An evaluation of respiratory health at a syntactic foam manufacturing facility

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation.

Highlights of this Evaluation

In March 2012, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation at a syntactic foam manufacturing facility in Massachusetts. The employees submitted the request because of concerns about exposures to various chemicals and respiratory, skin, and eye problems related to their work. We visited the facility in July 2012, and administered a health and work history questionnaire in August 2013.

What NIOSH Did

- In July 2012, we toured the main production areas, the research and development/ maintenance shop, and the shipping and receiving/paint shop building to understand work processes and conditions.
- We interviewed production managers, safety managers, and current and former employees.
- We collected air samples for volatile organic compounds and amines.
- In August 2013, we administered a questionnaire to current employees.

In response to employee concerns and a past 9-person cluster of work-related asthma recognized by state public health authorities, we interviewed current employees and assessed preventive measures in a syntactic foam manufacturing facility. Employees' risk of new onset asthma increased 12 times after hire, requiring additional prevention measures.

What NIOSH Found

- Nine of the facility's employees had been diagnosed with work-related asthma and reported to the Massachusetts Department of Public Health from 2008 to 2012.
- The Massachusetts Department of Public Health visited the site in 2010, and made recommendations about hazard communication, respiratory protection, and medical surveillance.
- The facility had some controls and practices in place to limit employees' exposure.
- Some controls and practices needed improvement.
- We did not detect any amines in the air samples collected.
- We detected, using evacuated canisters, the highest instantaneous concentration of volatile organic compounds in the painting area followed by the tumbler meter mix station.
- Real-time total particle concentrations were highest in the Bay 3 grinding area followed by the Bay 1 tumbler mezzanine.
- Real-time total volatile organic compound measurements indicated peak concentrations

were considerably elevated above background in the Bay 1 chemical storage area and in the Bay 1 tumbler mezzanine.

- Employees work with chemicals that are known asthmagens, sensitizing agents, and/or potential respiratory, skin and eye irritants.
- English was not the primary language for a large proportion of the workforce.
- The most commonly reported symptom was skin rash. Other commonly reported symptoms included eye symptoms, cough, asthma-like symptoms, and nasal allergies.
- Six of 154 participating employees reported being diagnosed with asthma after hire.
- Post-hire adult-onset asthma incidence was about 12 times higher than pre-hire adult-onset asthma incidence.
- Employees with five or more years tenure were more likely to report symptoms and more use of asthma medications.
- Employees in production areas reported more respiratory symptoms than those who did not spend time in production areas.
- Rash and work-related rash were more common in production and production support employees.

What the Employer Can Do

- Complete the respiratory protection program, based on the Occupational Safety and Health Administration respiratory protection standard, 29 Code of Federal Regulations 1910.134. We recommend quantitative fit testing for respirator use for all employees and staff who enter production areas. Encourage employees to report new or ongoing respiratory symptoms or skin problems.
- Send any employees with respiratory symptoms to occupational medicine physicians with expertise in occupational lung diseases.
- Investigate reported skin problems to determine if additional controls or personal protective equipment are needed to prevent skin contact with process materials.
- Reduce exposures to irritants and sensitizers with additional engineering controls.
- Perform air monitoring to ensure the success of any improvements or changes made to the plant, to identify any areas that need to be further improved, and to ensure ongoing status of improvements.
- For any material containers that are "re-purposed," remove original labels and replace with new labels with date and appropriate waste stream.
- Eliminate all dry sweeping in the plant. Vacuum cleaning with high-efficiency particulate air filters is a potential alternative.
- Move hanging racks with clean worker uniforms out of the production area to avoid contamination.

- Provide signage in additional languages (such as Portuguese) as necessary to improve hazard communication with employees who do not speak English. Continue to augment word-based signs with symbol-based signs, as some employees may have limited reading skills.

What Employees Can Do

- Wear personal protective equipment, such as respirators and gloves, as instructed by your employer.
- Participate in medical testing and air sampling offered by your employer.
- Keep chemicals off your skin. Wash hands or any exposed skin with soap and water after contact with chemicals. Wash your hands before and after wearing gloves.
- Wash your hands before eating, drinking, or smoking.
- Report respiratory symptoms or skin problems to the plant health and safety official and your physician.
- If you smoke, try to quit. Your physician may be able to help.

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Abbreviations

APR	Air-purifying respirator
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
EPS	Expanded polystyrene
GEC	Goldman Environmental Consultants, Inc.
HEPA	High-efficiency particulate air
mg/m3	Milligrams per cubic meter
MSDS	Material Safety Data Sheet
NIOSH	National Institute for Occupational Safety and Health
OHSP	Occupational Health Surveillance Program
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
ppb	Parts per billion
PPE	Personal protective equipment
ppm	Parts per million
R&D	Research and Development
REL	Recommended exposure limit
VOC	Volatile organic compound

Introduction

The Occupational Health Surveillance Program (OHSP) at the Massachusetts Department of Public Health conducts surveillance for work-related asthma. Starting in 2008, OHSP began receiving reports of work-related asthma in employees at a syntactic foam manufacturing facility. A total of nine cases was reported by six different physicians through 2012. The onset of the first asthma cases reportedly occurred after process changes in the facility that occurred in 2008. In response to these reports, OHSP visited the site in January and April 2010, provided recommendations, and encouraged the company to contact the National Institute for Occupational Safety and Health (NIOSH) to request a health hazard evaluation.

In March 2012, NIOSH received a confidential employee request for a health hazard evaluation at the same facility in Massachusetts. Employees expressed concern about exposure to various chemicals and respiratory, skin, and eye health effects. The facility had been acquired by a new corporation in October 2011. The new management was aware that employees were working with dermal and respiratory sensitizers and recognized that improvements were needed. NIOSH visited the facility on two occasions, July 2012 and August 2013.

Work-related asthma refers to asthma that is brought on by ("occupational asthma") or made worse by ("work-exacerbated asthma") workplace exposures [Tarlo and Lemiere 2014; Henneberger et al. 2011]. It includes asthma due to sensitizers, which cause disease through immune (allergic) mechanisms, and asthma due to irritants, which cause disease through non-immune mechanisms. Symptoms of work-related asthma include episodic shortness of breath, cough, wheeze, and chest tightness. The symptoms may begin early in a work shift, towards the end of a shift, or hours after a shift. They generally improve or remit during periods away from work, such as on weekends or holidays.

Process Description

The company manufactured syntactic foam flotation modules/devices for use in the offshore oil and gas industry. The production area occupied approximately 70,000 square feet. Research and development (R&D) and the maintenance shop were housed in a building across the street from the main production facility, and painting and shipping and receiving activities occurred in a separate building adjacent to the main production facility. As of July 2012, there were approximately 150 employees, about 115 of whom were in production-area jobs.

A variety of materials were used in the manufacture of the syntactic foam flotation modules including: polystyrene beads, epoxy resins (e.g., bisphenol A, epichlorohydrin, bisphenol A diglycidyl ether), amines (e.g., triethylenetetramine), reactive diluents, carbon fibers, milled fibers, glass microspheres, polyester resin adhesives, anhydrides (e.g., methyltetrahydrophthalic anhydride) and catalysts.

The main production area was divided into three bays. The production process began in Bay 1 with the expansion of polystyrene beads. The beads were loaded into a temperature-controlled hopper before they were fed through a series of steam expanders and cooling hoppers until they reached diameter specifications. The beads were then referred to as expanded polystyrene (EPS) beads.

In the tumbler department, the EPS beads were pneumatically transferred into tumbling machines where they were dried with warm air prior to being coated. The operator used a hand mixer to combine an epoxy resin and a curing agent (amine), which were dispensed from spigots into a five-gallon bucket. The resin mixture was immediately ladled into the tumbler containing the EPS beads. Other materials including carbon fibers, milled fibers, and glass microspheres were also either added by hand or pneumatically transferred to the tumblers during the coating process. The EPS beads were processed for up to three days with multiple coatings depending on the desired properties of the final product. Once the tumbling process was complete, the coated EPS beads were emptied from the tumbler into wooden totes for transfer to the jogging area. At the time of the site visit in July 2012, the machines in the front room of the tumbling department were being modified for automation and enhanced exposure protection as part of a Six Sigma project to reduce exposure to process materials.

The molds (referred to as "tool molds") used to form the modules were prepared in Bay 2 in the mold prep area. In this area, employees hand-applied a mold release coating, a polyester resin adhesive mixture, and pre-cut fiberglass matting to the interior of the mold. The prepared tool mold was transferred to the jogging area.

In the jogging area, the tool mold was positioned vertically in the filling station and the coated EPS beads were pneumatically transferred into the mold from the top. Once the tool mold was filled it was transferred to the vacuum tank.

In the vacuum tank, the tool mold was injected with a foam mixture from meter mix that filled the voids between the beads and suspended the beads relatively equally throughout the mold. The foam mixture consisted of resin, catalyst(s), hardener(s), and microballoons. The filled mold was transferred to a drying oven where it cured for several hours.

After cooling, the module was removed from the mold in the de-molding area. Employees in this area used air chisels on the exterior of the molds and solvents on the interior to remove residual resins before the tool molds were returned to the mold prep area for re-use.

Bay 3 also had mold prep, jogging, vacuum tank, oven, and de-mold areas. The main difference was that the foam mixture used to fill the molds was transferred from meter mix in Bay 2 via conduit to a holding tank for use in Bay 3.

Once the module was unmolded, it was taken to the sandblasting area in Bay 3 where coal slag abrasives were used to clean the surface of the module. Subsequently, the module was taken to the de-flashing room where a reciprocal saw was used to remove flashing, or excessive material from the edges of the module. In the grinding area, employees used hand grinders to remove surface imperfections on the modules in preparation for painting. They also patched small defective areas of the modules with another epoxy resin mixture.

Modules were tested and inspected in the quality assurance department. A module from each batch was evaluated using a hydrostatic test tank that allowed for testing of the module's performance to an equivalent water depth of up to 10,000 feet. If a defect was identified, the module was sent back to the grinding area for patching.

In the painting and shipping and receiving building, adjacent to the main production building, a two-part epoxy coating (base/hardener) was applied by roller to the modules as a cosmetic finish prior to shipment.

Production activities were informed by the company's R&D department, located across the street from the main production building. R&D utilized both wet and dry laboratories for evaluation of the composition of the current foam mixture as well as the development of new formulas using different chemical and temperature combinations. Laboratory space included a chemical mixing area, vacuum tank, and drying ovens.

The maintenance storage and tooling area was located in the same building as R&D. The primary maintenance demands were in bead expansion and the tumbling department. The majority of preventive maintenance activities took place on the weekends. For minor repairs, a small maintenance area was located in Bay 3 of the main production facility near the quality assurance area.

Personal Protective Equipment (PPE)

Employees in the production areas wore company-provided uniforms and were required to wear steel-toed shoes, hard hats, safety glasses/goggles, and nitrile gloves. In some areas employees also wore Tyvek suits and hoods, hearing protection, and respirators. Signage in English and with symbols was present at each of the areas, designating the required PPE.

The Respiratory Protection Program

The company was in the process of developing a respiratory protection program. Those employees required to wear respirators received annual training, medical evaluation, and fit-testing. Other employees who chose to use respirators on a voluntary basis received annual training and reviewed and signed Appendix D (Information for Employees Using Respirators When Not Required under the Standard) of the Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard, 29 Code of Federal Regulations (CFR) 1910.134. Employees who voluntarily wore disposable N-95 filtering facepiece respirators were not subject to the medical evaluation, cleaning, storage, and maintenance provisions of the program.

Methods

To initiate the evaluation, we interviewed requesters and the company's Health and Safety manager and the Quality, Health, Safety and Environment manager. We also reviewed documents including reports from other government agency evaluations, a facility map, contractor-conducted industrial hygiene survey reports, the written respiratory protection program and respirator training materials, hazard communication program, and Occupational Safety and Health Administration (OSHA) Form 300 Logs of Work-related Injuries and Illnesses for 2007-2011.

In preparation for the initial site visit, we learned that a significant proportion of the workforce had emigrated from the Cape Verde Islands and might not be able to communicate easily in English. The greatest need was for translation to Cape Verdean Creole, based on the Portuguese language, and Portuguese.

July 2012 Initial Site Visit

We visited the facility on July 23-24, 2012. During the visit, we held an opening meeting with employer and employee representatives to discuss the request. An interpreter provided real-time English-to-Cape Verdean Creole translation during the meeting. Elise Pechter, an industrial hygienist with the Massachusetts Department of Public Health OHSP, joined us for the opening meeting and facility tour. She had been at the facility on previous occasions in January and April of 2010, in response to reported cases of work-related asthma. We also interviewed a number of employees from a variety of work areas about symptoms and concerns related to their work.

We toured the main production areas, the R&D area, maintenance shop, and the shipping and receiving/paint shop building to observe work processes, work practices, and workplace conditions. We had informative meetings with various management staff, supervisory and team lead staff, and some production employees. Our environmental team collected a total of 18 air samples for amines and volatile organic compounds (VOCs) and ten bulk samples.

Eight air samples for amines were collected on silica gel sorbent tubes and analyzed for 1,2-diaminocyclohexane, hexamethylenediamine, and isophoronediamine. These three analytes were chosen based on a review of MSDSs for products used, communications with the Massachusetts Department of Health, and the availability of analytic methods. Sample locations are shown in Table 1. Each amine sample was collected over a period of 15 minutes at a flow rate of one liter per minute, and was analyzed by NIOSH Method 2007 [NIOSH 1994] modified with the following parameters: sample stabilization occurred upon arrival at the laboratory, and a nitrogen phosphorus detector was used to measure amines.

Ten air samples for VOCs were collected in 450 milliliter (mL) evacuated canisters in the production building and in the painting area of the painting/shipping building (Table 1). The canisters were equipped with instantaneous grab sampling attachments. All canister samples were analyzed in-house at the NIOSH-Morgantown Organics Laboratory using a preconcentrator/gas chromatograph/mass spectrometer system pursuant to a recently published method validation study [LeBouf et al. 2012]. At present, this canister method is partially validated and is in the process of being reviewed for incorporation into the NIOSH Manual of Analytical Methods. Fourteen analytes were quantified; pentane was qualitatively identified by comparison to a National Institute of Standards and Technology (NIST) 2008 Mass Spectral Library with estimated concentrations based on a standard response factor.

We collected ten bulk samples of chemicals used in the production process.

Real-time measurements of airborne particles and VOCs were collected prior to the aforementioned air sampling to identify possible sampling locations and observe processes that may cause fugitive emissions into the workplace. Total particles were measured using a DustTrak-DRX (Model 8533, TSI, Inc., Shoreview, MN) instrument. Total VOCs were measured using a ppbRAE (Model 2000, RAE Systems, Inc., San Jose, CA), which uses photoionization detection with a 10.6 electron volt lamp.

We conducted qualitative smoke tests at the entrance to and around the periphery of the tumblers in Bay 2 and at the ovens in Bay 2 and 3 to evaluate air movement and determine if there was potential for fugitive emissions.

In addition to the interviews conducted onsite with current workers, we also were available to meet with current and former workers during evening hours at a local community center. Interpreters were available for non-English speakers.

During the closing meeting, we again met with employee and employer representatives and shared some initial impressions. We commended the efforts that the company was making to improve conditions for employees, recognizing areas that needed improvement such as the ongoing redesign of the tumbling area. We had a few recommendations based on our observations:

- Complete the respiratory protection program, based on the OSHA respiratory protection standard, 29 CFR 1910.134. We recommended quantitative fit testing for all employees and staff that go into production areas.
- Send any employees with respiratory symptoms to occupational medicine physicians with expertise in occupational lung diseases.
- Perform air monitoring to ensure the success of any improvements or changes made to the plant, to identify any areas that need to be further improved, and to ensure ongoing status of improvements.
- For any containers that are "re-purposed," remove original labels and replace with new labels with date and appropriate waste stream.
- Eliminate dry sweeping in the plant. Vacuum cleaning is a potential alternative.
- Move hanging racks with clean worker uniforms out of the production area to avoid contamination.
- Provide signage in additional languages (such as Portuguese) as necessary to improve

hazard communication with employees who do not speak English. Continue to augment word-based signs with symbol-based signs, as some employees may have limited reading skills.

August 2013 Questionnaire Survey

We returned to the facility from August 8-12, 2013, and invited all current employees to complete an interviewer-administered questionnaire. The questionnaire (Appendix C) included questions from the American Thoracic Society's (ATS) adult respiratory questionnaire [Ferris 1978], the Third National Health and Nutrition Examination Survey (NHANES III) [DHHS 1996], and the European Community Respiratory Health Survey [Grassi et al. 2003]. Questions addressed respiratory and dermatological symptoms, asthma and other diagnoses, smoking history, work history and practices, and demographic information. The questionnaires were available in English, Spanish, and Portuguese. Interpreters fluent in Spanish, Portuguese, and Cape Verdean Creole were available to assist respondents as needed.

Following the questionnaire survey, we mailed letters to each participant at his or her self-provided home address. For those individuals whose responses in the questionnaire indicated the potential need for medical attention, the letters provided recommendations for how to follow-up with a physician. Specifically, we recommended that participants who reported currently having physician-diagnosed asthma or using medication for asthma speak with a doctor to see if their asthma could be related to work. We recommended that participants who did not report having a diagnosis of asthma but did report symptoms consistent with asthma see a doctor to determine if they have asthma, and whether that asthma could be related to their work. All other participants were advised to see a doctor if they developed any breathing problems in the future.

Statistical Methods

We defined asthma-like symptoms as one or more of the following: 1) current use of asthma medicine, 2) wheezing or whistling in the chest in the past 12 months, 3) awakening with a feeling of chest tightness in the past 12 months, or 4) attack of asthma in the past 12 months [Grassi et al. 2003]. We defined work-related symptoms as those that improved away from the facility, either on days off or on vacation.

We estimated the incidence density of physician-diagnosed adult-onset asthma before and after hire at the facility, using participants' self-reported birthdate, hire date, and date of asthma diagnosis. We considered asthma diagnosed after age 18 to be *adult-onset*. Participants with asthma diagnosed before age 18 were excluded from these calculations. All other participants were considered to be at risk for adult-onset asthma during two time periods: from age 18 until hire, and from hire until the date of the interview. For participants diagnosed with adult-onset asthma, risk ended at the date of diagnosis. For *pre-hire asthma* incidence density, we summed the number of adult-onset asthma diagnoses that occurred before hire and divided by the sum of participants' time at risk before hire. For *post-hire asthma* incidence density, we summed the number of adult-onset asthma diagnoses that occurred after hire and divided by the sum of participants' time at risk after hire.

We compared the observed prevalence of wheeze, eye symptoms, and asthma diagnoses among participants to expected values for the U.S. adult population obtained from the Third National Health and Nutrition Examination Survey [DHHS 1996] using indirect standardization for race (white, black, or Mexican-American), sex, age (17–39 years or ≥40 years), and cigarette smoking status (ever or never). We also compared the observed prevalence of asthma diagnoses to the expected values for the Massachusetts adult population obtained from the Behavioral Risk Factor Surveillance System [CDC 2010], using standardization for sex.

To explore potential associations between health problems and work, we examined questionnaire responses by work history characteristics including plant tenure and department. We used work histories to group participants into three categories (administration, production support, and production) based on participants' self-reported current department. "Administration" consisted of all office employees. "Production Support" consisted of maintenance, painting, shipping and receiving, production supervisors, quality assurance, and R&D. "Production" consisted of work in the following areas in Bay 1: mat cutting, bead expansion, and tumbling; Bay 2: demold, joggers, meter mix, mold prep, ovens, sandblast, and vacuum tanks; and Bay 3: grinding, joggers, mold prep, vacuum tanks, and ovens. Because production and production support workers were likely to have similar exposures, we also examined associations when these two groups were combined. We used contingency tables to examine associations; significance was assessed using the chi-square test. We used Fisher's exact test when cell sizes were less than 5.

Statistical analyses were conducted using SAS software version 9.3 and JMP software version 10.0.1 (SAS Institute, Inc., Cary, NC). We considered two-sided $p \le 0.05$ to be statistically significant.

Results

Below we provide the results of our evaluation, which reflect conditions in the facility up to August 2013. Additional information provided by the company to NIOSH on conditions in the facility after August 2013, is found at the end of this report.

Summary of Prior Facility and Industrial Hygiene Evaluations

Occupational Safety and Health Administration (OSHA)

An OSHA inspector visited the facility on December 6, 2007, after receiving a referral. While onsite she toured the facility, conducted employee interviews, and reviewed PPE, hazard communication, respiratory protection programs and training documents, and the OSHA Logs for the period 2005 to 2007. Citations were issued for improper PPE and deficiency of the respiratory protection program.

Goldman Environmental Consultants, Inc. (GEC)

The company provided us with two reports from GEC detailing observations and sampling results during the time period of October 2008, through January 2009. The first sampling campaign on October 6, 2008, was in response to respiratory complaints that reportedly began after changes in the production process in the summer of 2008. Amines and anhydrides used in the chemical composition of the liquid mixture used to coat the EPS beads in tumbling and the liquid used to fill the molds in meter mix were reportedly changed. The ovens were also upgraded to accommodate increased temperatures for curing related to this change.

The GEC report dated November 7, 2008, provides results for samples taken on October 6, 2008, and ventilation observations from November 3, 2008. On October 6, 2008, three vacuum Summa canister samples were collected for formaldehyde in tumbling, pentane in the bead expansion area, and VOCs from the area outside of oven 5 in Bay 2. Formaldehyde was reported to be measured at levels almost 10 times higher than the NIOSH recommended exposure limit (REL) of 0.016 parts per million (ppm) but lower than the OSHA permissible exposure limit (PEL) of 0.75 ppm (value of actual sample result was not reported). Pentane was detected in the sample collected in the mezzanine of the bead expansion area in Bay 1 but reported to be well under the OSHA PEL of 1000 ppm; again, the actual result value was not provided. Low levels of acetone and isopropyl alcohol were detected in the sample collected near oven 5 using the Environmental Protection Agency's (EPA) TO-15 analytical method. The static pressure inside of oven 5 in Bay 2 was measured by GEC on November 3, 2008. Pressure in this oven was found to be positive relative to the room, which would allow for material inside the oven to enter the general workplace air through leaks.

A particulate sample collected in tumbling was reported to have results very near the OSHA maximum limit for respirable particles. Details specific to sample collection and analytical method were not provided, and the actual measured value wasn't provided in the report. Only 25% of the tumblers were reported to be operating at the time the sample was collected.

The report recommendations included adjusting dampers on oven 5, checking and balancing remaining ovens, evaluating engineering controls when chemistry, equipment or process upgrades occur, reviewing PPE, and reviewing ventilation systems. The report specifically mentioned the ovens, bead expansion, tumbling room, grinding, and painting operation as areas where ventilation needed to be improved.

The second GEC report was dated February 23, 2009, and provided summaries of conversations, testing, and sampling that occurred at various times in the month of January 2009. On January 9, 2009, GEC met with facility management to discuss a variety of topics including:

- chemicals thought to be related to respiratory complaints;
- feedback to GEC from five analytical laboratories on method development for

1,2-cyclohexanediamine and methyltetrahydrophthalic anhydride;

- dates and nature of chemical changes;
- oven temperatures pre- and post- August 2008 upgrades;
- process areas where there were complaints;
- extent of ventilation work;
- use of occupational medical provider; and
- recommended approaches for developing a plan to address employee concerns.

The report summarized observations from each of the production areas. In Bay 3 a new rooftop exhaust fan had been installed above the maintenance area. GEC discussed with facility management the installation of exhaust ventilation units near the torch/burnoff, welding, and grinding work areas. A fine grey dust was reported to be visible on surfaces near vacuum pumps and compressors. They also reported seeing more employees wearing a variety of dust masks and respirators.

Ventilation measurements were taken in the grinding area at six exhaust drops, and flow rates ranged from 1200 cubic feet per minute (CFM) – 2000 CFM. At the time of this visit there were no regular maintenance records for the dust collectors available for inspection. In addition to the grinding area, the sandblast area was briefly inspected, and the material safety data sheet (MSDS) for the blasting media was requested.

In Bay 2, the pressure of oven 5 was measured using an inclined manometer; it was positive to the rest of the room. The positive pressure was also qualitatively confirmed using a visual tell-tail thread test. Oven 5 was described to have the most yellow residue buildup on its exterior. The qualitative pressure test and visible residue on the exterior indicate that outgassing from inside the oven was occurring. The thread test used at ovens 1 – 4 indicated they had a better seal. There were three large wall fans operating in Bay 2.

The tumbling room in Bay 1 was also inspected. A rooftop exhaust fan in the first room was reportedly not operating; a cold draft was felt entering from outside. The two operating tumblers in the first room were reported to have good negative exhaust into slot ducting. Two additional tumblers in the front room were evaluated and described to be positive to the room, with air from inside tumblers moving into the room. The exhaust dampers for each of the tumblers were noted to be partially closed. The room was described as being very warm with a noticeable amine odor. Several tumblers in the rear room were also noted to be blowing positive to the room. The tumblers with metal covers in place were described to appear to have better exhaust. The mixer area was said to be in need of housekeeping improvements and improved employee product handling techniques.

On January 20, 2009, general area samples were collected using 6L canisters in the maintenance and de-molding area. Three personal samples were collected using mini canisters for one operator in painting and two operators in tumbling. The canister samples were analyzed using EPA Method TO-15 requesting tentatively identified compounds. The maintenance sample was not analyzed because of a faulty sampler. A number of chemicals were detected including: ethanol, isopropanol, toluene, ethylbenzene, acetone, methyl ethyl ketone, hexane, styrene, chloromethane, trichloroethylene, 1,2,4-trimethylbenzene, m,p-xylene, o-xylene, dichlorodifluoromethane, cyclohexane, and benzene. No results of detected chemicals were reported at levels above PELs.

US Environmental Protection Agency (EPA)

In November 2009, representatives from the Massachusetts EPA, EPA Region I, and Weston Solutions Inc. Superfund Technical Assessment and Response Team III visited the facility after being contacted by the Avon, MA Fire Department with reports of two employees being hospitalized following chemical exposure. The company's OSHA Log documented that one employee had shortness of breath and chest pain and was transported to the hospital and symptoms were attributed to anxiety. A grab sample of air was collected using a 6L canister in the finishing room. The sample was analyzed in an EPA laboratory for VOCs. A total of 18 VOCs were identified at concentrations above the method limit of detection.

Occupational Safety and Health Administration (OSHA)

After being notified by EPA, an occupational health inspector conducted an inspection in the grinding area at the facility on November 30, 2009. She completed a visual assessment of the grinding area, collected noise dosimeter readings during grinding activities, requested copies of various company documents including MSDSs, respiratory protection program and fit testing documentation, hazard communication training records, audiometric testing results for grinding employees, and OSHA Logs for years 2007 to 2009. Six citations stemming from this investigation were issued on May 27, 2010, for exposures to fire and/or explosion hazards in the grinding, sandblasting, and adjacent areas.

Massachusetts Department of Public Health OHSP

In January 2010, representatives from the Massachusetts Department of Public Health OHSP visited the facility after seven cases of work-related asthma were reported by five different physicians and other data sources between May 2008 and January 2010. Following this initial visit, recommendations were provided in their report dated January 27, 2010, including:

- Review and implementation of OSHA's process safety management standard for guidance pertaining to analysis of process potentials for chemical release;
- Implementation of a "no-exposure plan" for amines;
- Provision of respirators in areas with potential amine exposure;
- Improvements to a comprehensive hazard communication program;
- Provide employees with information on recognition of respiratory symptoms; and
- Systematic review of pulmonary function test results by work area to examine for group declines.

They also encouraged facility management to invite NIOSH to conduct a Health Hazard Evaluation to assist in the identification of processes with exposure potential and development of control measures. In March 2010, the company notified the Massachusetts Department of

Public Health that they were acting on the recommendations and that they had contracted with OccuHealth Inc. to implement their recommendations.

Massachusetts Department of Public Health representatives returned in April 2010, to review steps taken by the company since their initial visit. In the interim period, the company had worked with a consultant and one of their product suppliers. They conducted an assessment of the building's ventilation system and as a result installed equipment to increase the amount of outdoor air being supplied. They also reportedly improved the fit of the doors on the tumblers and improved the local exhaust ventilation at the tumbler opening. Improvements were reportedly made to the ovens including upgrades to temperature control, exhaust ventilation, and seals on the doors. Job Hazard Analyses were said to have been completed but were not reviewed during this visit. Other changes observed during this site visit included enclosure of the storage and delivery of microspheres to the syntactic foam mix. A respiratory protection program had been initiated and included issuance of respirators and medical evaluations for fitness to wear a respirator. Some employees were observed wearing half-face air-purifying respirators (APRs) with organic vapor cartridges. One employee with a beard was observed wearing a respirator not compatible with facial hair. Additional steps proposed to identify health and safety hazards at the facility recommended in their report dated August 5, 2010 included:

- Explore methods for measuring diamines;
- Automate process steps where possible to minimize exposure to diamines;
- Prioritize diamine exposure locations;
- Conduct a hazard evaluation to identify areas and processes where there are potential exposures, especially to sensitizers and respiratory irritants;
- Develop a comprehensive respiratory protection program to include review of cartridge selections and ensure compliance;
- Work with occupational medicine consultant performing respirator medical clearance exams to review spirometry test results to look for patterns of decline and survey employees annually about respiratory and skin symptoms; and
- Continue implementation of hazard communication training.

OccuHealth Inc.

On February 1, 2012, eight samples (four personal, four area) were collected on silica gel tubes by OccuHealth Inc. and analyzed for 1,2-cyclohexanediamine. All of the personal samples were below the method's limit of detection. Two of the area samples in tumbling had measureable results. The sample collected in the rear area below the tumbler mezzanine was 0.11 ppm and the sample in the rear room in the tumbler area was 0.35 ppm.

NIOSH Evaluation

Summary of Employee Health Concerns

During telephone and in-person interviews from March to July 2012, prior to the site visit, some employees expressed concerns about health problems that they attributed to workplace exposures. Many felt that skin irritation and breathing problems were common among employees; some felt health problems were to be accepted as part of the job, as good jobs were difficult to find. They described breathing problems that began from late 2007 to 2009 and included symptoms such as throat burning, chest discomfort they described as "lung burning," wheezing, cough, chest tightness, shortness of breath, asthma, and sleep apnea. Some indicated that their symptoms improved over the weekend and over longer periods away from work. Several reported being prescribed inhaler medications that provided some relief. Employees noted these symptoms were worse in the main production building and expressed concerns about process changes and the introduction of new chemical components, including anhydrides and amines, in the summer of 2008 that they believed were responsible.

Some employees also noted eye irritation from chemicals and skin irritation from chemicals and carbon fibers. Skin symptoms included "red spots," eczema-like rashes, and itchiness of scalp, upper torso, and arms. The skin symptoms were reported to improve after a week or more away from work. Concerns were raised about similar skin symptoms in family members who came in contact with the employees' work uniforms.

Some believed that the change in company ownership that took place in 2011 led to improvements, while others did not perceive much improvement. With respect to PPE, some reported that physical conditions (e.g., heat) made it difficult to comply, others spoke of overgarments that did not fit, and still others stated that some just did not like wearing the dust masks. Mention was made that ventilation needed to be improved.

We were able to review pertinent medical records from five employees, which documented respiratory complaints and diagnoses of asthma. In two cases, there was evidence of significant improvement in lung function after bronchodilator medication, a finding consistent with asthma.

Summary of Respiratory Protection Program

The company's respiratory protection plan designated that employees in Production, Maintenance, R&D, and Quality Control were exposed to respiratory hazards during their routine work activities. The identified hazards included: chemical vapors, wood dust, cement dust, fiberglass dust, carbon dust, and welding mist, fumes, and vapors. According to the respiratory protection plan dated June 16, 2012, employees were required to wear half-face APRs with P-100/organic vapor cartridges in the grinding and finishing room, meter mix, vacuum tank, tumbler, and welding areas, and in the paint department. In the sandblast room, a supplied-air respirator was required.

The plan as reviewed was missing information in attachment 3 specific to respirator requirements for work tasks in confined spaces; information in attachments is defined in OSHA regulations. The plan did not include attachments 5 or 6. Attachment 5 should list the personnel required to wear respirators and specify the type of respirator they must use. Attachment 6 should contain detailed information identified during the hazard evaluation process including sampling data, results, and recommendation.

NIOSH Workplace Observations July 2012

During the site visit in July 2012, we observed employees in the production area wearing company-issued uniforms and a variety of PPE including hearing and eye protection, bump caps, and steel-toed shoes with non-skid soles. Some areas required the use of additional PPE including Tyvek® suits, nitrile gloves, hearing protection and respiratory protection. Many of the Tyvek suits worn by employees were torn, had portions of the sleeves removed or had been cut in the back to provide ventilation. A variety of respirators were observed in use including disposable N-95 filtering facepiece respirators, full-face and half-mask APRs, and supplied air respirators; current use of respiratory protection by employees appeared to be inconsistent. Some employees were wearing respirators during specific tasks while others performing similar tasks or working in adjacent areas were not wearing respirators. We also observed that when not in use, some employees' respirators were not being stored in protective bags to prevent contamination. We did not see an area designated for cleaning respirators. Laundered uniforms were stored on a clothes rack in Bay 1 of the production area near the fiberglass matting cutting area. There was signage throughout the facility indicating the PPE required in a given area. All signage was in English and symbols indicating types of PPE.

We found that the facility used many chemicals that are skin, eye, and respiratory irritants and/or allergens. We noted opportunities for potential exposure to particles and chemicals in various areas of the facility. In the tumbling area, we saw several activities that presented opportunities for exposure including dry sweeping, manual addition of epoxy resin and powders to tumblers, and the manual discharge of coated EPS from the tumbler. During these activities, we observed employees using different handling techniques, some of which generated plumes of dust in the worker's breathing zone.

We detected strong chemical odors in the tumbler, mold prep, meter mix, and paint areas. In various areas throughout Bays 1, 2, and 3, resin material was present on the floors and many open containers of resin and glue were visible. In the back of Bay 2, behind the vacuum tank area, there were several 5-gallon buckets draining into a large open tote. There were visible stains and product accumulation on many surfaces including tumbler doors, oven doors, and tool molds. This staining indicated to us that vapors and particles have escaped from production processes and presents the potential for employees to be exposed.

Local exhaust ventilation was being used in several areas. In the back room of the tumbling area, there were annular slotted hoods at the tumbler openings, and a backdraft hood was behind the tumbler manual epoxy dispensing system. In the tumbling area front room, there was one exhaust vent above the tumblers that sent air through a filtered dust collection system and returned the filtered air back to the room through several supply vents in the wall directly above the tumblers. In addition to the oven flues that discharge outside the building, the ovens located in the back of Bay 3 had additional exhaust fans to keep the ovens under negative pressure and to prevent smoke in the production area. The sandblasting and grinding rooms had local ventilation that was recycled after passing through a filtered dust collection system.

Material Safety Data Sheets Review

We reviewed 58 unique MSDSs for materials used at the facility for the years 2007-2012; 23 were in use in July 2012. The majority of products used posed skin, eye, and respiratory irritant hazards. Seven of the MSDSs reviewed contained ingredients that are considered to be asthmagens (materials that can induce asthma) and met the Association of Occupational and Environmental Clinics criteria for causes of sensitizer-induced asthma; four were in current use including epoxy resins and methyltetrahydrophthalic anhydride. Many of the products were identified by the Hazardous Material Information System label with a health rating of 2-Moderate Hazard or 3-Serious Hazard.

OSHA 300 Illness and Injury Log Review

There were 238 entries in the OSHA Logs for the time period of 2007 to 2011, resulting in 1,734 away-from-work days and 757 on-job-transfers or restriction days. The majority of reports were for injuries including burns, contusions, strains, lacerations, fractures, foreign object and debris in eyes, stitches, and fractures. There were also incidents of chemical burns included in the injury column. Reported skin disorders included rashes, contact dermatitis, chemical dermatitis, and skin sensitivity. There were nine entries for respiratory conditions including occupational asthma, bronchitis, pneumonia, work-related asthma, and shortness of breath following chemical exposure. Reports in the "All Other Illnesses" column included eye infections, chemical burns to body and eyes, heat exhaustion, and anxiety attack.

NIOSH Environmental Sampling July 2012

Detailed information on the sampling locations from the July 2012, environmental assessment is located in Table 1.

Amines

All amine sampling results were below method analytical detection limits; the minimum detectable concentrations were 0.03 ppm for 1,2-diaminocyclohexane, 0.01 ppm for hexamethylenediamine, and 0.02 ppm for isophoronediamine.

Volatile organic compounds (VOCs)

The results of the VOC sampling using evacuated canisters are shown in Table 2. The polystyrene bead storage area above the expansion process was studied to assess the effect of climate-controlled storage. Air-conditioning did not make an appreciable difference on most VOC concentration levels. Pentane levels (data not shown since only semi-quantitative data were available) were lower, while styrene levels were higher in the air-conditioned hopper compared to outside of it. The sample collected near the tumbler meter mix station (upstairs) in Bay 1 showed the highest concentrations of VOCs (980 parts per billion [ppb] toluene and 220 ppb m,p-xylene) in the production building. Measured VOCs were in the low ppb levels in the following areas: below tumbler meter mix station (downstairs), Bay 2 and 3 meter mix platforms, and Bay 3 mold prep. The highest VOC concentration was in the painting area of the painting/shipping building, with m,p-xylene at 2,200 ppb.

All concentrations measured were well below NIOSH RELs, where such RELs were available, including toluene and m,p-xylene whose NIOSH RELs are 100 ppm (100,000 ppb) as an 8-hour time-weighted average for each substance. Since these instantaneous samples present a snapshot in time, comparison against the time-weighted average NIOSH RELs is presented for context only. The measured VOC concentrations are indicators of potential for exposure, but should not be used for determining compliance with occupational safety and health regulations. Also note that these samples were not part of a comprehensive sampling strategy, and thus should not be construed as representative of the full range of exposures.

Real-time measurements

Average background total particle concentrations in air were 0.25 milligrams per cubic meter (mg/m3) for Bay 1, 0.17 mg/m3 for Bay 2, and 0.09 mg/m3 for Bay 3 and painting/shipping. Particle concentrations increased as we ascended to the tumbler mezzanine in Bay 1 and were highest at 3.7 mg/m3 around an empty tumbler. Particle concentrations also increased in Bay 2 as we entered the sandblasting area, where the maximum was 2.4 mg/m3 for a sandblasting operation. Particle concentrations increased again in Bay 3 as we entered the grinding area, where the maximum was 4.5 mg/m3 for a grinding operation. We observed employees wearing N95 filtering facepiece respirators in the tumbler area, supplied air respirators in the sandblasting area, and half-mask APRs in the grinding areas.

Average background total VOCs in air were 500 ppb for Bay 1, 680 ppb for Bay 2, 280 ppb for Bay 3, and 1500 ppb for painting and shipping and receiving. Average total VOCs increased in Bay 1 around the chemical storage area where concentrations reached 20,000 ppb. Also in Bay 1, total VOCs increased on the tumbler mezzanine, where two peaks around 45,000 and 139,000 ppb were observed while walking among tumblers.

Smoke tube evaluations

We used smoke tubes to qualitatively assess the local exhaust ventilation systems and to observe air movement in various locations including the tumbling and the oven areas in Bays 2 and 3. Smoke tube sampling in the back room of the tumbler area indicated that air flowed into the tumblers at the access ports through gaps at the port covers and into the slotted hoods above the upper half of the ports. Similar sampling at the new tumblers in the front room demonstrated that air flow was into the tumblers when the ports were open during the manual addition of resin. The backdraft exhaust hood at the manual epoxy dispensing station appeared to be plugged during the sampling.

There were five gas ovens in Bay 2. The ovens in Bay 2 were all positive with respect to the room (i.e., smoke blew into the room from the oven door). In this situation, any offgassing from inside the oven could enter the workplace air. There are four gas ovens located in Bay 3. Ovens 6, 8, and 9 were negative with respect to the room, while oven 7 was positive.

NIOSH Questionnaire Survey

A total of 154 (93%) of 165 current employees who were working the week of the survey completed the questionnaire. A total of 70 participants (45%) utilized an interpreter to complete the questionnaire interview. Table 3 shows participants' demographic characteristics and Table 4 shows participants' work history characteristics. The mean age of participants was 41 years (range 21-69). Most (97%) were male and about half identified themselves as black (47%); 10% identified themselves as Hispanic. There were 21 people who did not report their race. Sixty-nine percent of participants were born in countries other than the United States. Sixty-four percent of participants were never smokers, and 19% were current smokers. Mean plant tenure was 5 years (range 3 months – 21 years). Two-thirds of the participants were currently working in production. The combined category of production and production support included the vast majority of participants (92%). The "current" and "ever" versions of this combined category had the same composition of participants, meaning that participants who currently worked in administration had never worked in either production or production support.

Table 5 shows participants' responses to questions about symptoms. The most commonly reported symptom among all participants was rash, which was reported by 37% of participants. Eye symptoms (29%), cough (25%), asthma-like symptoms (23%), and nasal allergies (22%) were the other most commonly reported symptoms. The prevalences of wheeze and eye symptoms among participants were not significantly different from the expected prevalences calculated for the U.S. adult population (not shown). Large proportions (38-84%) of symptoms were described by participants as work-related, in that they improved away from the facility. In particular, 47% of cough, 61% of asthma-like symptoms, 75% of eye symptoms, 81% of burning throat, and 84% of rash were described as work-related.

Table 5 also shows participants' response to questions about asthma diagnosis. Nine percent (14/154) of all participants reported that they had ever been diagnosed with asthma, and 5% (7/154) reported that they still had asthma. These prevalences were not significantly different from the expected prevalences calculated for the U.S. adult population or for the Massachusetts adult population (not shown). Eight participants met the definition of adult-onset asthma; six of these reported being diagnosed with asthma after hire, from 2007 to 2013. One of the six was a current employee diagnosed after initial hire, but during an interval period when not employed at the facility. None of these six participants was listed as having occupational respiratory illness on the OSHA Logs for 2007 to 2011. Four of those with a post-hire asthma diagnosis reported work-related asthma-like symptoms. The pre-hire adult-onset asthma incidence density was 0.7 cases per 1000 person-years. The post-hire adult-onset asthma incidence density was 8.3 cases per 1000 person-years, which is about 12 times higher. The difference in adult-onset asthma between the pre-hire and post-hire group was statistically significant.

We asked the 63 participants who reported respiratory symptoms, use of asthma medicine, or a current asthma diagnosis if there was anything at work that they believed affected their breathing. Thirty-five (56%) of these participants said that something at work affected their breathing; responses included carbon, dust, lack of air circulation, heat, chemicals, amines, chemical smells, glue particles, fiberglass, tumbler dust, dust from grinding, wearing mask, and microballoons.

When asked to identify what caused or aggravated their eye symptoms, 77% of those with eye symptoms described conditions including computer work, dust, grinding, amines, carbon and glass fibers, smoke from ovens, heat, air quality, fiberglass, and chemical fumes.

Eighty-six percent of those with rash or skin problems reported that their rash or skin problem was caused or aggravated by heat, carbon fibers, fiberglass, chemicals, and/or dust in the grinding room. The areas of the body most commonly reported to be affected were the arms, hands, neck, face, and legs.

We looked at the relationship between symptoms and asthma diagnoses and plant tenure (Figures 1 and 2). Compared to participants with less than five years tenure at the plant, participants with five or more years tenure were more likely to report awakening with chest tightness (8% vs. 19%; p=0.05), work-related chest tightness (5% vs. 14%, p=0.03), work-related nasal allergies (2% vs. 16%, p=0.002), asthma-like symptoms (18% vs. 30%, p=0.06), work-related asthma-like symptoms (9% vs. 20%, p=0.06), throat burning (8% vs. 20%, p=0.03), and work-related throat burning (6% vs. 17%, p=0.02). Participants with longer tenure reported more use of asthma medications (1% vs. 12%, p=0.004).

Figure 3 shows participants' responses to questions about symptoms and asthma diagnoses by current department category, and Figure 4 shows participants' responses to questions about work-related symptoms by current department category. Respiratory symptoms were more common in production support and production workers compared to administration workers, but these differences were not statistically significant. Rash and work-related rash were significantly more common in production and production support workers (8% vs. 40%, p=0.03 for rash; 0% vs. 34%, p=0.01 for work-related rash). Asthma diagnoses did not differ significantly by current department category.

Given the complete overlap between current combined production category and ever combined production category, analyses by ever combined production category did not contribute additional information.

Discussion

We conducted a health hazard evaluation at a syntactic foam manufacturing facility with a 9-person cluster of work-related asthma reported to the state health department from 2008 to 2012. Most of these 9 workers were no longer employed at the facility at the time of our evaluation. Our evaluation documented opportunities for exposure to chemicals that are known respiratory irritants or asthmagens and additional work-related asthma in the current workforce as of 2013. Among current workers, asthma diagnoses increased 12-fold after hire compared to before hire, and most of those with post-hire asthma reported ongoing symptoms with a work-related pattern. Although we were unable to review all pertinent records, the available evidence suggests that few of the six current workers with post-hire asthma had been identified as having work-related asthma prior to our investigation. None was included on the 2007-2011 OSHA Logs as having occupational respiratory illness, despite the fact that all but one reported a year of diagnosis in this time period. The other was diagnosed in 2013, after the last of the cases was reported to the state.

Despite the apparent increase in asthma diagnoses post-hire, asthma diagnoses were not more common than expected in this workforce, when compared to the U.S. adult population or the Massachusetts adult population. There are several factors that likely contribute to this observation. First, we know that at least five and as many as eight of the nine workers with work-related asthma reported to the state were no longer employed at the time of our survey. Thus, our survey did not capture the full burden of asthma related to this facility. Had we included both current and former workers, we may have found that asthma diagnoses were more common for this facility than for the general population. In addition, it is important to point out that the number of current workers who reported symptoms consistent with asthma was 5 times greater than the number who reported a current diagnosis of asthma, suggesting there were likely undiagnosed cases of asthma in this workforce. It is possible that this workforce, with many recent immigrants and non-English speakers, had different health care-seeking behaviors than the general population [Mohanty et al. 2005; Tarraf et al. 2012; Tarraf et al. 2014], which could lead to an underestimation of asthma diagnoses.

We found evidence that asthma risk was higher for those who had been employed longer at the plant. Current asthma diagnosis was more common among those with longer tenure. In addition, asthma-like symptoms, including awakening with chest tightness, were reported more frequently by those with longer tenure. Those with five or more years of tenure were more likely to report use of asthma medications. Process changes that occurred in 2008, five years before our questionnaire survey, were temporally associated with the asthma cluster reported to the state. Thus it is possible that the associations we found among current workers between tenure and asthma reflect ongoing health consequences of exposures from that era. Nonetheless, the report of asthma-like symptoms and work-related asthma-like symptoms by participants with less than 5 years' tenure suggests there is a continuing asthma risk in this facility.

Respiratory symptoms were not evenly distributed throughout the current workforce. Rather, workers who spent time in production areas reported more respiratory symptoms than those who did not spend time in production areas. These differences were impressive, in that none of the non-production workers reported shortness of breath, chest tightness, or wheeze, whereas these symptoms were reported by 9-16% of production and production support workers. Similarly, asthma-like symptoms were reported by just 8% of non-production workers but 25% of production and production support workers. Work-related respiratory symptoms were exclusively reported by production and production support workers. These differences were not statistically significant, likely due to the small number of non-production workers (n=13). Interestingly, although non-production workers reported fewer respiratory symptoms, they had higher prevalence of lifetime and current asthma diagnoses; as with the comparisons to the general population, this observation could reflect differences between these groups of workers in terms of accessing care.

We also found evidence of other work-related health problems. Throat burning is an unusual symptom that was reported by some of the employees we interviewed in 2012. Our questionnaire survey documented higher prevalence of throat burning in the last 12 months and throat burning that improved away from the facility in those with longer tenure. In addition, none of the non-production workers but 15% of production and production support workers reported throat burning, most of which was described as having a work-related pattern. Similarly, rash in the last 12 months was reported by just 8% of non-production workers but 40% of production and production support workers. None of the non-production workers reported rash that improved away from work, whereas 34% of production and production support workers did. In contrast, prevalences of nasal allergies and eye symptoms were about the same among these groups.

Although we found compelling evidence of asthma in the current workforce, we were unable to determine the cause of work-related asthma at this facility. Workers attributed their symptoms to a variety of exposures, including carbon, heat, chemicals, amines, glue particles, fiberglass, tumbler dust, dust from grinding, and microballoons. We know that many causes of allergic asthma exist in the facility. Exposure to epoxy resin systems containing ingredients such as amines, bisphenol A diglycidyl ether, and anhydrides including methyltetrahydrophthalic anhydride can cause allergic reactions (both immediate and delayed), dermatitis, and asthma [Fawcett et al. 1977; Nielsen et al. 1989; Kanerva et al. 1991; Nielsen et al. 1992; Patussi et al. 1995; Yokota et al. 1999; Nielsen et al. 2001; Yokota et al. 2002; Nielsen et al. 2006; Hannu et al. 2009; Helaskoski et al. 2009; Malo and Chan-Yeung 2009; Foti et al. 2010]. In addition to allergic sensitizers, workers may have been exposed to irritant causes of work-related asthma such as butanediol diglycidyl ether, aliphatic amines, anhydrides, bisphenol A, epichlorohydrin, and milled fibers. Thus it is possible that a variety of exposures contributed to the burden of respiratory symptoms in this facility.

Despite the known use of multiple amines in the production areas, we did not detect amines in air samples during our July 2012 site visit. In January 2012, the company's consultant had conducted amine sampling for 1,2-diaminocyclohexane; samples had been stabilized immediately and analyzed at the same laboratory that NIOSH used. In two of the four samples collected by the company's consultant, measurable levels of 1,2-diaminocyclohexane were found upstairs (0.35 ppm) and downstairs (0.11 ppm) in the tumbler area. Differences between sampling conditions on the two occasions, such as timing of sample stabilization, flow rate, duration, and time of day, may partially explain the differences between the sets of results. Differences in production conditions, including status of the ongoing tumbler improvement program, the number of tumblers in operation, and potential differences in coating ingredients in use at time of sampling, may also have had an impact.

Indeed, a significant challenge was the lack of air sampling and analytical methods and exposure limits for the amines, anhydrides, and epoxy resins used in this facility. Methods need to be validated for the specific exposure agents prior to assessing workplace hazards. At the time of our site visit, no validated methods existed for these agents. Amine sampling (1,2-diaminocyclohexane, hexamethylenediamine, and isophoronediamine) was conducted using a modified NIOSH Method 2007 [NIOSH 2015] that was partially validated for two other amines. This method was prone to analyte instability on the sampling media; the method was modified to include an acid stabilization of the amines prior to analysis. Anhydrides were not sampled during this investigation. In December 2013, OSHA promulgated a sampling and analytical method for the determination of bisphenol A and diglycidyl ether of bisphenol A [OSHA 2013]. Bisphenol A is used in making epoxy resins. Diglycidyl ether of bisphenol A is used in epoxy surface coatings. No exposure limits were established but the method used a German exposure level (MAK) as a target concentration. Future industrial hygiene sampling efforts could include this method in an effort to characterize the airborne concentrations of epoxy resin constituents.

In a facility with many potential causes of asthma and few methods to characterize exposures, it may be impossible to determine which specific exposures led to development or exacerbation of asthma. Similarly, physicians who diagnose individual cases of asthma rarely have either blood tests or facilities available to safely expose their patients, one agent at a time, to determine cause. Under such circumstances, two preventive measures are key: overall exposure reduction aimed at reducing the risk of asthma development, and early identification of affected workers who may be developing asthma. Many chemicals that cause occupational asthma also induce allergic and contact sensitivity rashes in the skin. Skin exposure to chemicals called isocyanates has been found to be a risk factor for isocyanate asthma and may be relevant for other chemical causes of asthma [Bello et al. 2007; Redlich 2010]. As such, the associations we found between production work and rashes suggest that exposure reduction in this facility should include both respiratory and skin protection. Early identification of affected workers is important because their removal from continued exposure can result in asthma cure. Studies of workers who develop occupational asthma have found that workers who are removed from the triggering exposure are more likely to improve than those who continue to be exposed, even if exposures are reduced [Vandenplas et al. 2012]. For instance, in one study of workers exposed to an epoxy resin containing methyltetrahydrophthalic anhydride, sensitized workers who left employment had reduction in lung reactivity and became symptom-free, while workers who stayed experienced no such improvement, despite a ten-fold reduction in workplace exposures [Nielsen 1992].

In addition to concerns about occupational asthma, it is also worthwhile to note that during the production process the surface of the module is cleaned by abrasive blasting. Abrasive blasting techniques use compressed air or water to direct a stream of abrasive material onto a surface at a high velocity. The use of abrasive blasting presents both risk of physical injury and potential respiratory risks due to the generation of high levels of dust. Commonly used abrasive materials include steel shot, silica sand, coal slag, copper slag, and glass or plastic beads as well as other materials. OSHA has established regulatory requirements for ventilation, enclosures, and PPE during abrasive blasting [OSHA 2012]. Type CE airline respirators, required for work inside blast-cleaning enclosures, are equipped with head, neck, and upper body coverings to protect employees from rebounding abrasive blasting material [NIOSH 1987]. At the time of our visit, a coal slag media was in use. Slags often contain trace amounts of toxic metals such as arsenic, beryllium, and cadmium [OSHA 2013].

At this facility English was not the primary language for the majority of the workers in the production areas. The OSHA Hazard Communication Standard requires that employers provide employees with effective information and training on hazardous chemicals in their work area at the time of their initial assignment, and whenever a new physical or health hazard is introduced into their work area [OSHA 2010]. All job-specific training including task instruction, hazard communication, and personal protective equipment (including respirator) training should be tailored to the employee's language and education level.

Strengths of our evaluation included the high participation rate for the questionnaire survey, reflecting the interest and commitment of both the workers and the company. Indeed, the employer was fully supportive of the questionnaire survey, publicizing it among the workforce, providing ample time for participation during the workday, and providing rooms onsite where the questionnaire could be administered in private. Our use of interpreters facilitated the participation of non-English speakers, who made up a large proportion of the workforce. The questionnaire benefited from the inclusion of standard questions on respiratory symptoms and diagnoses, which allowed comparisons to normative populations. However, differences between this workforce and the general population are notable and could influence prevalence of symptoms and diagnoses, as discussed earlier. To that end, our calculation of asthma incidence pre- and post-hire was useful, in that the use of the workforce as its own control better demonstrated the effects of employment at the facility.

There are several limitations to address. The current workforce included in the survey may have been healthier than the entire cohort of people who had ever been employed at this facility [Li and Sung 1999]. Workers who develop work-related symptoms or diseases, including asthma, often transfer work areas or leave a workplace entirely. Those workers remaining in the facility are generally less susceptible and thus healthier. Although privacy concerns prevented sharing of identifiable information between NIOSH and the state health department, the available information indicated that the majority of the workers with work-related asthma cases that had been reported to the state were not currently employed at the facility. Thus, our focus on the current workforce likely underestimated the full burden of work-related disease associated with this facility. Another limitation is that we were unable to determine exactly which exposures were responsible for symptoms reported by participants. Nonetheless, the established risks of many of the chemicals used in the facility warrant an inclusive approach to exposure reduction.

Conclusions

Employees were exposed to a variety of chemicals during the manufacture of syntactic foam at this facility, the majority of which are irritants and some are recognized sensitizers and/or asthmagens. Three years after the state health department investigated a cluster of work-related asthma in this facility, we found additional work-related asthma in current workers. Evidence includes 1) asthma diagnoses increased more than ten-fold after hire; 2) most current workers with a current asthma diagnosis described improvement in their asthma symptoms away from work; 3) current asthma diagnosis and symptoms were related to length of employment at the facility; and 4) compared to non-production (administration) workers, workers who spent time in production areas reported more respiratory symptoms overall and more respiratory symptom that improved away from the facility. Although we could not determine which chemicals in use at the facility were responsible for these symptoms, our findings indicate a need for further exposure reduction that can be addressed through enhanced engineering controls, modified work practices, and improved use of respiratory protection. Surveillance for work-related respiratory symptoms and prompt relocation of affected workers are also critical.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage this syntactic foam manufacturing facility to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation.

Our recommendations are based on an approach known as the hierarchy of control. This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to first eliminate hazardous materials or processes, and then install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Where possible, substitute chemicals used for ones with fewer potential health effects. However, limited information is available about the adverse health effects of many chemicals. Thus, managers should be prepared for the possibility that newly introduced chemicals or combinations of chemicals, even those without documented toxicity, may have unanticipated adverse effects on employees' health.
2. Consider substituting coal slag with a less toxic abrasive blasting material to reduce potential exposure to toxic metals.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Evaluate the need for additional engineering controls to reduce worker exposures to irritants and sensitizers such as process and equipment design modifications to keep contaminants away from the workers' breathing zone.
2. Perform air monitoring to ensure the success of any improvements or process changes made, identify any areas that need to be further improved, and to ensure ongoing status of improvements.

Administrative Controls

"Administrative controls" refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Remove original labels from any containers that are "re-purposed," and replace with new labels with date and appropriate waste stream.
2. Eliminate dry sweeping in the plant. Avoid the use of compressed air for cleaning. Substitute vacuum cleaning with HEPA filters for dry sweeping throughout the facility wherever feasible.
3. Notify employees of process changes including new formulas using different chemical and temperature combinations. Encourage employees to report any changes that result in their work area.
4. Move hanging racks with clean worker uniforms out of the production area to avoid contamination.
5. Instruct employees to change out of uniforms and work boots at the end of their shift before leaving the facility.
6. Provide signage in additional languages (such as Portuguese) as necessary to improve hazard communication with employees who do not speak English. Continue to augment word-based signs with symbol-based signs, as some employees may have limited reading skills.
7. Consider implementing a policy requiring production employees to shower at the end of a shift to better ensure that irritant and sensitizing chemicals are removed from the skin.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment are needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Complete the respiratory protection program to meet all regulatory requirements specified under the OSHA respiratory protection standard 29 CFR 1910.134. We recommend quantitative fit testing for all employees and staff who go into production areas.
    a. Make sure that fit testing is done using the same make, model, style, and size respirator that will be used by each employee.
    b. Make sure that employees are aware of the respirator cartridge change out schedule based on the process chemicals.
    c. Ensure that employees wearing tight-fitting respirators (e.g., half and full-facepiece, and disposable N95 respirators) do not have facial hair or any condition that interferes with the face-to-facepiece seal.
    d. Ensure that all employees adhere to respirator recommendations when in areas of the facility with specific PPE recommendations, regardless of how little time they may spend in the area.
2. Provide employees with protective suits in a variety of sizes so that there is no need to alter them. Also make sure that the suits are rated for a higher level of liquid protection needed when working with chemicals that are dermal irritants/sensitizers.
3. Instruct employees how to change out of and discard protective suits that become soiled with chemicals that are dermal irritants/sensitizers.
4. Instruct employees to change gloves if they become torn.

Medical Surveillance

1. Establish a medical surveillance program that emphasizes skin and respiratory health. All employees who spend time in production areas should be included. At a minimum, the surveillance program should evaluate employees' skin and asthma symptoms annually.
2. Educate employees to recognize symptoms associated with occupational asthma.
3. Encourage employees to report any new or worsening respiratory symptoms to their supervisor and personal physician or other healthcare provider.
4. Refer any employees with respiratory symptoms to occupational medicine physicians with expertise in occupational lung diseases.

Update since Site Visit

In March 2014, the company provided an update to NIOSH on new workplace changes that had occurred since the questionnaire survey in July 2013. Below is a summary of the company's recent changes.

Engineering Controls

The company is focusing efforts on those areas with the highest potential for exposure. They have installed custom-built doors with an integrated dust collection system to collect powder emissions during the bead coating process on 26 tumblers. Manual handling of powders has been reduced by installation of hoppers which allow the powder to be transferred into the tumbler via an enclosed system with local exhaust ventilation. A vacuum transfer system has been installed on new tumblers to minimize dust emissions during the unloading of the tumblers. This system has a dust collection system with filters.

Work Practices

The company has instituted a mandatory PPE use program in the tumbler area as a secondary protective measure to the engineering controls. Area inspections are conducted weekly to evaluate PPE use. A combination dust and organic vapor cartridge is used with half-mask or full-face respirators, and cartridges are changed every 12 hours.

References

Bello D, Herrick CA, Smith TJ, Woskie SR, Streicher RP, Cullen MR, Liu Y, Redlich CA [2007]. Skin exposure to isocyanates: reasons for concern. Environ Health Perspect *115*:328-335.

Bernstein I, Bernstein D, Chan-Yeung M, Malo JL [2006]. "Definition and classification of asthma in the workplace" in Asthma in the Workplace. New York, NY: Taylor & Francis.

Blanc P, Toren K [1999]. How much adult asthma can be attributed to occupational factors? Am J Med *107*:580–587.

CDC (Centers for Disease Control and Prevention) [2012]. Behavioral Risk Factor Surveillance System Survey Data. Available at: http://apps.nccd.cdc.gov/BRFSS/. Accessed March 2015.

CFR (Code of Federal Regulations). Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Department of Health and Human Services (DHHS) [1996]. National Center for Health Statistics. Third National Health and Nutrition Examination Survey, 1988–1994, NHANES III Adult and Examination Data Files (CD-ROM). Public Use Data File Documentation Number 76200. Hyattsville, MD: Centers for Disease Control and Prevention.

Fawcett IW, Taylor AJ, Pepys J [1977]. Asthma due to inhaled chemical agents – epoxy resin systems containing phthalic acid anhydride, trimellitic acid anhydride and triethylene tetramine. Clin Allergy *7*:1-14.

Ferris BG [1978]. Epidemiology standardization project (American Thoracic Society). Am Rev Respir Dis *118*(6 Pt 2):1–120.

Foti C, Bonamonte D, Antelmi A, Nettis E, Cassano N, Vena GA, Angelini G [2010]. Airborne allergy to isophoronediamine and epoxy resin. Immunopharmacol Immunotoxicol *32*(3)528-529.

Grassi M, Rezzani C, Biino G, Marinoni A [2003]. Asthma-like symptoms assessment through ECRHS screening questionnaire scoring. J Clin Epidemiol *56*(3):238–247.

Hannu T, Frilander H, Kauppi P, Kuuliala O, Alanko K [2009]. IgE-mediated occupational asthma from epoxy resin. Int Arch Allergy Immunol *148*:41-44.

Helaskoski E, Kuuliala O, Aalto-Korte K [2009]. Occupational contact urticaria caused by cyclic acid anhydrides. Contact Dermatitis *60*(4):214-221.

Henneberger PK Redlich CA, Callahan DB, Harber P, Lemière C, Martin J, Tarlo SM, Vandenplas O, Torén K; ATS Ad Hoc Committee on Work-Exacerbated Asthma [2011]. An official American Thoracic Society statement: work-exacerbated asthma. Am J Respir Crit Care Med *184*(3):368–378.

Kanerva L, Jolanki R, Tupasela O, Halmepuro L, Keskinen H, Estlander T, Sysilampi ML [1991]. Immediate and delayed allergy from epoxy resins based on diglycidyl ether of bisphenol A. Scand J Work Environ Health *17*(3):208-218.

LeBouf RF, Stefaniak AB, Virji MA [2012]. Validation of evacuated canisters for sampling volatile organic compounds in healthcare settings. J Environ Monit *14*(3):977-983.

Li CY, Sung FC [1999]. A review of the healthy worker effect in occupational epidemiology. Occup Med (Lond) *49*:225-229.

Malo JL, Chan-Yeung M [2009]. Agents causing occupational asthma. J Allergy Clin Immunol *123*(3):545-550.

Mohanty SA, Woolhandler S, Himmelstein DU, Pati S, Carrasquillo O, Bor DH [2005]. Health care expenditures of immigrants in the United States: a nationally representative analysis. Am J Public Health. *95*:1431-1438.

Nielsen J, Welinder H, Sverfving S [1989]. Allergic airway disease caused by methyltetrahydrophthalic anhydride in epoxy resin. Scand J Work Environ Health *15*(2):154-155.

Nielsen J, Welinder H, Horstmann V, Skerfving S [1992]. Allergy to methyltetrahydrophthalic anhydride in epoxy resin workers. Br J Ind Med *49*(11):769-75.

Nielsen J, Welinder H, Jonsson B, Axmon A, Rylander L, Skerfving S [2001]. Exposure to hexahydrophthalic and methylhexahydrophthalic anhydrides – dose-reponse for sensitization and airway effects. Scand J Work Environ Health *27*(5):327-334.

Nielsen J, Welinder H, Bensryd I, Rylander L, Skerfving S [2006]. Ocular and airway symptoms related to organic acid anhydride exposure- a prospective study. Allergy *61*(6)743-749.

NIOSH [1987]. Guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-116.

NIOSH [2015]. NIOSH Manual of Analytical Methods (NMAM). 4th ed. Cincinnati, OH. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 94-113 (August 1994); 1st Supplement Publication 96-135, 2nd Supplement Publication 98-119; 3rd Supplement 2003-154. http://www.cdc.gov/niosh/docs/2003-154/. Accessed March 2015.

NIOSH [2010]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2010-168c. http://www.cdc.gov/niosh/npg/. Accessed March 2015.

Occupational Safety and Health Administration. Hazard Communication [2010]. OSHA training standards policy statement. Washington DC: US Department of Labor, Occupational Safety and Health Administration. http://www.osha.gov/dep/standards-policy-statement-memo-04-28-10.html. Accessed March 2015.

OSHA [2012]. U.S. Department of Labor Occupational Safety and Health Administration. Directorate of Standards and Guidance. Office of Maritime. An OSHA guidance document. December 2006. http://www.osha.gov/dts/maritime/standards/guidance/shipyard_guidance.html. Accessed March 2015.

OSHA [2015]. OSHA sampling and analytical methods. A. Pearce, D, Salt Lake City, UT: U.S. Department of Labor, Occupational Safety and Health Administration. https://www.osha.gov/dts/sltc/methods/validated/1018/1018.pdf. Accessed March 2015.

OSHA [2013]. Protecting workers from the hazards of abrasive blasting materials. https://www.osha.gov/Publications/OSHA3697.pdf. Accessed March 2015.

Patussi V, Kokelj F, Buttazzi P [1995]. Occupational airborne allergic contact dermatitis due to 3-amino-methyl-3,5,5-trimethylcyclohexylamine. Contact Dermatitis *32*(4):239.

Redlich CA. 2010. Skin exposure and asthma: is there a connection? Proc Am Thorac Soc. *7*:134-137.

Tarlo SM, Lemiere C [2014]. Occupational asthma. N Engl J Med *370*:640-649.

Tarraf W, Miranda PY, González HM [2012]. Medical expenditures among immigrant and nonimmigrant groups in the United States: findings from the Medical Expenditures Panel Survey (2000-2008). Med Care *50*:233-242.

Tarraf W, Vega W, González HM [2014]. Emergency department services use among immigrant and non-immigrant groups in the United States. J Immigr Minor Health. *16*:595-606.

Toren K, Blanc PD [2009]. Asthma caused by occupational exposures is common—a systematic analysis of estimates of the population-attributable fraction. BMC Pulm Med *9*:7.

Vandenplas O, Dressel H, Nowak D, Jamart J; ERS Task Force on the Management of Work-related Asthma [2012]. What is the optimal management option for occupational asthma? Eur Respir Rev *21*:97-104.

Yokota K, Johyama Y, Yamaguchi K, Takeshita T, Morimoto K [1999]. Exposure-response relationships in rhinitis and conjunctivitis caused by methyltetrahydrophthalic anhydride. Int Arch Occup Environ Health *72*(1):14-18.

Yokota K, Johyama Y, Yamaguchi K [2002]. A cross-sectional study of 32 workers exposed to hexahydrophthalic and methylhexahydrophthalic anhydrides. Ind Health *40*(1):36-41.

Tables

Table 1: Sampling location information for amines and volatile organic compounds (VOCs), collected on July 24, 2012, at a syntactic foam manufacturer

		Bay 1								Bay 2	Bay 3		Painting/ shipping
Work Area/ Process	Field blank***	Poly-styrene beads in white burlap sack	Poly-styrene beads in cardboard container	Poly-styrene beads in AC-controlled hopper	Poly-styrene bead expansion tank #2	Below tumbler meter mix station (downstairs)	Near tumbler meter mix station (upstairs)	Below tumblers #7 and 8 (downstairs)	Near tumblers #7 and 8 (upstairs)	Meter mix platform above vacuum chamber	Meter mix platform above vacuum chamber	Mold prep	Painting
*Time Collected**		12:28	12:27	12:26	12:24	12:20	12:44	12:17	12:46	13:10	13:35	13:38	13:59
*Amine Samples***	ü ü					ü	ü	ü	ü	ü ü	ü	ü	
VOC Samples	ü	ü	ü	ü	ü	ü	ü			ü	ü	ü	ü

<u>Notes</u>:
*"Time collected" is the starting time for the 15-minute amine samples and the time that instantaneous canister (VOC) samples were collected.
**Two check marks denotes two samples taken.
*** A field blank is a sample media that has no sample collected but is taken to the sampling site·

Table 2: Concentrations of volatile organic compounds (VOCs) in parts per billion (ppb) using evacuated canisters, collected on July 24, 2012, at a syntactic foam manufacturer

Work Area/ Process		Bay 1						Bay 2	Bay 3		Painting/ shipping			
Chemical	Field blank	Poly-styrene beads in white burlap sack	Poly-styrene beads in cardboard container	Poly-styrene beads in AC-controlled hopper	Poly-styrene bead expansion tank #2	Below tumbler meter mix station (downstairs)	Near tumbler meter mix station (upstairs)	Meter mix platform above vacuum chamber	Meter mix platform above vacuum chamber	Mold prep	Painting	*LOD* (ppb)*	*LOQ* (ppb)*	*Maximum calibration point (ppb)*
ethanol	-	17	17	12	13	16	25	110	56	39	380	1.5	5.0	41
acetone	(0.97)	20	49	76	15	26	21	16	26	25	14	0.9	2.9	42
isopropyl alcohol	(1.2)	13	8.0	(3.6)	12	5.0	13	9.6	10	30	7.3	1.0	3.2	41
methylene chloride	-	(1.0)	-	-	-	-	-	-	-	-	-	0.4	1.5	40
hexane	-	-	(1.0)	-	-	-	-	-	-	-	-	0.5	1.6	41
chloroform	-	(2.3)	-	-	-	-	-	-	-	-	-	0.6	1.9	42
benzene	-	-	(1.5)	(1.6)	-	-	-	-	-	-	-	0.5	1.8	41
toluene	-	4.7	4.4	4.2	4.4	4.0	980	33	17	67	23	0.6	2.0	42
ethylbenzene	-	4.2	4.0	4.3	4.5	(2.1)	51	(0.96)	-	-	440	0.6	1.9	40
m,p-xylene	-	3.8	(2.9)	3.1	6.5	4.3	220	4.2	-	-	2200	0.6	1.9	41
o-xylene	-	(1.6)	(1.4)	(1.4)	(2.6)	(1.9)	95	(2.1)	-	-	750	0.6	2.0	41
alpha-pinene	-	-	-	-	-	-	-	-	-	-	-	0.7	2.3	41
limonene	-	-	-	-	-	-	-	-	-	(3.8)	-	1.3	4.4	41
styrene	-	10	33	42	16	(6.6)	-	-	-	-	-	1.7	5.6	33
Dilution factors	NA	1.51	1.54	1.50	1.50	1.50	1.54	1.55	1.55	1.56	1.55			

Notes: Results greater than the maximum calibration point were subsequently analyzed with smaller aliquots or dilution.
No recovery correction was performed. There were no interferences with qualitatively identified compounds.
Dashes represents values below the limit of detection (LOD); numbers in parentheses are values between LOD and limit of quantification (LOQ).
*LODs and LOQs shown in table are for samples without dilution; actual limit for each sample compound after dilution may be calculated by multiplying the LOD or LOQ by the dilution factor.

Table 3. Demographic characteristics of the survey participants (N=154), August 2013 at a syntactic foam manufacturer

Characteristic	Value
Age, years, mean (range)	41 (21 - 69)
Male, n (%)	149 (97)
Race, n (%)	
White	53 (34)
Black	73 (47)
Other*	28 (18)
Country of Origin, n (%)	
Cape Verde Islands	68 (44)
United States	48 (31)
Other†	38 (25)
Smoking status, n (%)	
Current	29 (19)
Former	27 (17)
Never	98 (64)

*Includes 21 participants who did not report race
†Angola, Azores, Brazil, Dominican Republic, El Salvador, Ghana, Greece, Guinea Bissau, Haiti, Laos, Portugal, Puerto Rico, Spain

Table 4. Work history characteristics of the survey participants (N=154), August 2013 at a syntactic foam manufacturer

Characteristic	Value
Tenure, years, mean (range)	
Current job	3 (<1 - 21)
Total at facility	5 (<1 - 21)
Work in administration, n (%)	
Current	13 (8)
Ever	16 (10)
Work in production, n (%)	
Current	102 (66)
Ever	111 (72)
Work in production support, n (%)	
Current	39 (25)
Ever	46 (30)
Work in production or production support, n (%)	
Current	141 (92)
Ever	141 (92)

Table 5. Symptoms and self-reported diagnoses of the survey participants (N=154), August 2013 at a syntactic foam manufacturer

Symptom	Overall, n (%)	Work-related, n (%)*
Shortness of breath†	13 (8)	8 (5)
Cough†	38 (25)	18 (12)
Wheeze†	23 (15)	15 (10)
Chest Tightness†	20 (13)	14 (9)
Burning throat†	21 (14)	17 (11)
Asthma attack†	5 (3)	2 (1)
Asthma-like symptoms‡	36 (23)	22 (14)
Nasal allergies (includes hay fever)	34 (22)	13 (8)
Eye symptoms†	44 (29)	33 (21)
Rash†	57 (37)	48 (31)
Diagnosis		Diagnosis after hire, n (%)
Asthma		
Ever	14 (9)	6 (4)
Current	7 (5)	

*Work-related symptoms were defined as symptoms that improved away from the facility, either on days off or on vacation.

†In the last 12 months.

‡Asthma-like symptoms were defined as current use of asthma medicine and/or one or more of the following symptoms in the last 12 months: wheezing or whistling in the chest, awakening with a feeling of chest tightness, or attack of asthma.

Figures

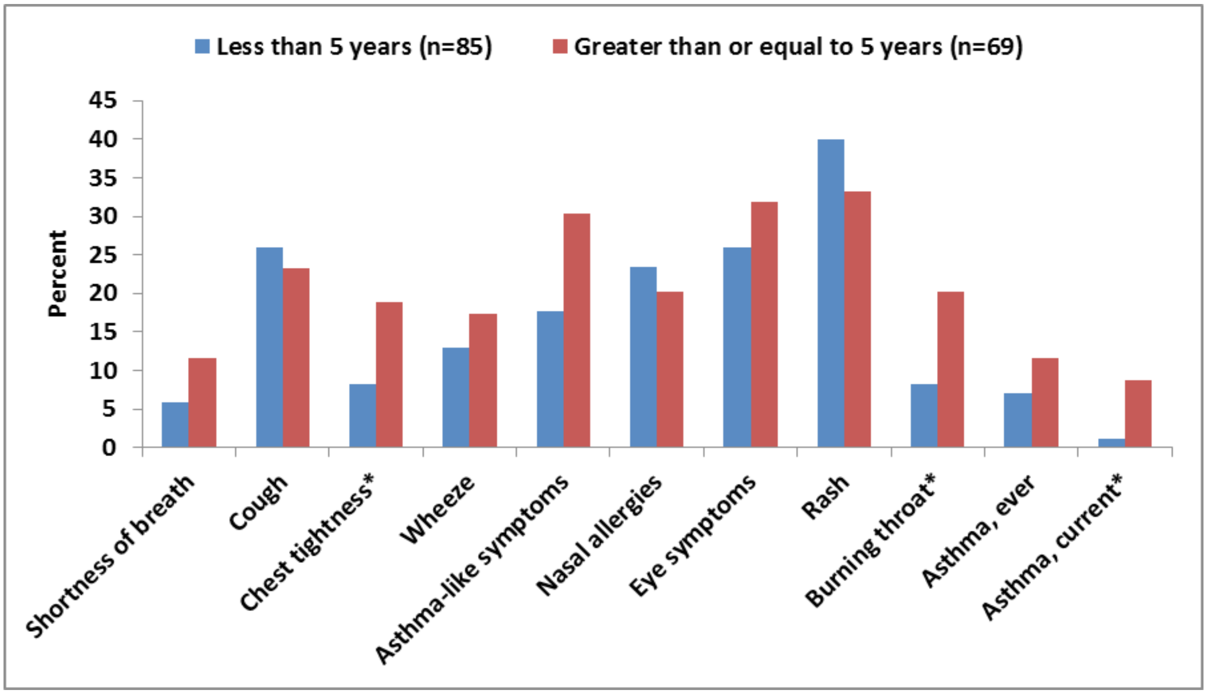

Figure 1. Prevalence of symptoms and asthma diagnoses by employment tenure group, August 2013 at a syntactic foam manufacturer. All symptoms except nasal allergies were specific to the last 12 months. Asthma-like symptoms were defined as current use of asthma medicine and/or one or more of the following symptoms in the last 12 months: wheezing or whistling in the chest, awakening with a feeling of chest tightness, or attack of asthma. Statistically significant differences ($p<0.05$) are indicated by an asterisk next to the name of the symptom or diagnosis.

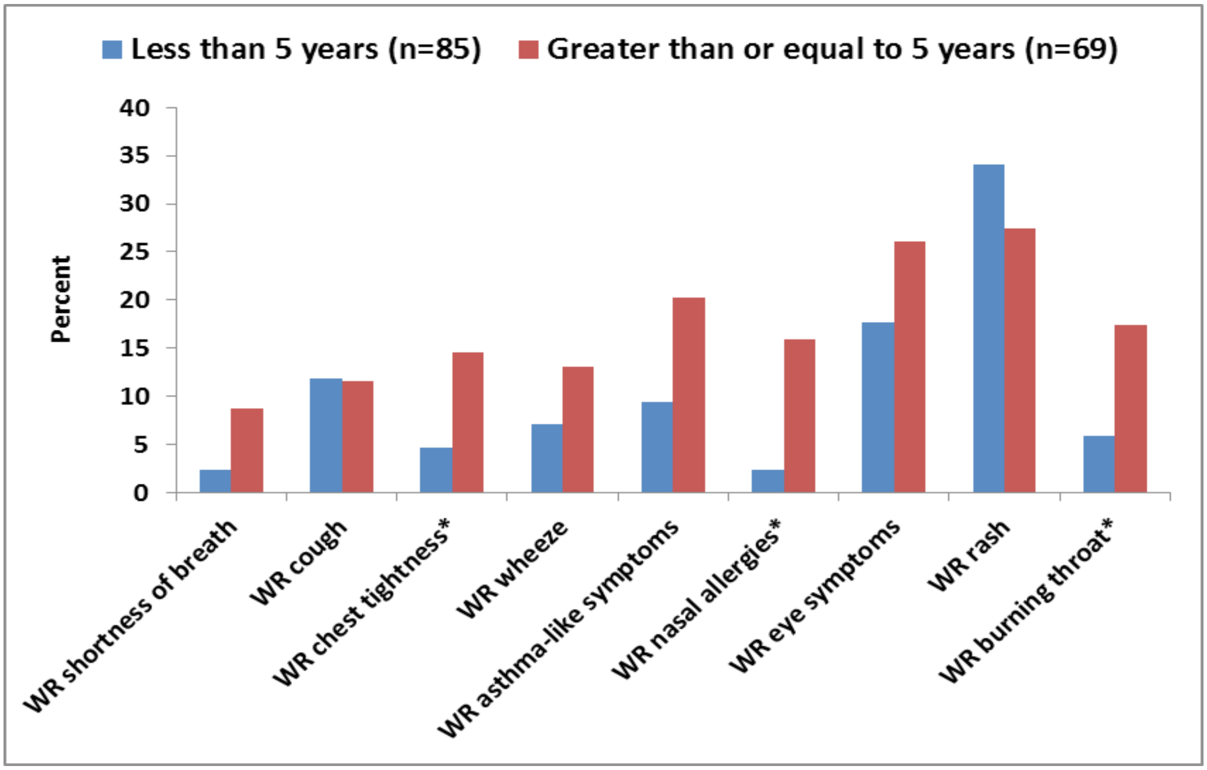

Figure 2. Prevalence of work-related (WR) symptoms by employment tenure group, August 2013 at a syntactic foam manufacturer. Work-related symptoms were defined as symptoms that improved away from the facility, either on days off or on vacation. All symptoms except nasal allergies were specific to the last 12 months. Asthma-like symptoms were defined as current use of asthma medicine and/or one or more of the following symptoms in the last 12 months: wheezing or whistling in the chest, awakening with a feeling of chest tightness, or attack of asthma. Work-related symptoms were defined as symptoms that improved away from the facility, either on days off or on vacation. Statistically significant differences ($p<0.05$) are indicated by an asterisk next to the name of the symptom.

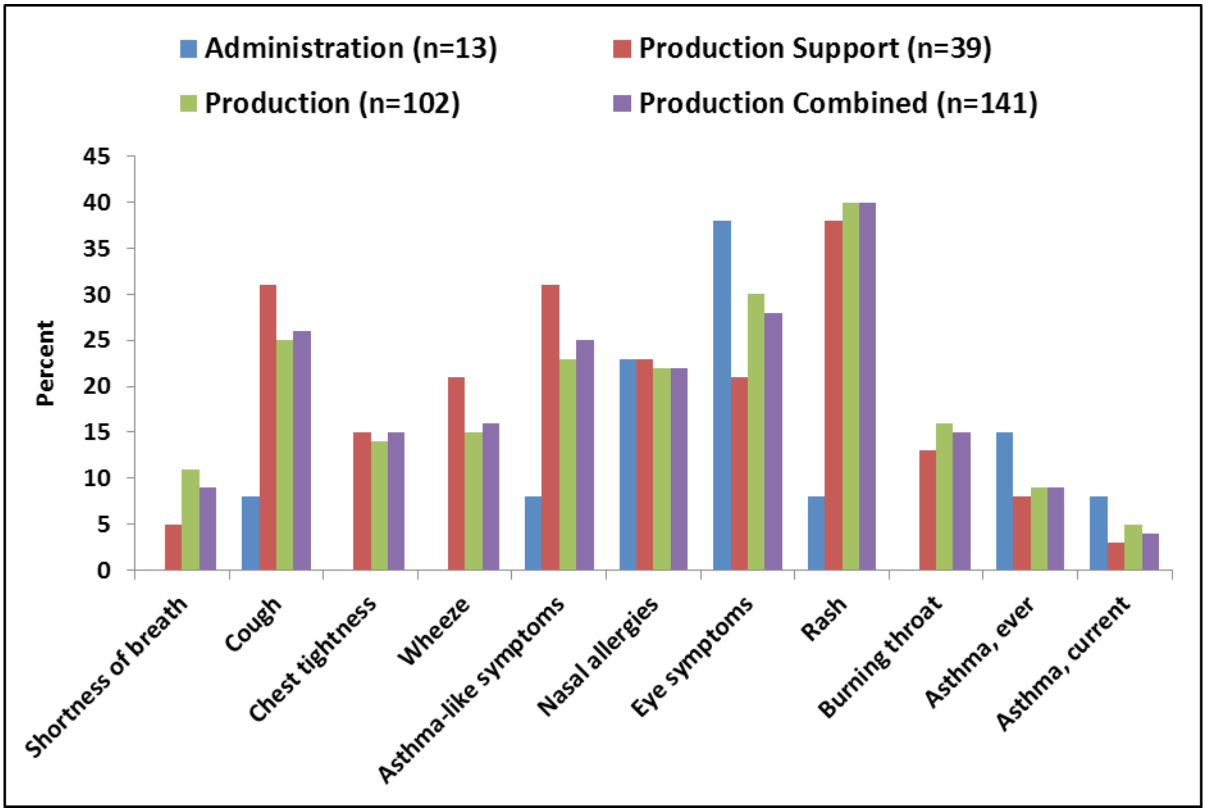

Figure 3. Prevalence of symptoms and asthma diagnoses by current department category, August 2013 at a syntactic foam manufacturer. All symptoms except nasal allergies were specific to the last 12 months. Asthma-like symptoms were defined as current use of asthma medicine and/or one or more of the following symptoms in the last 12 months: wheezing or whistling in the chest, awakening with a feeling of chest tightness, or attack of asthma. "Production combined" includes all participants in production support and production categories. The difference in prevalence of rash between administration and production combined was statistically significant (p=0.03). All other comparisons between administration and production combined were not statistically significantly different.

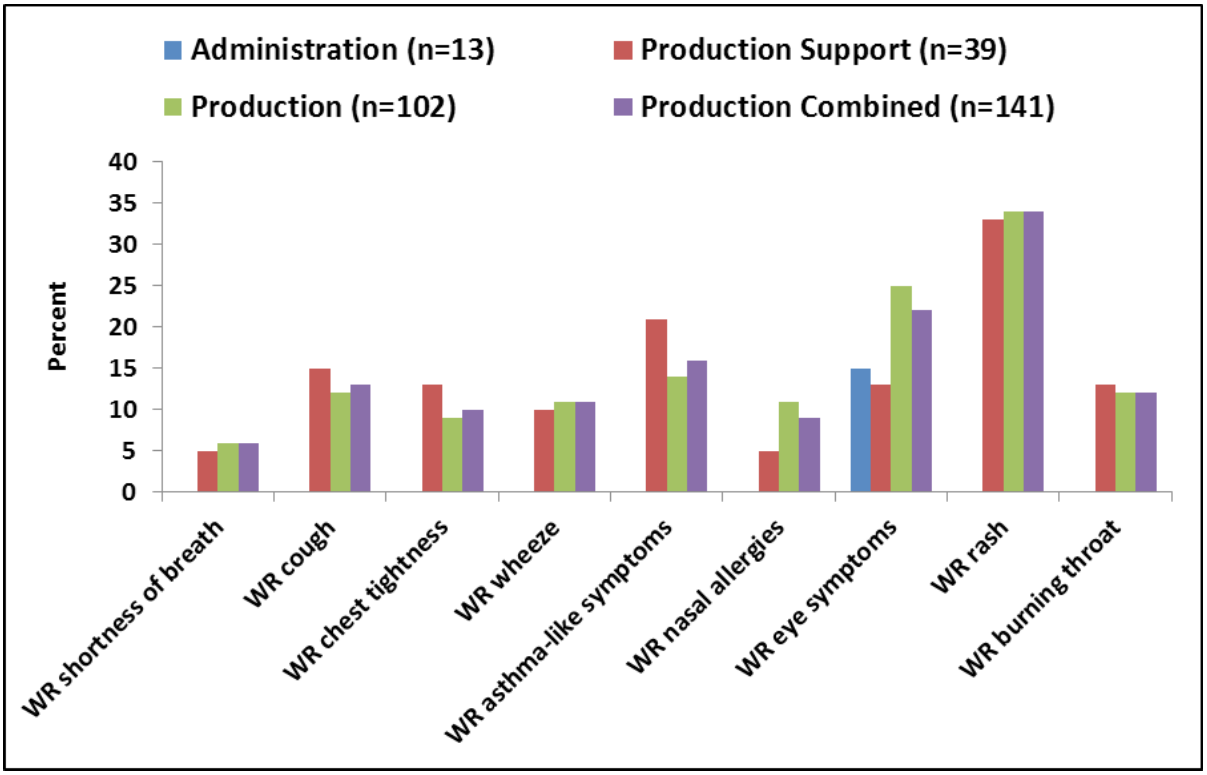

Figure 4. Prevalence of work-related (WR) symptoms by current department category), August 2013 at a syntactic foam manufacturer. Work-related symptoms were defined as symptoms that improved away from the facility, either on days off or on vacation. All symptoms except nasal allergies were specific to the last 12 months. Asthma-like symptoms were defined as current use of asthma medicine and/or one or more of the following symptoms in the last 12 months: wheezing or whistling in the chest, awakening with a feeling of chest tightness, or attack of asthma. Work-related symptoms were defined as symptoms that improved away from the facility. "Production combined" includes all participants in production support and production categories. The difference in prevalence of work-related rash between administration and production combined was statistically significant (p=0.01). All other comparisons between administration and production combined were not statistically significantly different.

Survey Questionnaire (Versions were available in Spanish and Portuguese)

ID:_______

HETA 2012 –0107

This questionnaire is part of a National Institute for Occupational Safety and Health (NIOSH) health hazard evaluation (HHE) of workplace health issues at the facility. Included are questions about health symptoms that you may have now or had in the past, and some questions about your current job and work history. Participation in this HHE and completion of this questionnaire are voluntary. There is no penalty for choosing not to participate. However, full participation will allow NIOSH to better understand current health issues among employees at your workplace.

Please answer all questions to the best of your ability. If you don't understand a question, please ask for help. All personal information from this questionnaire will be kept confidential according to federal law. Group summary results of this evaluation (without any personal identifying information) will be provided to employees and management in a final report after the evaluation has been completed.
(GIVE WORKER A COPY OF FACT SHEET, WHETHER OR NOT S/HE PARTICIPATES.)

Interviewer: _______________ Interview Date: __ __ / __ __ / __ __ __ __
(Month) (Day) (Year)

Section I: Identification and Demographic Information

Name: ______________________ ______________________ ____
(Last Name) (First Name) (M.I.)

Address: ____
(Number, Street, and/or Rural Route)

___________________________ ___________ _________
(City) (State) (Zip Code)

Primary Telephone Number: (____) - ____ - ______ [ ] Home [ ] Cell

---

1. Date of Birth: __ __ / __ __ / __ __ __ __
(Month) (Day) (Year)

2. Sex: 1. ____ Male 0. ____Female

3. Are you Spanish, Hispanic or Latino? 1. ____ Yes 0. ____No

4. Select <u>one or more</u> of the following categories to describe your race:

1.___ American Indian or Alaska Native
2.___ Asian
3.___ African-American or Black
4.___ Native Hawaiian or Other Pacific Islander
5.___ White

5. What is your country of origin?

1._____ Cape Verde Islands
2._____ Angola
3._____ United States
4._____ Other (_________________________)

Section II: Health Information

I'm going to ask you some questions about your health. The answer to many of these questions will be "Yes" or "No." If you are in doubt about whether to answer "Yes" or "No," then please answer "No."

6. Have you had wheezing or whistling in your chest at any time in the last <u>12 months</u>? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 7, IF 'YES':

6.1. When you are away from this facility on days off or on vacation, is this wheezing or whistling:
1. ___ The same
2. ___ Worse
3. ___ Better

7. Have you woken up with a feeling of tightness in your chest at any time in the last <u>12 months</u>? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 8, IF 'YES':

7.1. When you are away from this facility on days off or on vacation, is this feeling of tightness in your chest:
1. ___ The same
2. ___ Worse
3. ___ Better

8. Have you been woken by an attack of shortness of breath at any time in the last <u>12 months</u>? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 9, IF 'YES':

8.1. When you are away from this facility on days off or on vacation, are these attacks of shortness of breath:
1. ___ The same
2. ___ Worse
3. ___ Better

9. Have you been bothered or troubled by coughing in the last <u>12 months</u>? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 10, IF 'YES':

9.1. When you are away from this facility on days off or on vacation, is this coughing:
1. ___ The same
2. ___ Worse
3. ___ Better

10. Have you had burning in your throat in the last <u>12 months</u>? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 11, IF 'YES':

10.1. When you are away from this facility on days off or on vacation, is this burning in your throat: 1. ___ The same 2. ___ Worse 3. ___ Better

11. Have you had an attack of asthma in the last 12 months? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 12, IF 'YES':

11.1. When you are away from this facility on days off or on vacation, are these attacks of asthma: 1. ___ The same 2. ___ Worse 3. ___ Better

12. Are you currently taking any medicine (including inhalers, aerosols or tablets) for asthma? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 13, IF 'YES':

12.1. When you are away from this facility on days off or on vacation, do you use medicine for asthma: 1. ___ The same 2. ___ More often 3. ___ Less often

13. Has a physician ever told you that you have asthma? 1. ___ Yes 0. ___ No

IF 'NO' GO TO INSTRUCTION BEFORE QUESTION 14, IF 'YES':

13.1. In what month and year were you first told you had asthma? ____MM _ _ _ _ YYYY

13.2. Do you still have asthma? 1. ___ Yes 0. ___ No

IF 'NO' TO QUESTIONS 6, 7, 8, 9, 10, 11, 12 AND 13.2 GO TO QUESTION 15,
IF 'YES' TO ANY OF 6, 7, 8, 9, 10, 11, 12 OR 13.2:

14. Is there anything at work that affects your breathing? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 15, IF 'YES':

14.1. What do you think affects your breathing?

____

15. Do you have any nasal allergies including hay fever? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 16, IF 'YES':

15.1. When you are away from this facility on days off or on vacation, are your nasal allergies:
1. ___ The same
2. ___ Worse
3. ___ Better

16. Have you had any rash or skin problems in the last 12 months? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 17, IF 'YES':

16.1. When you are away from this facility on days off or on vacation, is your rash or skin problem:
1. ___ The same
2. ___ Worse
3. ___ Better

16.2. Which of the following areas of your body are affected by a rash or skin problem? *(check all that apply)*

a.	Your face	1. ___ Yes	0. ___ No
b.	Your neck	1. ___ Yes	0. ___ No
c.	Your arms	1. ___ Yes	0. ___ No
d.	Your hands	1. ___ Yes	0. ___ No
e.	Other areas?	1. ___ Yes	0. ___ No

Specify other areas ____

16.3. Is there anything at work that affects this rash rash or skin problem? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 17, IF 'YES':

16.3.1. What do you think affects this rash or skin problem?

____

17. In the last 12 months, have you had any episodes of watery, itchy, red or sore eyes? 1.____ Yes 0. ____ No

IF 'NO' GO TO QUESTION 18, IF 'YES':

17.1. When you are away from this facility on days off or on vacation, are these eye symptoms:
1.___ The same
2.___ Worse
3.___ Better

17.2. Is there anything at work that affects these eye symptoms? 1. ___ Yes 0. ___ No

IF 'NO' GO TO QUESTION 18, IF 'YES':
17.2.1. What do you think affects these eye symptoms?

____

Section III. Work Information

18. I'm now going to ask you to list all of the jobs that you have had while working at the facility, including any time spent as a contract or temporary worker. We will start with your current job and work back through time.

(Use facility map to help participant locate job. Location and job title for main job; 'other jobs' for work done in other areas on less frequent/irregular/occasional basis)

Job Number	Where did you work? (location)	What was your job title? (what you did)	Start Date	End Date	If Office Job, see text below	Other jobs (e.g. overtime)
number	Drop down menus populated with lists + map	Drop down menus populated with lists	MM/YYYY	MM/YYYY	Hrs/wk in production areas	Drop down menus populated with lists

IF THE JOB WAS IN THE PRODUCTION BLDG. OFFICE AREAS, OR IN R & D:
In an average week, how many hours per week (do/did) you spend in production areas?

("Production areas" refers to main production bldg. areas where the flotation devices are manufactured.)

Section IV: Tobacco Use Information

I'm now going to ask you about tobacco use.

19. Have you ever smoked cigarettes? 1. ___ Yes 0. ___ No

(*NO if less than 20 packs of cigarettes in a lifetime or less than 1 cigarette a day for 1 year*.)

IF 'NO' GO TO THANK YOU STATEMENT, IF 'YES':

19.1. Do you still smoke cigarettes? 1. ___ Yes 0. ___ No

THANK YOU FOR PARTICIPATING IN THIS SURVEY!

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Keywords: NAICS 333132
(Oil and gas field machinery and equipment manufacturing), work-related asthma, sensitizers, respiratory, syntactic foam, epoxy resin, amines, anhydrides

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Availability of Report

Copies of this report have been sent to the employer, employees, and union at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

This report is available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0107-3233.pdf.

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