A Health Hazard Evaluation of Antimony Exposure in Fire Fighters

Marie A. de Perio, MD, Srinivas Durgam, MSPH, MSChE, CIH, Kathleen L. Caldwell, PhD, and Judith Eisenberg, MD, MS

Objectives: Some firefighter station uniforms contain the flame-retardant, antimony trioxide. National Institute for Occupational Safety and Health investigated a possible outbreak of antimony toxicity wherein 30 firefighters reported elevated antimony levels on hair analyses. **Methods:** We surveyed and collected urine samples from firefighters not wearing (Fire Department A) and wearing (Fire Department B) antimony-containing pants. Urine antimony concentrations were measured and adjusted for creatinine. **Results:** All 20 participating firefighters from Fire Department A and 41 (97.6%) of 42 participating firefighters from Fire Department B had urine antimony concentrations below or within the national reference range. No differences in urine antimony levels between departments were detected. **Conclusions:** Wearing antimony-containing uniforms does not pose a risk for antimony toxicity. This investigation highlights the importance of using validated methods for toxicity determination and of accurate, timely risk communication.

Antimony oxides, in combination with halogens, have been used as flame retardants in textiles, plastics, rubber, adhesives, and paper since the 1960s.[1–3] Antimony is a silver-white metal that is found at very low levels throughout the environment. Most of the general population in the United States is exposed to low levels of antimony every day, primarily in food, drinking water, and air.[4] Signs and symptoms of chronic antimony toxicity include headache, sleeplessness, dizziness, metallic taste, weight loss, nausea, vomiting, diarrhea, impairment of sense of smell, and pain or tightness in the chest.[5]

In October 2008, the Centers for Disease Control and Prevention's (CDC) National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the Fire Chief at Fire Department A regarding a possible outbreak of antimony toxicity. Many of the department's 199 firefighters expressed concerns about their possible exposure to antimony through their station uniform pants made from FireWear fabric.

FireWear fabric (Spring Industries, Incorporated, Fort Mill, SC) consists of 55% fibrous flame retardant (FFR) fiber and 45% cotton. The FFR fiber is a patented, engineered modacrylic, consisting of the Protex fiber (Kaneka Corporation, Osaka, Japan) and contains antimony trioxide and a chloride component for their flame retardant properties. Station uniforms made from FireWear fabric meet the requirements set by the National Fire Protection Association (NFPA) 1975: Standard on Station/Work Uniforms for Emergency Services.[6] Other uniforms that comply with NFPA 1975 include those made from cotton, wool, or other flame resistant fabrics. Uniform pants made from FireWear fabric are widely worn by fire departments across the United States, including departments in large metropolitan areas.

In the weeks before the HHE request, unexplained neurologic symptoms in one firefighter prompted 29 additional firefighters to undergo hair testing for heavy metals, ordered by a local physician. All firefighters were reported to have elevated antimony levels in their hair samples. All hair samples were analyzed by the same commercial laboratory. Although many of these firefighters did not report any symptoms, those that did reported fatigue, headache, muscle cramps, and joint pain. Some firefighters at Fire Department A hypothesized that they had been exposed to antimony through their station uniform pants made from FireWear fabric. Fire Department A recalled the pants from firefighters in early October 2008 as a result of these concerns.

Media reports and firefighter on-line blogs caused national concern over the safety of these uniform pants made from antimony-containing fabric. Fire departments and firefighter unions across the country contacted NIOSH with concern, and multiple fire departments discontinued use of these pants. We asked the Acting Fire Chief at Fire Department B (also in Florida) to participate in our evaluation because its firefighters were still wearing uniform pants made from FireWear fabric.

The objectives of our evaluation were to measure concentrations of antimony among firefighters using the validated and reliable method of urine testing, to compare concentrations between firefighters that were wearing and not wearing pants made from FireWear fabric, and to describe the occupational risk factors associated with elevated concentrations of antimony.

METHODS

The 112 invited participants at Fire Department A included 42 on-duty firefighters, 50 additional firefighters who had submitted workers' compensation claims, and 20 chief officers and fire inspectors. At Fire Department B, 42 of the 96 firefighters were invited to participate because they had worn pants made from FireWear fabric in the previous 2 weeks. A 2-week cutoff was chosen because the half-life of antimony in urine is ~95 hours.[7]

After obtaining informed consent, we administered questionnaires to participants that included questions concerning personal characteristics, work history, and possible sources of exposure to antimony. For our job title classification, the firefighter category included firefighters, firefighter-drivers, and firefighter-paramedics. Company officers included lieutenants and captains, whereas chief officers included battalion, assistant, division, and fire chiefs.

We collected spot urine samples to measure antimony. The urine samples were shipped on dry ice to the Inorganic Toxicology Laboratory in the Division of Laboratory Sciences at the National Center for Environmental Health, CDC, in Atlanta, Georgia. Urine concentrations of antimony were measured by inductively

From the Division of Surveillance, Hazard Evaluations, and Field Studies, (Dr de Perio, Mr Durgam, Dr Eisenberg), Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, Ohio; and Division of Laboratory Services (Dr Caldwell), Centers for Disease Control and Prevention, National Center for Environmental Health, Atlanta, Ga.

All authors have contributed significantly to the work and have reviewed and approved the manuscript.

The findings and conclusions in this report are those of the authors and do not necessarily represent the view of NIOSH.

None of the authors have any potential conflicts of interest, and we have not received any external funding for this project.

Address correspondence to: Marie A. de Perio, MD, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Pkwy, R-10, Cincinnati, OH 45226; E-mail: Mdeperio@cdc.gov.

DOI: 10.1097/JOM.0b013e3181c7514a

coupled dynamic reaction cell plasma mass spectrometry following published protocols.[8] Urine specimens were analyzed for creatinine using a commercial enzymatic kit (Roche Diagnostics, Indianapolis, IN). The antimony concentrations were then adjusted for urine creatinine.

The analytical limit of detection (LOD) for antimony is 0.032 micrograms per liter (μg/L), and the national reference range for antimony in the urine is 0.130 to 0.340 μg/L or 0.120 to 0.364 micrograms per gram (μg/g creatinine).[9] The national reference range is based on National Health and Nutrition Examination Survey (NHANES) data from 2690 individuals, a representative sample of the civilian, non-institutionalized population in the United States.[9] The geometric mean urine antimony concentration for the general population is 0.134 μg/L or 0.126 μg/g creatinine.[9]

Each participant was informed in writing of his or her individual urine test results and their significance. As a public health response, per the guidelines of Title 45 Code of Federal Regulations part 46, this clinical evaluation was determined to not require review by an institutional review board.

Statistical analysis was performed using SAS 9.2 (SAS Institute, Cary, North Carolina). We calculated means and proportions of variables from the questionnaire. We also calculated the geometric mean urine antimony concentrations for both Fire Department A and B participants. Concentrations less than the LOD were assigned a value equal to the LOD divided by the square root of 2.[10] Because urine antimony concentrations were log normally distributed among participants, we compared the means of the log transformed values for urine antimony concentrations between participant groups using the *t* test.

RESULTS

Questionnaire Results

Twenty of 112 invited Fire Department A firefighters participated. Fire Department A participants included 2 firefighters, 3 company officers, 3 fire inspectors, and 12 chief officers. Four non-firefighter civilian employees also participated, giving a total of 24 Fire Department A participants. All 42 Fire Department B firefighters, who had worn pants made from FireWear fabric in the previous 2 weeks, participated. The participants included 29 firefighters, nine company officers, two fire inspectors, and two chief officers. Demographic and work characteristics of both Fire Departments A and B participants are shown in Table 1.

None of the participating Fire Department A employees had worn pants made from FireWear fabric in the preceding 4 months. Fire Department B participants wore FireWear pants for a mean of 92 hours, or close to four 24-hour shifts, during the previous 2 weeks. Fire Department B participants reported wearing the FireWear pants for a mean of 4 years and owned a mean of four pairs of the pants.

Urine Antimony Measurements

Four Fire Department A participants and nine Fire Department B participants were found to have urine antimony concentrations below the analytical LOD of 0.032 μg/L. All Fire Department A participants and all but one Fire Department B participants were found to have creatinine corrected urine antimony concentrations below or within the national reference range of 0.120 to 0.364 μg/g creatinine for the general population.[9] One Fire Department B participant had a urine antimony concentration of 0.366 μg/g creatinine, a negligible difference from the upper limit of the national reference range. The range of urine antimony concentrations for Fire Department A participants was 0.027 to 0.285 μg/g creatinine, whereas the range of urine antimony concentrations for Fire Department B participants was 0.017 to 0.366 μg/g creatinine.

TABLE 1. Characteristics of Participants

Demographic Characteristic	Fire Department A, No. (%) (n = 24)	Fire Department B, No. (%) (n = 42)
Age (yr) (mean)	49.3	39.0
Male, sex	23 (95.8%)	39 (92.9%)
Current smoker	2 (8.3%)	1 (2.4%)
Job title*		
Fire fighter	2 (8.3%)	29 (69.0%)
Company officer	3 (12.5%)	9 (21.4%)
Inspector	3 (12.5%)	2 (4.8%)
Chief officer	12 (50.0%)	2 (4.8%)
Civilian employee	4 (16.7%)	0 (0%)
Years as fire fighter (mean)	25.8	12.7
Years at fire department A or B (mean)	22.8	10.9

*The fire fighter job title category included fire fighters, fire fighter-drivers, and fire fighter-paramedics. Company officers included lieutenants and captains, while chief officers included battalion, assistant, division, and fire chiefs.

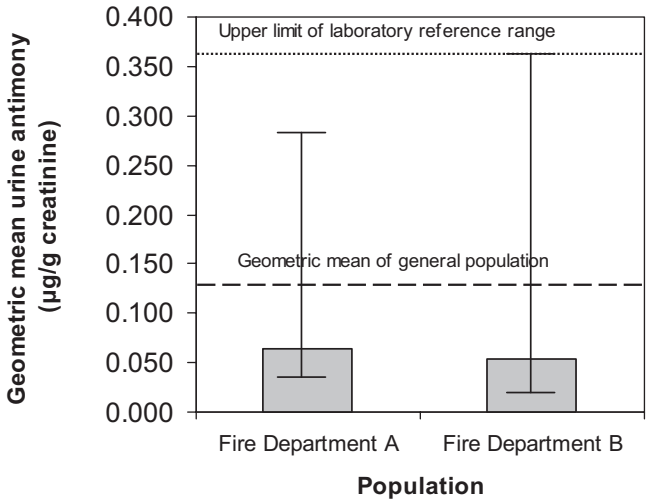

FIGURE 1. Geometric mean urine antimony concentrations with ranges.

The geometric mean urine antimony concentration was 0.063 μg/g creatinine for Fire Department A participants, 0.054 μg/g creatinine for Fire Department B participants, and 0.126 μg/g creatinine for the general population (shown in Fig. 1).[9] The means of the log transformed urine antimony concentrations of Fire Department A and B participants were not significantly different (P = 0.31). Nevertheless, the mean of the log transformed urine antimony concentrations of Fire Department A and B participants was significantly lower than that of the general population ($P <$ 0.001). Only two Fire Department A (8.3%) participants and four Fire Department B (9.5%) participants had urine antimony concentrations higher than the geometric mean for the general population.

Urine antimony concentrations were similar between the 62 fire service employees and the 4 civilian employees. Urine antimony concentrations were also similar between the 22 firefighters who had participated in a live fire response in the preceding weeks and the 40 firefighters who had not. In addition, urine antimony concentrations were similar between a group comprised of firefighters and company officers and another group comprised of inspectors and chief officers.

None of the participants from either fire department reported participating in other work activities that might expose them to antimony, including metal smelting or battery, ceramics, and flame-retardant materials manufacturing. In addition, none of the participants reported being treated with pentavalent antimony, also known as sodium stibogluconate or Pentostam for any parasitic diseases in the previous 2 weeks.

Urine antimony concentrations of the four participants who reported shooting of firearms in the previous 2 weeks and those that did not were similar. Urine antimony concentrations were also similar between the three participants who were current smokers and those who were non-smokers.

DISCUSSION

We found that firefighters from Fire Departments A and B had urine antimony concentrations that fell below or within the normal range for the general population whether or not they were wearing pants made from FireWear fabric. Our results indicated that wearing these pants did not pose a risk for antimony toxicity. In addition, it did not appear that firefighters at these fire departments were exposed to high levels of antimony during the course of their work.

Edelman et al reported the only previously published study concerning the exposure of firefighters to antimony. They found that urine antimony concentrations of firefighters responding to the World Trade Center fires and collapse were significantly higher than those of New York City firefighters who were assigned to office duties as a result of prior injury (0.203 vs 0.165 μg/L, $P < 0.01$).[11] These firefighters were wearing no clothing or gear containing antimony compounds so their exposures could have been either through products of combustion, smoking, or through normal environmental exposures. For example, when plastics, upholstery, or other fabric made with antimony-containing fire retardant fibers burns, the ashes remaining could represent a source of antimony exposure.

Our investigation found that urine antimony concentrations were similar between firefighters who had participated in a live fire response the preceding 2 weeks and firefighters who had not. Nevertheless, our group of firefighters who had participated in a live fire response participated in a mean of 1.5 fires during this time, which likely represents significantly less exposure to combustion products than the World Trade Center firefighters likely experienced. In addition, our investigation revealed that, on average, firefighters from both departments had urine antimony concentrations that fell below the average level for the general population. The possible reasons for this difference include regional differences in the amount of antimony present in food and drinking water and random variation that can be found when comparing a small group to a large group. It is important to emphasize that concentrations among World Trade Center firefighters were still within the reference range found in the general population, as was found in our population.[9]

No studies have been published about the health effects after dermal exposure to antimony or about dermal absorption of antimony in humans.[4] Our results indicate that no significant dermal exposure occurs in firefighters who wear pants containing antimony. On the basis of these findings, we recommended that Fire Departments A and B continue to issue, and its firefighters continue to wear station uniforms that comply with the NFPA 1975: Standard on Station/Work Uniforms for Emergency Services.[6]

Our evaluation had some limitations. We were unable to elucidate the etiology of the index firefighter's neurologic symptoms, because this was beyond the scope of the HHE. Nevertheless, neurological effects have not been observed in humans after inhalation, oral, or intravenous exposure to antimony.[4] Firefighters have been found to have a high incidence of acute pesticide-related illness, which may lead to neurological health effects compared to other occupational groups.[12] Nevertheless, neurological disease in general among firefighters has not been well described in the literature. Although the index firefighter declined to participate in our evaluation, this firefighter's original urine antimony concentration performed by his personal physician was within the normal range.

We did not account for the aging of the FireWear fabric of the uniform pants of FD-B participants in the analysis. It is possible that the aging of the fabric might increase potential skin exposure and absorption, but we do know that FD-B participants had been wearing pants made from FireWear fabric for 4 years. It is less likely that exposure to heat or chemicals at the fire scene could increase potential skin exposure and absorption because we did not find any differences in antimony concentrations between fighters who had participated in a live fire response the preceding 2 weeks and firefighters who had not.

Testing of the pants for leaching of antimony compounds was not thought to be necessary and was not conducted as part of this evaluation. If antimony was being released from the pants and absorbed through the skin, the urine tests would have indicated that firefighters wearing pants made from FireWear fabric had levels higher than the U.S. population and the firefighters not wearing these pants. We found neither of these scenarios in our HHE.

Our investigation highlights the importance of using validated methods for toxicity determination. The decision to perform laboratory testing for heavy metals, including antimony, should be based on whether documented health symptoms are consistent with overexposure to these metals. Urine testing is the most reliable and valid test method for measuring antimony concentrations in the body.[13] CDC has established reference ranges for urine concentrations of antimony for the general population.[9]

Hair testing is not a reliable or valid method for measuring concentrations of heavy metals in the body, except for methylmercury.[14] It is not recommended by the American Medical Association[15] or the Agency for Toxic Substances and Diseases Registry[16] for heavy metals, and it has many limitations. First, accepted standards on methods of collection, storage, and analysis of hair are lacking. Second, problems exist with the regulation and certification of laboratories conducting hair analysis. It has been shown that different laboratories can report different results for hair samples collected from the same person and can report different reference ranges.[17] Third, reference ranges have not been established by CDC or other groups for hair concentrations of antimony for the general population. Fourth, hair analysis cannot distinguish between internal and external exposure. Fifth, hair analysis for heavy metals does not predict toxicity or disease.[14] Because results from elemental hair analysis do not provide sufficient evidence of heavy metal toxicity, they should not be used to justify searching the workplace for exposures or to treat heavy metal toxicity.

Our investigation also highlights the public health importance of effectively communicating accurate information. During the investigation, we learned that many of the Fire Department A firefighters had received inaccurate medical information from both their personal physician and the Internet that urine testing was inferior to hair testing for heavy metals. Media reports and firefighter blogs, containing both reliable and unreliable information, then spread national concern over the safety of the uniform pants, and NIOSH was contacted by concerned firefighters, fire chiefs, and union leaders nationwide.

In response to this situation of low hazard and high outrage,[18] we recognized a need to disseminate accurate and timely information. Before the site visit to both fire departments, we distributed information about antimony, the shortcomings of

hair analysis, and our planned HHE. An NIOSH health communication specialist also accompanied the team in this investigation. Shortly, after the site visit, we posted frequently asked questions and answers about the evaluation on the NIOSH web site at http://www.cdc.gov/niosh/fire/spotlight.html, the International Association of Fire Fighters web site, and a national web site devoted to firefighter safety and survival. The final HHE report is now accessible to the public on the NIOSH web site at www.cdc.gov/niosh/hhe.

We conclude that wearing pants made from FireWear fabric did not pose a health hazard from antimony exposure. Reliable and recommended testing methods with well-validated reference ranges should be used to measure the concentration of heavy metals in the body when health symptoms are consistent with overexposure to these metals.

REFERENCES

1. Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological Profile for Antimony.* Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service; 1992.
2. Carson BL, Ellis HV, McCann JL. *Toxicology and Biological Monitoring of Metals in Humans.* Chelsea, MI: Lewis; 1986:21–26.
3. Stokinger HE. The metals: 2. Antimony, Sb. In: Clayton GD, Clayton FE, eds. *Patty's Industrial Hygiene and Toxicology.* 3rd ed. Vol. IIA. New York: Wiley-Interscience; 1981:1505–1517.
4. Winship KA. Toxicity of antimony and its compounds. *Adverse Drug React Acute Poisoning Rev*. 1987;6:67–90.
5. U.S. Department of Health and Human Services [1988]. *Occupational Safety and Health Guideline for Antimony and its Compounds.* 1988. Available at: http://www.cdc.gov/Niosh/pdfs/0036.pdf. Accessed March 2009.
6. National Fire Protection Association (NFPA). NFPA 1975: *Standard on Station/Work Uniforms for Emergency Services,* 2009 Edition. Quincy, MA: National Fire Protection Association; 2009.
7. Kentner M, Leinemann M, Schaller KH, Weltle D, Lehnert G. External and internal antimony exposure in starter battery production. *Int Arch Occup Environ Health*. 1995;67:119–123.
8. Caldwell K, Hartel J, Jarrett J, Jones RL. Inductively coupled plasma mass spectrometry to measure multiple toxic elements in urine in NHANES 1999–2000. *At Spectrosc*. 2005;26:1–7.
9. Centers for Disease Control and Prevention (CDC). *Third National Report on Human Exposure to Environmental Chemicals.* Atlanta, GA: U.S. Department of Health and Human Services; 2005:15–17.
10. Taylor JK. *Quality Assurance of Chemical Measurements.* Chelsea, MI: Lewis Publishers; 1987:79–83.
11. Edelman P, Osterloh J, Pirkle J, et al. Biomonitoring of chemical exposure among New York City fire fighters responding to the World Trade Center fire and collapse. *Environ Health Perspect*. 2003;111:1906–1911.
12. Calvert GM, Barnett B, Mehler LN, et al. Acute pesticide-related illness among emergency responders, 1993–2002. *Am J Ind Med*. 2006;49:383–393.
13. Goldfrank L, Flomenbaum N, Lewin N, et al. *Goldfrank's Toxicologic Emergencies.* 8th ed. New York: McGraw-Hill Professional; 2006:1244–1250.
14. Harkins DK, Susten AS. Hair analysis: exploring the state of the science. *Environ Health Perspect*. 2003;111:576–578.
15. American Medical Association (AMA). *Hair Analysis: A Potential for Abuse. Policy No. H-175.995*. Chicago, IL: American Medical Association; 1994. Reaffirmed 2004.
16. Agency for Toxic Substances and Disease Registry (ATSDR). *Hair Analysis Panel Discussion: Exploring the State of the Science. Summary Report.* Atlanta, GA: U.S. Department of Health and Human Services; 2001. Available at: http://www.atsdr.cdc.gov/hac/hair_analysis/index.html. Accessed March 2009.
17. Seidel S, Kreutzer R, Smith D, McNeel S, Gilliss D. Assessment of commercial laboratories performing hair mineral analysis. *JAMA*. 2001;285:67–72.
18. Covello V, Sandman PM. Risk communication: evolution and Revolution. In: Anthony Wolbarst, ed. *Solutions to an Environment in Peril.* Baltimore, MD: John Hopkins University Press; 2001:164–178.