantly from the other investigator.

In the laboratory portion of this study where gauze patches were tested, few of the PAHs listed in Tables 2-4 as 9-16 were detected after washing. The same was not seen in the field samples. In most cases, the last eight PAHs shown in Tables 2-4 had unchanged concentrations after laundering, while the first eight shown in Tables 2-4 were reduced by one half or more. The last eight compounds are relatively inert and have limited solubility in water due to their high molecular weights. It is possible that the solvent was able to remove many of these PAHs, but the water and detergent used in the washing machine had little effect.

Traces of PAHs were found in the bulk lint collected from the dryer and were also seen in some blanks. This indicates that clothes washed simultaneously with a soiled uniform may result in the other (non-contaminated) clothing picking up traces of PAHs. However, none of the washer and dryer wipe samples taken before and after the uniforms were washed and dried showed detectable PAH levels. Thus, the potential for contamination of subsequent loads of laundry is low.

Lastly, many carcinogen research studies have used benzo(a)pyrene or B(a)P as a marker for PAHs. In this study, B(a)P was present, and the levels changed little with laundering. Due to its high molecular weight and poor solubility in water, it may remain more easily on home-laundered clothing than other PAHs. These results may indicate a potential for carcinogen exposure to an ATF agent in the field that should be kept as low as feasibly possible.

CONCLUSIONS

Based upon the results of this study, contamination of a washing machine/dryer used by an ATF fire scene investigator to launder his/her uniform is unlikely. The contamination of subsequent loads of laundry is also unlikely. However, there is a potential for contamination of other clothing being laundered with soiled uniforms.

Due to the number of uncontrolled variables in this study, definitive conclusions cannot be made as to whether a significant amount of PAH contamination was removed during the laundering of soiled field uniforms. Additional studies are needed to provide for better comparisons of field samples and known contaminants.

RECOMMENDATIONS

Due to the potential for exposure to PAHs, some of which may be carcinogenic, NIOSH investigators recommend the use of protective clothing for ATF agents involved in fire scene investigation. To reduce the potential for carrying these contaminants home, disposable coveralls should be worn at the fire scene then discarded when the investigation is finished prior to entering a personal or official vehicle. Alternatively, a professional laundry service could be used to launder the uniforms currently worn by fire scene investigators. In addition, ATF agents should wear disposable, chemical-resistant gloves to further protect themselves from dermal exposures at a fire scene.

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TABLES

Table 1
Phase 2: Field Sample Collection and Analysis of Cotton Patches
Analyzed October 27-28, 2004

PAH Compound	Levels Detected (estimated)
Naphthalene	0.001-0.2 µg/sample
Acenaphthylene	0.001-0.04 µg/sample
Acenaphthene	0.001-0.04 µg/sample
Fluorene	0.001-0.04 µg/sample
Phenanthrene/Anthracene	0.001-0.2 µg/sample
Fluoranthene/Pyrene	0.001-0.2 µg/sample
Chrysene/Benzo(a)anthracene	0.001-0.2 µg/sample
Benzo(a)pyrene/Benzo(b)fluoranthene/ Benzo(k)fluoranthene	0.001-0.2 µg/sample

Limit of Detection = estimated 0.001 µg/sample

Table 2
Phase 3: Spiking and Washing of New Uniform Patches, Analysis in January 2005
(All results reported in µg)

Sample Type	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
20 µg, control	16	20	20	20	21	20	18	17	19	19	22	21	20	24	25	23
Blank, control	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0	3.0	2.0	1.8	2.0	1.8
20 µg, Wash only	9.7	4.5	3.1	5.0	6.0	11	7.4	4.8	14	16	13	17	14	21	23	17
Blank, Wash only	ND	1.0	0.70	0.70	1.1	0.50	0.90	0.88	0.46	ND	ND	ND	ND	ND	ND	ND
20 µg, wash and dry	5.5	2.1	1.3	2.1	3.4	5.9	6.0	4.7	16	20	13	19	16	22	23	17
Blank, wash and dry	ND	ND	0.4	ND	0.81	0.40	0.93	0.81	0.47	ND	ND	ND	ND	ND	ND	ND
200 µg, control	100	160	165	168	185	182	175	187	177	178	180	178	182	202	210	200
200 µg, wash only	60	14	10	40	55	120	62	54	137	158	105	155	135	187	200	137
200 µg, wash and dry	37	7.6	5.3	19	38	84	58	49	140	163	105	156	137	163	190	127
100 µL control	36	114	59	12	6.4	5.7	15	5.9	6.3	8.7	14	7.9	7	13	13	7.1
100 µL, wash only	ND	ND	ND	ND	ND	ND	1.0	0.55	ND	ND	1.8	ND	ND	3.2	3.2	1.3
100 µL, wash and dry	ND	ND	ND	ND	ND	ND	ND	0.52	0.52	1.2	1.5	ND	ND	2.8	3.0	1.5

Table 2
Phase 3: Spiking and Washing of New Uniform Patches, Analysis in January 2005
(All results reported in µg)

Sample Type	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Blank, hung on clothesline	ND	ND	ND	ND	0.06	ND	ND	ND	ND	ND	ND	ND	ND	0.70	0.72	0.64
LOD range	0.5-1.0	0.30-0.70	0.60-0.90	0.30-0.70	0.30-1.0	0.30-1.0	0.30-2.0	0.30-0.90	0.30-0.90	0.40-2.0	0.90-1.0	0.90-4.0	0.90-3.0	0.60-4.0	0.90-3.0	0.80-3.0
LOQ range	2.0-4.0	1.0-2.0	1.0-3.0	1.0-2.0	1.0-4.0	1.0-3.0	1.0-6.0	1.0-3.0	1.0-3.0	1.0-5.0	3.0-4.0	3.0-9.0	3.0-9.0	2.0-12	3.0-10	3.0-9.0

LOD = Limit of Detection
ND = Parameter not detected above the limit of detection (LOD)
LOQ = Limit of Quantification

Table 3
Phase 3: Spiking and Washing of New Uniform Patches (Shirt Patches only), Analysis in February 2005
(All results reported in µg)

Sample Type	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
20 µg, control	15	20	21	21	19	18	22	19	20	19	19	21	20	23	21	21
20 µg, Wash only	6.4	2.2	2.2	4.5	6.1	11	7.4	7.0	14	17	12	17	15	16	16	13
20 µg, wash and dry	3.1	ND	0.7	1.5	3.9	6.8	6.9	6.5	14	17	12	16	15	17	17	15
Blank, wash and dry	ND	ND	ND	ND	ND	ND	0.90	0.90	ND	ND	ND	ND	ND	ND	ND	ND
200 µg, control	160	227	232	237	220	220	228	218	235	217	218	230	230	250	235	242
200 µg, wash only	40	16	19	65	85	152	94	83	177	190	165	207	170	168	168	148
200 µg, wash and dry	20	4.7	5.0	32	66	127	86	77	170	180	158	193	167	177	178	155
LOD range	0.60	0.80-1.0	0.60	0.60	0.60-0.90	0.80-1.0	0.60-0.80	0.60-0.80	0.60-1.0	0.70-0.80	0.70-2.0	1.0-2.0	1.0-2.0	0.60-1.0	0.60-1.0	0.60-1.0
LOQ range	2.0	3.0-4.0	2.0	2.0	2.0-3.0	3.0	2.0-3.0	2.0-3.0	2.0-4.0	2.0-3.0	2.0-6.0	4.0-5.0	3.0-5.0	2.0-4.0	2.0-5.0	2.0-4.0

LOD = Limit of Detection
ND = Parameter not detected above the limit of detection (LOD)
LOQ = Limit of Quantification

Table 4
Phase 4: Analysis of Field Uniform Patches, Analysis in February 2005
(All results reported in µg)

Sample Number	Location		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Investigator # 659																		
F-1	Pant, front, left thigh #1	Unwashed	0.30	0.20	ND	ND	0.76	0.20	0.44	0.30	0.20	0.10	ND	ND	ND	ND	ND	ND
F-63	Pant, front left thigh #1	Washed and dried	ND	ND	ND	ND	0.06	ND	0.07	ND	ND	0.05	ND	ND	ND	ND	ND	ND
F-2	Pant, front, left thigh #2	Unwashed	0.50	0.20	ND	0.10	0.78	0.20	0.46	0.45	0.20	0.20	ND	ND	ND	ND	ND	ND
F-62	Pant, front left thigh #2	Washed and dried	ND	ND	ND	ND	0.08	ND	0.12	0.10	0.06	0.07	0.10	ND	ND	ND	ND	ND
F-3	Pant, front, left thigh #3	Unwashed	0.30	0.10	ND	ND	0.60	0.10	0.36	0.30	0.10	ND	ND	ND	ND	ND	ND	ND
F-61	Pant, front left thigh #3	Washed and dried	ND	ND	ND	ND	0.06	ND	0.09	0.10	ND	ND	ND	ND	ND	ND	ND	ND
F-4	Pant, front, right thigh #1	Unwashed	0.40	0.20	ND	0.10	0.75	0.02	0.46	0.30	0.10	0.10	ND	ND	ND	ND	ND	ND
F-66	Pant, front, right thigh #1	Washed and dried	ND	ND	ND	ND	0.08	ND	0.12	0.20	0.07	0.07	ND	ND	ND	ND	ND	ND
F-5	Pant, front, right thigh #2	Unwashed	0.30	0.10	ND	ND	0.56	0.10	0.38	0.40	0.10	0.10	ND	ND	ND	ND	ND	ND
F-65	Pant, front, right thigh #2	Washed and dried	ND	ND	ND	ND	0.06	ND	0.10	0.10	0.06	0.06	ND	ND	ND	ND	ND	ND

Table 4
Phase 4: Analysis of Field Uniform Patches, Analysis in February 2005
(All results reported in µg)

Sample Number	Location		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
F-6	Pant, front, right thigh #3	Unwashed	0.91	0.40	ND	0.20	1.5	0.40	0.88	0.76	0.30	0.20	0.20	ND	ND	ND	ND	ND
F-64	Pant, front, right thigh #3	Washed and dried	ND	ND	ND	ND	0.18	0.08	0.23	0.27	0.10	0.11	0.20	ND	0.10	ND	ND	0.10
F-7	Shirt, top, left elbow #1	Unwashed	0.66	0.20	ND	0.10	0.63	0.20	0.35	0.30	0.10	0.10	ND	ND	ND	ND	ND	ND
F-59	Shirt, top left elbow #1	Washed and dried	0.43	0.10	ND	0.12	0.50	0.20	0.45	0.54	0.24	0.18	0.44	0.20	0.30	0.20	0.10	0.33
F-8	Shirt, top, left elbow #2	Unwashed	0.40	0.10	ND	ND	0.40	ND	0.20	0.20	0.10	ND	ND	ND	ND	ND	ND	ND
F-60	Shirt, top left elbow #2	Washed and dried	0.26	0.06	ND	0.07	0.25	0.09	0.26	0.28	0.10	0.10	0.30	0.10	0.20	ND	ND	0.20
F-9	Pant, front, left, knee	Unwashed	0.63	0.20	ND	0.10	0.86	0.20	0.48	0.40	0.20	0.10	ND	ND	ND	ND	ND	ND
F-57	Pant, front, left knee	Washed and dried	ND	ND	ND	ND	0.07	ND	0.12	0.10	0.07	0.07	0.10	ND	ND	ND	ND	ND
F-10	Pant, front, left shin #1	Unwashed	0.40	0.20	ND	ND	0.72	0.20	0.37	0.48	0.20	0.10	ND	ND	ND	ND	ND	ND
F-55	Pant, front,left shin #1	Washed and dried	ND	ND	ND	0.04	0.15	ND	0.21	0.24	0.10	0.10	0.10	0.09	0.10	ND	ND	0.10

Table 4
Phase 4: Analysis of Field Uniform Patches, Analysis in February 2005
(All results reported in µg)

Sample Number	Location		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
F-11	Pant, front, left shin #2	Unwashed	ND	ND	ND	ND	0.40	ND	0.20	0.20	ND	ND	ND	ND	ND	ND	ND	ND
F-58	Pant, front, left shin #2	Washed and dried	ND	ND	ND	ND	0.07	ND	0.11	0.10	0.07	0.05	ND	ND	ND	ND	ND	ND
F-12	Pant, back, left cuff	Unwashed	2.4	1.3	0.20	0.77	5.4	1.3	3.5	2.9	1.2	1.3	1.3	0.50	0.99	0.70	0.60	0.50
F-51	Pant, back, left cuff	Washed and dried	ND	ND	ND	ND	0.10	0.06	0.20	0.20	0.10	0.09	0.20	0.20	ND	ND	ND	ND
F-13	Pant, front, right shin #1	Unwashed	0.50	0.20	ND	0.10	0.83	0.20	0.46	0.44	0.10	0.10	ND	ND	ND	ND	ND	ND
F-56	Pant, front, right shin #!	Washed and dried	ND	ND	ND	ND	0.13	ND	0.16	0.20	0.08	0.07	0.10	ND	0.08	ND	ND	0.09
F-14	Pant, front, right shin #2	Unwashed	ND	ND	ND	ND	0.50	0.10	0.20	0.20	ND	ND	ND	ND	ND	ND	ND	ND
F-54	Pant, front, right shin #2	Washed and dried	ND	ND	ND	ND	0.08	ND	0.14	0.15	0.09	0.06	ND	ND	ND	ND	ND	ND
F-15	Pant, front, left cuff	Unwashed	ND	ND	ND	ND	0.50	ND	0.20	0.20	ND	ND	ND	ND	ND	ND	ND	ND
F-50	Pant, front, left cuff	Washed and dried	ND	ND	ND	ND	0.09	ND	0.11	0.11	0.05	ND	ND	ND	ND	ND	ND	ND

Table 4
Phase 4: Analysis of Field Uniform Patches, Analysis in February 2005
(All results reported in µg)

Sample Number	Location		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
F-16	Pant, front, right knee	Unwashed	0.30	0.20	ND	0.10	0.88	0.20	0.48	0.40	0.20	0.10	ND	ND	ND	ND	ND	ND
F-52	Pant, front, right knee	Washed and dried	ND	ND	ND	ND	0.10	0.04	0.17	0.17	0.07	0.06	ND	ND	ND	ND	ND	ND
F-17	Pant, front, right cuff	Unwashed	0.20	0.10	ND	ND	0.76	0.20	0.43	0.30	0.20	ND	ND	ND	ND	ND	ND	ND
F-53	Pant, front, right cuff	Washed and dried	ND	ND	ND	ND	0.10	0.05	0.19	0.20	0.09	0.07	ND	ND	ND	ND	ND	ND
F-18	Shirt, top, right, elbow	Unwashed	0.40	0.10	ND	ND	0.50	0.10	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND
F-49	Shirt, top right elbow	Washed and dried	0.36	0.09	ND	0.09	0.47	0.16	0.48	0.44	0.25	0.20	0.34	0.10	0.25	ND	0.20	0.30
F-19	Pant, back, right cuff	Unwashed	0.93	0.49	0.09	0.30	2.0	0.45	1.2	1.2	0.43	0.42	0.40	0.14	0.33	ND	0.20	0.10
F-48	Pant, back, right cuff	Washed and dried	0.20	0.04	ND	0.10	0.42	0.11	0.29	0.27	0.20	0.10	0.10	ND	0.10	ND	ND	ND
F-20	Shirt, top, right upper arm	Unwashed	0.62	0.17	ND	0.10	0.77	0.20	0.47	0.55	0.21	0.20	0.22	0.06	0.20	ND	0.09	0.09
F-47	Shirt, top, right upper arm	Washed and dried	0.30	0.05	ND	0.06	0.32	0.12	31	0.30	0.20	0.10	0.20	0.08	0.20	ND	ND	0.20

Table 4
Phase 4: Analysis of Field Uniform Patches, Analysis in February 2005
(All results reported in µg)

Sample Number	Location		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Investigator #664																		
F-21	Pant, right knee #1	Unwashed	0.73	0.27	ND	0.20	1.3	0.31	0.77	0.81	0.26	0.26	0.21	0.09	0.18	ND	0.10	0.09
F-43	Pant, right knee #1	Washed and dried	ND	ND	ND	ND	0.10	0.04	0.24	0.20	0.09	0.09	0.10	0.10	0.20	ND	0.20	0.20
F-22	Pant, right knee #2	Unwashed	0.42	0.17	ND	0.10	0.83	0.20	0.51	0.60	0.21	0.18	0.20	0.06	0.15	ND	ND	ND
F-44	Pant, right knee #2	Washed and dried	ND	ND	ND	ND	0.10	0.04	0.18	0.18	0.09	0.08	0.01	ND	0.20	ND	0.10	0.10
F-23	Pant, left knee #1	Unwashed	1.7	0.57	0.07	0.28	1.9	0.45	0.97	1.1	0.30	0.28	0.26	0.09	0.21	ND	0.10	ND
F-41	Pant, left knee #1	Washed and dried	ND	ND	ND	ND	0.10	0.05	0.14	0.14	0.07	0.08	0.10	0.10	0.20	0.37	0.31	0.38
F-24	Pant, left knee #2	Unwashed	0.37	0.17	ND	0.10	0.94	0.23	0.53	0.73	0.20	0.19	0.20	0.08	0.16	ND	0.09	0.09
F-42	Pant, left knee #2	Washed and dried	ND	ND	ND	ND	0.10	0.06	0.27	0.22	0.10	0.08	0.20	0.09	0.20	0.20	0.20	0.20
F-25	Shirt, right arm cuff #1	Unwashed	0.51	0.13	ND	0.06	0.44	0.10	0.20	0.22	0.06	0.05	ND	ND	ND	ND	ND	ND
F-45	Shirt, top right cuff #1	Washed and dried	0.30	ND	ND	0.05	0.26	0.11	0.36	0.22	0.10	0.10	0.20	0.10	0.20	0.20	0.20	0.20

Table 4
Phase 4: Analysis of Field Uniform Patches, Analysis in February 2005
(All results reported in µg)

Sample Number	Location		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
F-26	Shirt, right arm cuff #2	Unwashed	2.5	0.44	0.12	0.30	0.88	0.20	0.29	0.38	0.09	0.08	ND	ND	0.07	ND	ND	ND
F-46	Shirt, top right cuff #2	Washed and dried	1.4	0.16	0.10	0.22	0.65	0.20	0.72	0.60	0.26	0.20	0.40	0.20	0.26	0.25	0.30	0.39
Limit of Detection Range			0.05-0.20	0.04-0.10	0.04-0.10	0.04-0.10	0.04-0.10	0.04-0.10	0.04-0.09	0.04-0.10	0.04-0.10	0.04-0.10	0.06-0.20	0.04-0.20	0.04-0.20	0.06-0.40	0.06-0.30	0.08-0.30
Limit of Quantification Range			0.20-0.50	0.10-0.40	0.10-0.30	0.10-0.30	0.10-0.50	0.10-0.40	0.10-0.30	0.10-0.40	0.10-0.40	0.10-0.40	0.20-0.60	0.10-0.60	0.08-0.70	0.20-1.0	0.20-1.0	0.30-0.90

ND= Parameter not detected above the limit of detection (LOD).

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