

Evaluation of Exposures and Health at a Specialty Chemicals Plant, West Virginia

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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

The National Institute for Occupational Safety and Health (NIOSH) received a confidential request from employees at a specialty chemicals plant in West Virginia. The requestors had concerns about respiratory and skin exposures to multiple chemicals used at the plant. They felt that such exposures were causing respiratory disease and other illnesses.

What NIOSH Did

- We interviewed employees, managers, and the company's medical consultants by telephone.
- We reviewed documents, including air sampling reports and medical records.
- In February 2013, we visited the plant.
- During the visit, we met with company industrial hygienists and conducted private, in-person interviews with employees randomly selected from a variety of departments and shifts.
- We also took a tour of the plant and observed workers performing their tasks.
- We provided an interim letter detailing recommendations for improvements.
- We held a conference call with the company several months later to review the changes that had been implemented.

What NIOSH Found

- Management was cooperative and employees were willing to talk with us.
- The plant uses and produces many chemicals with respiratory toxicity.
- One worker's physician diagnosed him/her with bronchiolitis obliterans, an irreversible lung disease that this physician attributed to chemical exposures at the plant.
- A second worker also became sick. This worker's symptoms have been attributed to occupational asthma secondary to isocyanate exposure by a pulmonologist. Other physicians have felt these symptoms were consistent with asthma or reactive airways dysfunction syndrome.

We evaluated a specialty chemicals plant for skin and respiratory exposures leading to health problems. We found that eye and respiratory irritation are common among employees, who are generally concerned about their exposures. Two workers have sought care for illnesses they attributed to exposures at work: one was diagnosed with bronchiolitis obliterans while the other was diagnosed with occupational asthma and reactive airways dysfunction syndrome. Workers described apprehension about reporting accidents and unsafe conditions to superiors. We recommended that the company discuss such concerns with employees, invest further in the medical surveillance program, and modify the industrial hygiene program.

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- Employees seemed to know where to find out about personal protective equipment requirements and were knowledgeable about its proper use.
 - Workers were concerned about several issues: decreased local exhaust ventilation when many hoses were functioning simultaneously; delayed preventative maintenance leading to potentially catastrophic equipment failures; difficulty of wearing correct protective equipment in the summer months or when running multiple jobs; and understaffing at the plant impacting safety by requiring multi-tasking.
 - Workers felt that certain tasks were more likely to lead to exposures; these included filter cleaning, flushing of lines/kettles, and hand charging of kettles.
 - Some workers also expressed concern about reporting of unsafe conditions. They felt anonymous reporting mechanisms did not exist. Some expressed reluctance to submit reports for this reason.
 - The company has anonymous reporting mechanisms, including a phone line, but they may not be widely recognized.
 - Some workers perceived that accidents led to retaliation.
 - The company forbids retaliation for accidents, but says that employees may be punished for safety lapses that lead to accidents. These may be uncovered when the accident is investigated.
 - The plant has an onsite clinic capable of conducting spirometry testing, but this testing has not been included in standard annual employee examinations for several years.
 - The plant conducts air monitoring to assess and manage workers' exposures. Throughout the course of each year, approximately 300 personal air samples are collected.
 - Air monitoring is mainly focused on obtaining personal average exposures during tasks rather than during a full shift.
 - Workers frequently work 12 hour shifts plus mandatory overtime, leading to 40-80 hour work-weeks.
 - Exposure limits are not adjusted to account for extended shifts.

What the Employer Can Do

- Communicate with employees about areas and tasks which concern operators, and investigate such concerns.
- Work with the union and health and safety committee to increase awareness of existing ways, or develop new ways for employees to anonymously report unsafe conditions.
- Invest in changing the perception of retaliation for accidents, so that incidents and near misses do not go unreported.
- Include annual spirometry in the employee wellness exams.

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- Analyze spirometry results for excessive decline in lung function over time, and for clustering of abnormal results in certain departments.
 - Evaluate employees for bystander and intermittent high exposures, and include chemicals without a specific Threshold Limit Value-Ceiling or Short-Term Exposure Limit.
 - Consider area monitoring with direct reading instruments to help guide peak or short-term exposure sampling in areas of concern.
 - Conduct full shift sampling, and adjust regulatory limits for longer work days and work weeks.
 - Develop a strategy to judge whether each group exposure profile is acceptable, unacceptable, or uncertain.

What Employees Can Do

- Report conditions that appear to be unsafe either to a supervisor or using the anonymous reporting system.
- Check jobs for required personal protective equipment, and wear it as directed.
- Bring concerns about exposures to union or health and safety representatives.
- Report accidents, incidents, and near-misses to the appropriate person so that procedures can be improved in the future.

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Abbreviations

µm	Micrometer
ACGIH®	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
CFR	Code of Federal Regulations
EHS	Environmental health and safety
HazCom	Hazard communication
HEG	Homogenous exposure group
JSA	Job safety analysis
LOD	Limit of detection
mg/m ³	Milligrams per cubic meter
mL	Milliliter
MSDS	Material safety data sheet
NAICS	North American Industry Classification System
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OP	Operating procedure
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
PPE	Personal protective equipment
ppm	Parts per million
REL	Recommended exposure limit
SEG	Similar exposure group
SOP	Standard operating procedure
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
UCR	Unsafe Condition Report
VPP	Voluntary Protection Program

Summary

In September 2012, the National Institute for Occupational Safety and Health (NIOSH) received a confidential health hazard evaluation request from employees at a specialty chemicals plant. They were concerned about skin and respiratory exposures to chemicals used at the plant. They felt that workers were at risk for lung disease, rashes, and cancer, among other illnesses. In February 2013, NIOSH visited the plant. During the visit, we confidentially interviewed a variety of employees, talked to company officials (local and corporate), met with the union president, and toured the plant. We also reviewed documents provided by the company, including a list of some chemicals used at the plant, results of recent industrial hygiene sampling, injury and illness logs, and information about how unsafe conditions are reported. We found that the plant uses and produces many chemicals with respiratory toxicity, and two employees have sought medical attention for respiratory illnesses. One employee's physician diagnosed him/her with bronchiolitis obliterans, which is an irreversible lung disease that the physician attributed to chemical exposures at the plant. Another employee was diagnosed with occupational asthma and reactive airways dysfunction syndrome. In conversations with employees, we found that many had concerns about the effect of work-related exposures on their health, though most did not have symptoms they specifically attributed to the plant. Workers expressed concern about mechanisms for reporting of safety concerns, feeling that filing a complaint led to a "black mark" on their record, instead of being recognized as a proactive safety initiative. Some workers reported concerns about accidents as well, saying people who were involved in accidents were eventually fired or disciplined, and stated that they would hesitate to report an accident. The plant does not allow retaliation for accidents, but notes that workers can be disciplined for failing to follow safety procedures. During the tour we noticed that the plant had a variety of chemical odors in different areas, and although workers were careful about required personal protective equipment and local ventilation, bystanders in similar areas were not required to adhere to the same protection standards. The industrial hygiene sampling plan focused on measuring task-based exposure and workers with the highest exposure potential. Sampling was not performed on bystanders; neither did the plan account for simultaneous exposures to multiple chemicals during an eight-hour shift or the extended shifts worked by many employees. We made several recommendations in an interim letter in May 2013. Since that time, the company has begun to implement some changes. These include adding spirometry to annual medical exams and planning for changes in the industrial hygiene monitoring protocol for 2014. Given the potential exposure to recognized respiratory toxins, the occurrence of respiratory illness in the workforce, and employees' concerns about exposure and health, we recommend that the company use an improved comprehensive exposure assessment strategy and medical monitoring to guide preventive interventions.

Introduction

In October 2012, the National Institute for Occupational Safety and Health (NIOSH) received a confidential health hazard evaluation request from employees of a specialty chemical plant. The requestors were concerned about respiratory and skin exposures to the various chemicals

used at the plant, and several potential health effects. From February 25 to 27, 2013, four NIOSH employees visited the plant, met with employees and management, and toured the plant. In May 2013, we sent an interim letter to the company with recommendations. The company replied in a formal letter in July 2013, and we followed up by phone in September 2013.

Background

The plant is located on 60 developed acres of a 1300-acre tract in a rural area. It has been in operation since 1955 and currently employs about 400 people, including over 200 chemical union members (International Chemical Workers, Local 698) who are hourly employees. Work shifts are typically 8 or 12 hours. The plant produces a range of specialty chemicals for a wide variety of industrial customers. The three main business lines are specialty fluids (e.g., defoamers, lubricants, cosmetics, and softeners), urethane additives (precursors for polyurethane foam applications), and silanes (e.g. adhesives, insulating material, wires, and rubber applications). The large plant is organized around four production departments referred to as Polymers I (or Specialties West), Polymers II, New Product Development (or Specialties East), and Silanes. The production departments are further supported by Warehouse and Distribution, Research and Development, a Quality Control Laboratory, and Environmental Protection Units.

Process Description

Thousands of raw ingredients are used at the plant for a large number of batch recipes that are made according to customer orders. The batch orders change often and the work is variable. Some chemical classes include acid anhydrides, acrylates, amines, isocyanates, chlorides, silanes, and volatile organic solvents. Platinum salts may also be used as a catalyst. Most of the volatile organic solvents are routinely used in batches and for cleaning of equipment between batches. Nitrogen gas is also used often to purge empty kettles, storage tanks, and drums before filling in order to reduce flammability.

Departments typically have one or more control rooms outfitted with computers and multiple monitors to control operations. The control room is located in a different room or building than the production floor. Operators follow company operating procedures (“OPs,” a term used by the company that is comparable to the widely used standard operating procedures [SOPs]), which are designed by engineers to include recipes and instructions for reacting raw or intermediate ingredients in a kettle. The special combination of raw ingredients is called a “batch”. Kettles range in size from 30 to 9,000 gallons. On the production floor, an operator “charges” a kettle by adding solid (powdered) and liquid ingredients manually (i.e., “hand charges”) or automatically. Manual charging occurs through the “manhole”, which is a small bolted door at the top of the kettle. This is done by directly pouring the hand charge into the kettle or by using a funnel. Operators also use local exhaust to ventilate when the manhole is open. Automated charging occurs via hoses or pipes tied to tanks equipped with pumps or directly from drums and trailers. During the production process, certain chemicals may

be removed (i.e., “stripped”) from the mixture through distillation and transferred to a strip tank. Depending on the circumstances, the stripped chemical can be the final product or an impurity. Most kettles have an agitator device that mixes ingredients inside. Samples are taken by operators at multiple stages of the process. Operators will collect samples from the kettles from inline valves into a 4-ounce glass jar. Samples are sent to the Quality Control Laboratory for analysis.

The product may be filtered when the reaction is complete or during agitation. This is done directly to the finished product or after being piped to a larger tank. The filtering may occur with bags or open frames containing filtering plates. Frames in the older filtering system are open, whereas bags and frames in newer systems are enclosed. In the older filtering system, the operators must attach filter paper to the plates, while the newer, enclosed system has built-in filters. A filtering aid, such as diatomaceous earth or activated charcoal, is added to the product in slurry to facilitate the removal of impurities. After contact with the filter, the impurities collect on the plates and bags, allowing a cleaner product to pass through.

After a product run is complete, the older plate frame filter system is cleaned by manually scraping off the slurry and filter paper material with a large spatula or scraper and shaking it into a pit located below the filter. The kettle and/or filter may be stripped with solvents like toluene, isopropyl alcohol, ethanol, methanol, or xylene. The stripping process is enclosed, as the solvent is piped into the kettle and blown into a waste solvent tank. Waste solvent is transferred to a portable tank, or dumpster, to be treated. This waste is managed onsite at a private wastewater treatment plant, a rotary kiln incinerator for solvents and solids, or by being transferred to an onsite landfill. Hazardous wastes are treated with neutralizing compounds (e.g., lime) to bring pH back to neutral and run through primary clarifiers. Some waste water is transported to an offsite commercial treatment facility.

Finished products are packaged into drums in the production area in some areas and piped to storage tanks and held until transferred to a drum filling station in others. At this station, distribution transfer operators weigh and fill drums through a pipe opening or drum dip tube under local exhaust ventilation. Intermediate products that will be used at the plant to make final products are transferred to drums or centralized storage tanks where they are held until needed. All final products are transferred into drums or large shipment tanks for transport.

Emergency Response

The plant operates a fire brigade and hazardous materials response team that is on call at all times. Brigade members receive hands-on training in fighting chemical fires at an annual course held in South Carolina. The fire brigade responds to fires, vapor clouds (which may occur due to leaks or pipe ruptures), leaks, spills, and the formation of a potentially explosive “hydrolysate ball” in the production of silanes. The ball is formed on pipes when a leak is present. The employer estimates that the fire brigade responds to about 10 calls per year.

Personal Protective Equipment and Respiratory Protection Program

Required personal protective equipment (PPE) in production areas includes hard hats, safety glasses, steel toe shoes, and flame retardant clothing. Depending on the type of chemicals required for a batch recipe, operators may also wear gloves, rain suits, and respiratory protection. Respiratory protection consists of disposable filtering facepiece respirators, full facepiece respirators with cartridges, and tight-fitting full facepiece masks used with a self-contained breathing apparatus or supplied air. The type of respiratory protection varies depending on the chemical ingredients in a batch recipe. Multiple information resources are provided to operators, allowing them to determine what type of respirator is required. These include a Job Safety Analysis (JSA) document, the OPs, the Lab Information Management System for labeling (LIMS), and the material safety data sheets (MSDSs). All workers have access to the JSA system and MSDSs from computers located in the control rooms. Employees in the respiratory protection program undergo annual medical evaluation (questionnaire and physical examination) followed by quantitative fit testing with a TSI PortaCount® respirator fit tester. Spirometry was not routinely conducted at the time of our evaluation.

Methods

Prior to Site Visit

Prior to our visit to the plant, we had several phone conversations with the plant industrial hygienist, the Environmental Health and Safety (EHS) manager, and the corporate industrial hygienist. We also talked with the medical team, including the plant nurse, the corporate physician, and the plant physician in order to learn more about the medical programs at the plant. Lastly, we interviewed the requestors and other workers from the plant over the phone, in order to understand health concerns, safety practices, and potential exposures at the workplace.

The company industrial hygiene and EHS team described the plant's operations and safety programs to us and provided the documentation that we requested. These documents included: Occupational Safety and Health Administration (OSHA) 300 logs of illness and injury, the hazard communication (HazCom) manual, the management of change plan, the written respiratory protection plan, and the OSHA Voluntary Protection Program (VPP) site review report. Additionally they provided the Superfund Amendment and Reauthorization Act Tier 2 chemical report from 2011, industrial hygiene monitoring data for the past 5 years, a list of chemicals within certain families used at the site, and a brief description of their homogenous exposure group (HEG) strategy. In preparation for the visit, they also sent us an employee roster. We reviewed all this information carefully, and asked for clarifications and other information where necessary. We also reviewed existing medical and industrial hygiene literature about known health effects from the chemicals used at the plant.

Site Visit

Upon arrival at the site, we had an opening conference, attended by local and corporate management, industrial hygienists, the corporate physician, supervisors and team leads

from around the plant, and a union representative from the International Chemical Worker's Union, Local 698c. During this meeting, we viewed a slide show about the plant's history and manufacturing, and we discussed our plan for the visit. Afterwards, we watched a safety video about the plant.

That afternoon, we toured the facility to improve our understanding of the plant processes. We observed workers performing their tasks. We took photographs of equipment and safety provisions, and also learned about how the need for PPE is determined.

Subsequently, the two industrial hygienists on our team explored the plant in more depth. They revisited some areas, including New Product Development and Distribution Transfer, examined PPE use and OPs, and observed employees performing tasks (e.g., hand charging kettles, drum-filling, and laboratory experiments). Additionally, they spoke in depth about the plant's current exposure assessment strategy and historical exposures with the plant and corporate industrial hygienists, as well as the union representative from the plant.

The two physicians on the team spent time interviewing workers from all over the plant. These confidential interviews were intended to better understand individual safety practices and PPE use, and to address any health and safety concerns that might exist in the workforce. We provided copies of an informational handout regarding our visit, and had available pamphlets on the NIOSH health hazard evaluation program [NIOSH 2009]. Lastly, we reviewed medical records and discussed health and safety issues and medical surveillance procedures and capabilities with medical personnel.

At the end of the visit, we had a closing meeting, during which we discussed our findings, preliminary recommendations, and the future course of the investigation. We requested, and have received from the plant, a list of photos designated as trade secret, 2 sample JSAs, a sample unsafe condition report (UCR) form, a HazCom label, and the preventative maintenance procedures for the plant.

After the Site Visit

We prepared an interim letter summarizing our findings and interim recommendations. This was sent to the company, confidential requestors, OSHA, and the state health department in May 2013. The company reports that they posted the letter for 30 days as requested. In July 2013, they composed and mailed a response letter, which detailed their implementation of our recommendations and the changes at the plant subsequent to our visit. It also included some information in response to our observations. We followed up with a phone call in September 2013. During this phone call, we clarified questions and statements from the plant's response letter. We also asked about further changes since the time of the letter. We offered to review the quality of spirometry and their amendments to industrial hygiene sampling strategy.

Results

Document Review

During conversations prior to our visit, the management team disclosed information about 2 workers with respiratory illness. The first had been diagnosed with bronchiolitis obliterans (also called obliterative bronchiolitis). Obliterative bronchiolitis is a severe lung disease, previously reported to be associated with chemical exposures in a variety of industries [Kreiss 2013]. The lung function decline is irreversible and may result in the need for lung transplant.

The second worker had been diagnosed with occupational asthma and reactive airways dysfunction syndrome. At least one physician related these symptoms to the worker's reported prior isocyanate exposure at this plant. This worker had been potentially exposed to isocyanates during a spill response prior to the onset of symptoms. Some isocyanates are associated with asthma, asthma-like symptoms, and other obstructive lung disease [Pala et al 2011; Pronk et al 2009]. Chemical sensitivity has also been described in the literature; it has been associated with several chemicals used at the plant, including di-isocyanates [Mapp et al 1988].

Our review of the chemicals used at the plant revealed that many are skin and/or eye irritants. Additionally, others have been associated previously with respiratory injury and irritation. There is some literature available that certain exposures through the skin may lead to respiratory sensitization and thus irritation on subsequent exposure [Kimber and Dearman 2002]. Additionally, solvent exposure has been linked to toxic encephalopathy (nervous system damage) as well as other health effects [Beningus et al 2009].

In our review of the OSHA VPP program application and assessment, we noted that OSHA had recommended a review of the conversation record. This is a record generated when the company investigates a UCR which has been turned in by an employee. These become part of the employee's file and are widely perceived by employees to have a negative impact. The report stated that OSHA did not find evidence these were misused, though workers reported concerns about this process and the union felt it was disciplinary. When we asked the managers about this process prior to and during our visit, they stated that the conversation record remained largely unchanged, but they were discussing how to alter its perception among workers.

From our review of the industrial hygiene documents, we learned that the plant applies a Similar Exposure Grouping (SEG) and HEG strategy to assess and manage workers' exposures. There are two SEGs (hourly and salaried employees) and 39 HEGs, which are called similar exposure groups by the American Industrial Hygiene Association (AIHA). In this document we use the company's terminology and will refer to them as HEGs. We analyzed the industrial hygiene monitoring data from 2008 to 2012 that the company provided. According to the defined working nature of each specific HEG, the company's industrial hygienist monitored for specific airborne exposures to a range of chemicals. Over the course of 5 years, there were 126 combinations of HEGs and chemicals monitored

(obtained from 35 HEGs and 44 chemicals monitored), for a total of 1,031 airborne measurements. Among those HEGs, Maintenance Welders were most frequently monitored (21% of the total number of measurements), followed by Distribution Transfer Operators (13%). Several HEGs, including Maintenance Welders, Distribution Transfer Operators, and other Operators in the production departments, were monitored for potential airborne exposures to more than 5 chemicals. Among all 44 chemicals, toluene was the most frequently monitored chemical, with over 19% of the total measurements (from 24 HEGs), followed by acrylonitrile (8% from 9 HEGs), acrolein (6% from 5 HEGs), and allyl chloride (4% from 6 HEGs) [Figures 1 and 2 at the end of the report].

Employee Interviews

Everyone at the plant was friendly, welcoming, and generally willing to talk to us and answer questions. Overall, most employees felt that safety and the work environment at the plant had improved over the past several decades. Many mentioned a decrease in large scale incidents and emergencies such as vapor clouds and fires. They also commented that the plant responded to incidents with new safety regulations when appropriate.

Many employees felt that there were additional steps that plant management could take in order to provide a safe working environment. Many workers stated that accidents frequently go unreported due to a fear of reprisal. Workers generally agreed that they would avoid reporting an accident if possible. Additionally, many employees acknowledged that the design of the UCRs was good in theory, but felt that they did not work as intended. In the past, employees were positively recognized for drawing attention to potential health and safety issues (by being entered into a drawing for a free gift). Workers stated that currently the UCR forms are used to follow back with employees about whether the problem has been fixed, in the process creating a “conversation record”. This record is viewed negatively by workers, who feel it is used solely as a disciplinary tool.

In terms of health, few employees reported symptoms that they attributed to the workplace, but many seemed to feel that working at the plant would ultimately negatively impact their health. The most frequent symptoms reported were eye burning or stinging during the filter stripping process or when using solvents. A number of people reported chronic cough or shortness of breath, though these were rarely attributed to work.

Nonetheless, workers had concerns about possible exposures. Some specific concerns included: a) insufficient local exhaust ventilation when many of them within the same work area were operating simultaneously; b) delayed preventative maintenance and repairs, potentially leading to catastrophic equipment failure; c) difficulty in wearing correct PPE during the warmer months and while running multiple jobs requiring different PPE; and d) the current understaffing of the plant, leading to additional responsibilities and extended work shifts.

Three tasks routinely mentioned by employees as potential sources of exposure were cleaning of filters, flushing of the lines and kettles, and hand charging of materials into the kettle.

According to workers, filter cleaning often involves the use of solvents and may be performed manually in sinks or at the filter station. Although the sinks are ventilated, workers were concerned because the filters continue to emit chemical odors while drying. Similarly, piping and tanks must be routinely cleaned with solvents or other solutions. Though harsher solvents are piped to a hazardous waste collection area, many cleaning solutions can be emptied directly into drains in the buildings, which could result in exposure to the remnants of whatever was in the tank prior to cleaning.

On-site interviews with health professionals

We interviewed the plant nurse, plant physician, and corporate physician. During these discussions, we learned about the medical team's interest in health promotion among employees. Employees get a yearly physical exam, part of which involves filling out a respiratory questionnaire. Responses to the respiratory questions may prompt spirometry testing in the clinic. Through our discussion with the nurse, and review of records, we found that fewer than 30 employees underwent spirometry testing each year, and these results tended to be normal. Previously, the plant periodically conducted surveillance spirometry, but this was no longer the case at the time of our visit. Attempts to review records from surveillance spirometry were hampered by the age and condition of the records, making examination difficult. We were able to review two spirometry reports from employees who required further testing based on their respiratory questionnaire. These two spirometry tests appeared to be of acceptable quality.

On-site interview with Industrial Hygienists

We also interviewed both plant and corporate industrial hygiene personnel during the site visit. From the interview, we learned that every year a chemical monitoring strategy is developed by adapting and modifying the previous year's plan. The chemical monitoring strategy was originally designed using a primarily observational, qualitative approach. This involves using job characteristics, chemical toxicity, frequency of chemical usage, and worker input to determine sampling goals. Throughout the course of each year, approximately 300 samples are collected from various HEGs.

The plant has historical industrial hygiene monitoring data collected over more than two decades, and we commended the efforts by the plant's industrial hygienist to collect such information. However, this abundance of data has not been used to more effectively manage workers' exposures by confirming or adjusting the grouping of HEGs or the number of samples collected for each HEG. From the interview, we also found that the plant does not have a strategy to judge whether each HEG exposure profile is acceptable, unacceptable, or uncertain. Rather, the plant has been adapting a traditional method in evaluating workers' exposure by comparing the highest exposure worker's result to occupational exposure limits (OEL) such as the American Conference of Governmental Industrial Hygienists' (ACGIH) threshold limit values (TLVs) and OSHA permissible exposure limits (PELs). In addition, most samples were taken only during job-specific tasks (rather than full-shift sampling) though results were compared to 8-hour TWA (time-weighted average) limits.

Field Observations

During the site visit, our industrial hygiene personnel learned that potential exposures to workers performing tasks such as hand and drum charges are monitored routinely. We observed close adherence to PPE guidelines and safety protocols for workers interacting with chemicals during batch processes. Local exhaust ventilation was used when tasks involved direct contact with chemicals, opening kettles, or during distribution and transfer into drums and other containers. However, bystanders adjacent to active work areas were not monitored, even for confirmation of low or absent exposures. In addition, we learned that throughout the course of a single work-shift, workers may be working with several different chemical agents resulting in potential multiple chemical exposures and that work shifts may be up to 12-hours a day. With the addition of mandatory overtime, many workers are working 40-80 hours per week.

After the Site Visit: Company Response and Updates

The company was concerned that employees stated accidents go unreported due to fear of reprisal. They described their process for investigating accidents and unsafe conditions. They felt strongly that workers are not punished for accidents, but stated that the investigations can reveal that an employee was not following safety standards, therefore resulting in disciplinary action. Additionally, all events, including accidents, incidents such as fires and explosions, near misses for incidents or accidents, and spills or leaks are investigated by a team. The team may consist of only the area manager and operator, or may involve the entire EHS group. They keep track of such incidents in a database. They informed us that there are about 350-400 per year, all of which are investigated.

We had suggested that the company discuss the negative perception of their UCRs, and consider anonymous reporting. The company maintains that anonymous reporting avenues already exist. They have an anonymous phone line to an organizational ombudsman that employees can call with their concerns. This phone line was not mentioned by workers during our interviews, and it is unclear how much of the workforce is aware of this option. The company also stated that Union Safety Representatives can bring anonymous concerns to the committee, and they plan to improve this option in the future.

We had reported that employees felt that there was not enough attention paid to routine maintenance and that the equipment (in some cases) was at risk for catastrophic failure. Several instances were described by a variety of employees. The company provided us with information about preventative maintenance for pipes and tanks. They also informed us that regular preventative maintenance is performed depending on the age of the equipment, manufacturer recommendations, and history of usage. The company stated that they have not had any overdue critical safety preventative maintenance work orders in the last 5 years, and that they performed over 1400 critical safety preventative maintenance work orders in the last year alone.

The regular medical exam that employees receive includes a hearing evaluation and respiratory questionnaire. As of July 2013, the company restarted annual spirometry as we

recommended. Secondary to our recommendations in the interim letter, their medical team is considering ways to look at the spirometry data longitudinally by plant area to check for excessive decline over time and correlations with employee jobs. We suggested SPIROLA software as a potential tool, but the company believes their current software has the ability to do similar analyses. They are currently entering information into this database and plan to examine it in concert with industrial hygiene information based on area sampling and HEG results.

Likewise, the company is looking into the concerns voiced by employees about over reliance on PPE. Because workers are aware of the existing engineering controls, they often inquire about the need for PPE. The company states that it requires PPE in some cases to protect against potential equipment failures that could result in exposure. They plan to add information about existing controls into their annual posting series, which educates workers about different aspects of the job at the plant.

The plant is examining specific areas and tasks that employees felt were potentially hazardous, such as New Product Development, Polymers I and II, and filter cleaning. They informed us that these were going to be “priority areas” for some of the changes they are implementing based on our recommendations. In addition, these areas will be built into the 2014 industrial hygiene sampling plan, with guidance from the AIHA’s manual on assessment and managing occupational exposures [AIHA 2006].

We had raised concerns about bystander exposures and the lack of area monitoring. The company reported that they plan to use qualitative measures as a screening tool to determine the need for area monitoring. They informed us that they will prioritize the areas where operators are concerned. Since there are a variety of potential exposures at the plant, the real-time or near real-time area monitoring will allow the industrial hygienist to identify where and when personal sampling for short-term or bystander exposure should be performed. In addition, the company has added a new task to each HEG called “bystander”, which will allow these workers to be analyzed as a new group.

The plant is currently evaluating how to take into account longer work shifts and extended work weeks. They stated that exposures will be assessed against PELs and TLVs which will be adjusted for longer work periods in the future. In addition to the simple Brief and Scala [1986] method that we recommended for the adjustment, they are looking at utilizing pharmacokinetic modeling. Furthermore, the plant industrial hygienist checked with the analytical laboratory and was informed that they are able to analyze multiple chemicals (certain combinations of solvents, excluding methanol) with a single sample, which will make it easier for the plant industrial hygienist to evaluate workers’ simultaneous exposure to multiple chemicals.

The plant industrial hygienist has signed up for continuing education. She has taken the AIHA course for exposure assessments and statistics. Additionally, she attended the 2013 virtual AIHA conference.

Discussion

Health Effects

Employees at the plant were concerned about potential exposures while at work. They complained of eye and respiratory irritation when exposed to certain chemicals. Several people reported chronic cough or shortness of breath, but they did not attribute these symptoms to work.

Several of the chemicals used at the plant have been identified as respiratory toxins. For example, isocyanates, epoxy resins, and methyl methacrylate have been reported to cause or aggravate asthma [NIOSH 2004, Hannu et al 2009, Borak et al 2011]. Isocyanates have been studied extensively in the literature, and in addition to asthma, have been associated with hypersensitivity pneumonitis, obstructive lung disease, non-asthmatic neutrophilic bronchitis, and contact dermatitis [NIOSH 2004, Pronk et al 2009, Pala et al 2011]. In particular, a single over-exposure to isocyanates can lead to triggering of a respiratory reaction upon future exposures, even if these are well below regulatory limits [NIOSH 2004]. Such exposures have been reported in a wide variety of industries, including polyurethane foam, reinforced plastics, spray painting, foam packaging, iron foundries, and aircraft assembly [NIOSH 2004].

One of the facility's employees was diagnosed with obliterative bronchiolitis, a disease in which the lung's smallest airways are irreversibly scarred, leading to cough and shortness of breath. Obliterative bronchiolitis cannot be excluded by normal spirometry, as individuals may have obstructive, restrictive, mixed, or no abnormalities on the test [King et al 2011]. Definitive diagnosis involves lung biopsy [Kreiss 2013]. As a result of its non-specific symptoms, variable spirometric findings, and relative rarity compared to more common airways diseases such as asthma and emphysema, obliterative bronchiolitis is frequently misdiagnosed. There is no specific therapy for the disease; advanced cases may require oxygen therapy and lung transplantation.

Obliterative bronchiolitis is associated with inhalational exposures to gases or vapors including chlorine, dimethyl disulfide, hydrochloric acid, sulfur mustard, hydrogen sulfide, nitrogen oxides, diacetyl, ammonia, and household cleaners [Seaton 2008, Kreiss 2013]. Cases have also been described in relation to other types of inhalational exposures, such as iron oxide, fly ash, and World Trade Center dust [Seaton 2008, Kreiss 2013]. The classic description was of chronic impairment following acute illness after a massive exposure (such as from an act of war or an accidental release), but more recent information points to the indolent evolution of impairment without antecedent overwhelming exposure or acute illness [Kreiss 2013]. For instance, obliterative bronchiolitis has occurred in flavoring chemical-exposed workers without unusual over-exposure events or acute illness [Kreiss et al 2002, CDC 2007]. Thus, this disease is often insidious at onset, but can rapidly progress to significant disability and the need for lung transplant.

The work-relatedness of occupational obliterative bronchiolitis may go unrecognized because declines in lung function secondary to work-related lung disease are not always

clinically apparent, and many people do not associate their symptoms with work [Kreiss 2007a, Kreiss 2013]. Furthermore, identifying the specific cause of a particular case can be challenging, especially in the setting of multiple chemical exposures. The first cases of obliterative bronchiolitis in flavoring manufacturing workers were reported in 1986, but hundreds of flavoring chemicals were in use, obscuring the cause [Kreiss 2007b]. It was not until a cluster of disease was noted in microwave popcorn workers using only butter flavoring chemicals that a link to diacetyl was made [Kreiss et al 2002, Kreiss 2007b]. Thus an absence of prior literature linking obliterative bronchiolitis to a particular chemical does not mean that the chemical does not cause this disease. Indeed, it has been argued that “obliterative bronchiolitis may be regarded as a possible consequence of exposure to any gas, fume, or fine soluble dust with potential to damage airways either on account of its strongly acidic or alkaline pH or because of its ability to release toxic free radicals” [Seaton 2008].

Additionally, many of the chemicals have effects outside the respiratory system. Many are classified as skin and eye irritants, and some have adverse reproductive effects, while others may be carcinogens [NIOSH 2010]. For example, aromatic amines have been linked to bladder cancer [Ward et al 1996] while solvent inhalation has been linked to neurotoxicity [Beningus et al 2007].

At this time, it is unknown whether exposures at this plant pose a risk of disease to the workers. Literature, employee concerns, and reports of two sick employees suggest that such a link is plausible. The company has appropriate resources to investigate possible work-related illness, and medical surveillance over time may help to answer this question.

Industrial Hygiene Monitoring

Compliance monitoring at the facility simply focuses on the employees with the highest exposure potential with the assumption that the rest of the workers’ exposures are below occupational exposure limits. In contrast, comprehensive exposure assessment (based on SEGs in the literature, or HEGs in the plant’s terminology) is the state-of-the-art approach to help an organization better understand and manage the risks associated with the exposures. Comprehensive exposure assessment aims to characterize all exposures for all workers on all days based on the monitoring of worker groups having similar exposures. The goal is to understand each worker’s exposure, and hopefully, the risks that such exposures entail. This approach emphasizes the importance of day-to-day and between-worker variations in evaluating a given group’s exposure profile. We commend the industrial hygiene team at the company for taking on such efforts.

The assumption that workers’ exposures are low or negligible in the absence of monitoring data may be incorrect. Some employees were also worried about chemical odors that drifted from adjacent work areas, and we also noticed odors during the plant tour. Although one worker might be required to wear respiratory protection while working with specific agents, other workers (e.g., a supervisor) in the area or the nearby adjacent area may not be wearing equivalent protection. The significance and severity of this exposure is unknown because workers are not routinely sampled for bystander exposures. As with bystander exposure, there

may be exposures that precede or follow specific job tasks. The assumption of low or absent exposure outside these measurement times may be false, as most samples are taken only during job specific tasks and yet results are compared OELs-TWA and PELs for an 8-hour full shift during a 40-hour week. Therefore, taking some full-shift samples is important to fully understand workers' exposure during an entire period of work. This is particularly useful if the samples can be analyzed for multiple contaminants (e.g., solvents).

From our conversations during the site visit, we learned that understanding peak exposures of workers is particularly critical in this plant, considering the consistent potential risks of leak and periodic manual batch processes. Appropriate use of direct-reading instruments can help industrial hygienists identify targeted sampling for peak or short-term exposures and reduce the number of samples that are below the limit of detection. Although there are two real time monitors currently located in the laboratory and laboratory storage area to measure airborne levels of isocyanates, there were no real time air monitors for isocyanates or other chemicals in production areas.

TLVs, RELs (NIOSH recommended exposure limits), and PELs normally refer to exposures over an 8-hour shift during a 40-hour week; adjusted standards for workers with longer shifts and longer work weeks should be lower than the 8-hour standards. Thus, exposure assessment for those workers requires modification to account for longer exposure periods [AIHA 2011]. Additionally, exposure to multiple chemicals during the work shift may produce interactions among chemicals, resulting in additive, synergistic, or antagonistic health effects; particularly for respiratory (e.g., asthma) and skin sensitizers [Brodeur et al 2001]. Therefore, it is important to investigate the potential of multiple exposures stemming from mixtures and potential interactions of multiple chemicals even though no individual chemical is over an OEL.

Other

Many workers felt that current preventative safety maintenance was not sufficient to prevent all catastrophic equipment failures, and that engineering controls could be used more often throughout the plant. Additionally, several employees had concerns regarding the reporting of unsafe conditions, the plant's method for dealing with accidents, and the use of the conversation record as a disciplinary tool.

Conversations with employees suggested a lack of awareness of anonymous reporting options. OSHA requires that companies provide a mechanism for employees to report concerns and suggests that there be multiple paths [OSHA 2013]. Ensuring that employees are aware of these options, including anonymous reporting routes, is important.

The negative perception of UCRs, conversation records, and accident retaliation is concerning. Regardless of the realities of retaliation and frequency of safety maintenance, such concerns among workers may lead to real problems. For example, if workers feel that preventative maintenance is not dealt with appropriately, they may be less likely to report things that need attention because they perceive that repairs may not happen in a timely

fashion. Though the company maintains that conversation records can be good or bad, the general perception among workers is that conversation records are a negative tool. Thus, they may avoid reporting concerns in an effort to avoid this perceived undesirable outcome.

Conclusions

This HHE was requested secondary to worker concerns about exposures at a chemical plant leading to a variety of health effects. During the investigation we reviewed the literature on some chemicals used at the plant, health effects at similar plants, information from the company's industrial hygiene monitoring, and medical records. We found that the facility uses a large number of chemicals, some of which are known respiratory toxins, and that two workers developed respiratory problems that could be related to workplace exposures. While we cannot determine if the employees are at risk of health effects secondary to work exposures, we do feel that there is potential for exposures and secondary health effects due to the large number of chemicals used. Our recommendations for medical surveillance and changes to industrial hygiene monitoring strategies are intended to assist the company in identifying some problematic areas or workers who would benefit from enhanced protection from ongoing exposures.

Recommendations

On the basis of our findings, we recommend the actions listed below. As the plant has a labor-management health and safety committee, we suggest that the group 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 situations at this plant. Though the plant has made some changes based on our interim letter as discussed above, we include these recommendations for completeness.

Our recommendations are based on an approach known as the hierarchy of controls. This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and 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. As mentioned in the discussion of this report, many of the chemicals used at this plant have known or suspected health effects. Yet effective substitutes may not be

available for many of these substances, and those that do exist may also pose a risk of health problems. Thus, we focus our recommendations on ways to assess and control exposures from chemicals currently used. If safe and effective substitutes become available, we would recommend the use of these when possible.

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. We understand that putting engineering controls into place is costly, especially in an older plant. Nevertheless, workers were concerned about over-reliance on PPE. We encourage the plant to assess engineering controls and changes to processes to minimize workers' exposure during the decision making process for capital project improvements.

Administrative Controls

The term 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. The potential for chemical exposures at the plant poses risks of occupational lung disease, especially from episodic or peak exposures. Some workers have concerns about these risks. Therefore, we recommend that the plant institute annual spirometry for all employees who regularly enter the production area or work with chemicals.
2. We recommend that the medical staff analyze individual and group spirometry by looking at changes in function over time, which may allow early, pre-symptomatic, identification of workers suffering from lung disease. For a test interval of 1 year, a decline in the forced expiratory volume in one second (FEV_1) of greater than 10% is considered excessive and should prompt referral to a lung specialist familiar with occupational lung disease [Wang et al 2006]. Additionally, looking at longitudinal spirometry data by area of the plant can help pinpoint areas of the plant that may be problematic. Such analysis can be done on-site using software that is currently available. NIOSH has designed a free tool called SPIROLA, available on the NIOSH website [NIOSH 2013] to facilitate this.
3. We suggest that the plant continue to discuss with the plant health and safety committee and union ways to change the perception of UCRs, including the possibility of anonymous reporting of problematic areas. This may include increasing awareness of existing anonymous reporting mechanisms. Additionally discuss with the committee ways to make sure accidents are perceived as opportunities to learn and improve, as opposed to mechanisms to punish people. Regardless of the reality of retaliation, employee perception of such retaliation influences reporting behaviors. The under-

reporting of accidents and unsafe conditions can lead to unrecognized hazards, and ultimately to exposure and accidents.

- Workers were concerned that local exhaust ventilation was insufficient when many within the same work area were operating at the same time. We suggest you evaluate the systems when multiple exhaust ventilations are in operation. To check adequate airflow at the opening of the exhaust, the plant can use inexpensive smoke generation tubes or air velometers [ACGIH, 2004].
- Bystander exposure is a concern, especially when people are performing different tasks in relatively close proximity. The precautionary approach would state that unless the exposure is demonstrated to be zero, “no exposure” should not be assumed. We suggest that the plant assess the possibility of bystander exposure with industrial hygiene sampling. The company has begun to examine ways to do this, and we encourage the continuation of this effort.
- Area monitoring with direct-reading instruments may be used to collect data on background, variations, spikes, and changes in levels due to process or ventilation controls. Direct-reading instrument data can also be used to identify targeted sampling for peak or short-term exposures and reduce the number of samples below the limit of detection.
- For extended shift workers, the OEL-TWA can be adjusted by applying an OEL reduction factor [ACGIH 2013]. We suggest altering the sampling procedure by conducting full-shift sampling and then adjusting calculations to take this into account. An example calculation for a 12 hour shift is included [Brief and Scala 1986]:

$$\text{OEL-TWA Reduction Factor} = \frac{8}{\text{hours worked}} \times \frac{\text{hours off work}}{16}$$

$$\text{For 12 hour-work shift, OEL-TWA Reduction Factor} = \frac{8}{12} \times \frac{12}{16} = 0.5$$

It is also possible to apply a work-week correction factor for employees who work longer than 40-hour weeks. This calculation is delineated in the same resource, though other methods are available.

- Special consideration should be given to assessing exposures to a mixture of two or more chemicals with additive effects by summing the ratios of measured TWA to OEL-TWA [ACGIH 2013]. We are aware the company has begun looking at the combined effects of multiple solvents, and recommend that they expand this to other chemicals as feasible.
- We suggest that the company develop an evaluation strategy which allows for characterization of the complete exposure profile for each of the HEGs. For detailed information on how to perform such a comprehensive exposure assessment, the following AIHA publication may be useful: Bullock WH and Ignacio JS 2006.
- The company stated that air sampling was limited by budgetary concerns. Since the

plant is sampling on a fixed budget, we suggest increasing frequency of the sampling on areas of concern. Some of these areas include new product development and polymers I and II - particularly the filter presses and filter cleaning areas in these locations. Workers may be able to pinpoint other areas that they feel need attention.

11. In addition to the current approach for sampling, we recommend that the plant incorporate some quantitative methods to define HEGs to optimize sampling strategy. Please note that reference materials will call these groupings SEGs. Some recommendations include:
 - a. Consider increased sampling on or investigating HEGs when there is large variability of measured exposures within the HEGs (large geometric standard deviation). Handle non-detectable (<LOD) samples in a uniform way [Hornung and Reed 1990].
 - b. If exposures are within 10% of the occupational exposure limit for a given compound, re-sampling (4-6 additional random measurements) within the HEG should take place to increase power of compliance testing.
 - c. In each HEG, continue to choose the subset of workers and sample days at random while aiming to cover some amount of seasonal variation. Samples should span over the course of 2 or more seasons.
 - d. Continue to perform task-specific sampling (e.g. STEL) if the task is high-exposure or if the task occurs infrequently.
 - e. Continue to involve workers directly in the sampling procedure (performing self-monitoring with passive monitoring badges).
 - f. Analyze historical measurement data to evaluate if all HEGs are appropriately grouped.

12. We recommend that the company continue to support the plant industrial hygienist for continuing education, so that she can be up-to-date on comprehensive exposure assessment strategy and industrial hygiene statistics.

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 may be 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. Continue to train employees on the need for PPE, and ensure that PPE is stored in clean, accessible areas. Employees should be able to voluntarily increase their level of protection (such as by choosing to wear a full face mask instead of a half mask).
2. Additionally, ensure that employees performing simultaneous tasks requiring different PPE have enough time to change PPE safely between tasks.

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Figures

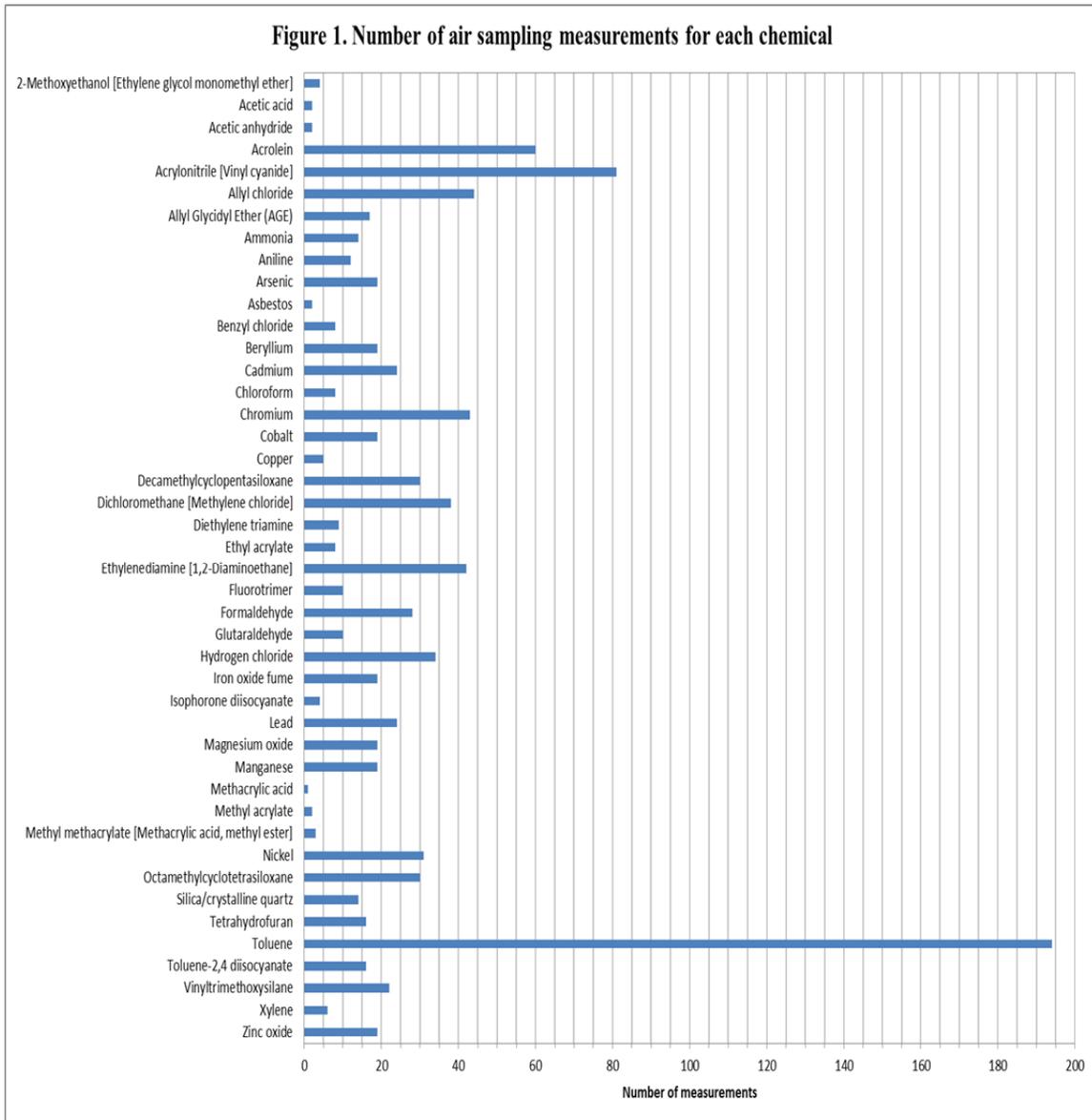
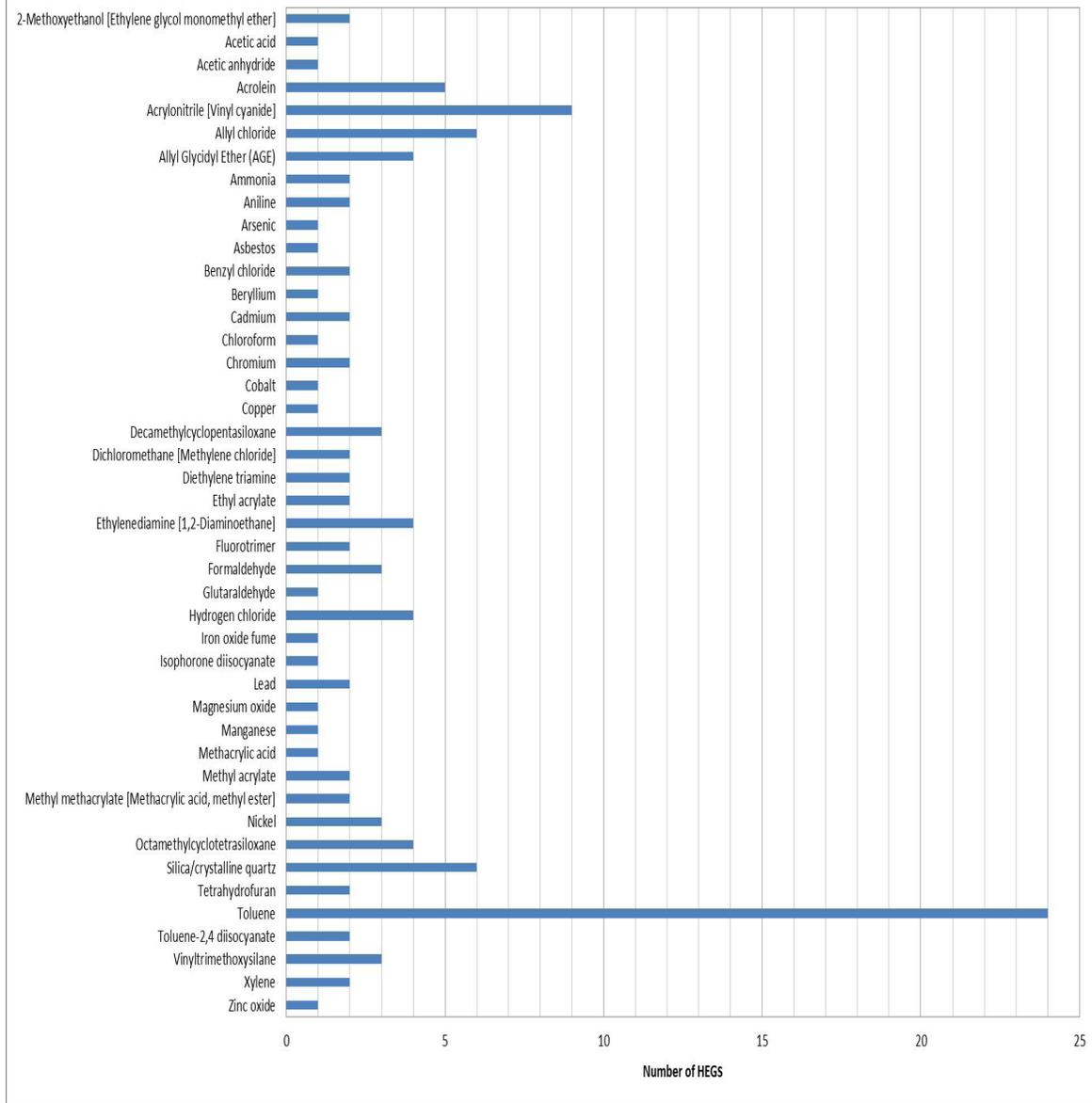


Figure 2. Number of HEGs monitored for each chemical, 2008-2012



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Keywords: NAICS 325199 (All Other Basic Organic Chemical Manufacturing) and 325411 (Medicinal and Botanical Manufacturing).

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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/2012-0222-3203.pdf>.

NIOSH 2014. Health hazard evaluation report: Evaluation of Exposures and Health at a Specialty Chemicals Plant, West Virginia. By McCague A, Cummings K, Armstrong J, Park J. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA No. [2012-0222-3203](http://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0222-3203.pdf).

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