**Supplemental Material: Case Reports**

**Case Report #1 (New Jersey)**

A 27 year old Hispanic male presented to the emergency department complaining of cough, chest pain, and mild shortness of breath due to chemical exposure at work. He was diagnosed with acute bronchitis, and prescribed Albuterol. He was a non-smoker with no previous medical history of asthma. Spirometry results were not available. Approximately two months later, he presented to the emergency department again after experiencing similar symptoms, with the addition of difficulty breathing and congestion. He reported inhaling airborne chemicals two hours earlier that day while at work. The patient was continued on Albuterol and discharged with an ICD-9 code of 493 (asthma) with workers’ compensation as the primary payer.

The patient worked as a lamination machine operator at a company that manufactured and finished laminated fabrics for industrial, medical, apparel, home furnishing, upholstery, and specialty applications. This company used both flame and adhesive lamination to produce their products. The adhesive lamination process used either a water-based adhesive or a 2-part, solvent-based adhesive that contained trichloroethylene (TCE) and up to 5% toluene diisocyanate (TDI). Once the lamination process was complete, the laminated product passed through several rollers (some heated) and collected on a final roll which was then transferred to another area of the plant for curing.

The New Jersey Department of Health conducted an on-site evaluation of the plant, an employer interview, and real-time measurements of organic vapor concentrations at the laminating machine operator stations (including the area where the patient worked). Three laminating machines were operating during the walk-through evaluation: one using water-based adhesive and two using solvent-based adhesive that contained TDI and TCE. The company did not have a written respiratory protection program, nor had they conducted the assessment to determine if one was required. Real-time organic vapor sampling measurements were used to detect fugitive emissions of the adhesive in the lamination process and to evaluate the effectiveness of the existing local exhaust ventilation system. The areas with the highest relative organic vapor readings (likely TCE) were found near one machine where open containers of adhesive were stored and midway between that machine and a nearby vertical duct. Elevated readings were also found near one machine on which small doors were left open. The presence of elevated concentrations of TCE in several locations indicated inadequate engineering controls and thus potential exposure to TDI as well.

Recommendations included additional sampling for specific identification of the source of emissions and a change in work practices, including keeping access doors on the machine enclosures closed during operation and keeping containers of adhesive tightly covered. Personal protective clothing and equipment specific to isocyanates was recommended including an OSHA-compliant Respirator Protection Program including medical evaluation and fit testing.

**Case Report #2 (Massachusetts)**

A 50 year old man developed wheezing and shortness of breath six months after he was transferred into the spray-painting department of a golf ball manufacturing facility for the second time. He was diagnosed with work-related asthma (WRA) a year and a half later by a pulmonologist. He had been employed for seven years at this facility and had worked for a short time in the spray-painting department previously. He had been transferred out of painting after developing pneumonia, but had not been diagnosed with asthma at that time.

In the spray-painting department, he monitored the automatic spray-painting of golf balls, with a white base-coat primer that contained hexamethlyene diisocyanate (HDI) and CX-100, a cross linking agent with polyfunctional aziridine in an enclosed booth. Additional duties included changing the paint-soaked filters and inspecting the balls to ensure complete coating. The company used large quantities of diisocyanates in the manufacturing of golf balls in other areas of the plant, reporting over 9,000 pounds of diisocyanates processed in 2007. Methylene bisphenyl diisocyanate (MDI) was used in casting the external shell of golf balls.

During this second assignment in spray painting, his symptoms worsened at home after work and throughout the workweek, and improved on vacations and weekends. He had no known allergies. He was a current smoker of 10 cigarettes a day for 30 years. He was prescribed a short acting bronchodilator, which he eventually stopped using because his symptoms became less severe when he was transferred out of spray-painting the second time; however, his symptoms did not go away completely.

This case was one of 13 employees from the same company with suspected or confirmed WRA reported to the Massachusetts Department of Public Health (MDPH) between 1992 and 2008. However, the company reported that there may have been others with asthma who were not reported to MDPH, over the same period, including the company’s physician, who had spent time on the shop floor during his decades-long tenure there. The company noted that none of the cases of WRA had occurred in casting with MDI, but that many had occurred over the years in spray painting, where employees were exposed to both the cross-linking agent and HDI.

An onsite investigation was conducted by MDPH. Despite several company programs for wellness, health and safety, isocyanate awareness and respiratory protection, gaps existed in worker protection. Recommendations from the MDPH investigation included the following: systematically explore exposures to both HDI and CX-100; pay attention to concentrations of chemicals during short intensive exposure tasks, and not just the usual exposures over the whole day; improve respiratory protection during brief high-exposure tasks; seek additional methods to limit exposures during filter changes; ensure all WRA cases are reported to MDPH; and integrate asthma prevention and treatment into ongoing wellness programs. Also, the policy of moving employees with early symptoms to green zones, defined as areas with no potential diisocyanate exposure, was a good secondary prevention step, but further attention to primary prevention was suggested.

**Case Report #3 (Michigan)**

A man in his 50s developed shortness of breath six months after beginning to work at a facility that manufactured foam-insulated stainless steel chilling equipment used in restaurants and bars. His shortness of breath would occur at work when he would trim excess foam from the ice bins, approximately 30 minutes after a two-part MDI-based foaming operation was performed. The trimming operation was performed approximately 15 feet away from the foaming operation.

He continued to work at the facility and delayed seeking medical care for another year. His FEV1 was 43% of predicted with a 21% (400 ml) improvement after a bronchodilator. He had evidence of air trapping on lung volumes but a normal diffusing capacity. He had negative skin testing to common allergens, and normal sinus films. Specific IgE for HDI, MDI and TDI were negative and his total IgE was within normal limits. He was started on a combined inhaled steroid/long acting bronchodilator and was prescribed a short acting bronchodilator as needed. He had smoked one pack of cigarettes per day for 20 years and had quit 12 years before his employment at this facility. He was obese and had sleep apnea. On follow up examination after being removed from the workplace, he was asymptomatic. He continued to take an inhaled steroid but no short or long-term bronchodilator.

During an OSHA enforcement inspection, a total of six 5-minute ceiling MDI air levels were measured at different locations in the assembly, trimming and foaming areas. Three of the six samples had detectable levels of MDI (0.026, 0.036 and 0.057 mg/m3(all below the MIOSHA and NIOSH ceiling limit of 0.2 mg/m3)); the remaining three were less than limit of detection (LD).Four of the samples were taken during foaming operations (0.057, 0.026 and 2 with <LD), one was taken at the trimming operation (<LD) and one was taken at the assembly operation (0.036). The MDI was applied through a “foam gun” held by an operator. There was no local exhaust; the operator leaned over the piece while applying the MDI. Approximately 75 parts had MDI applied per day. The company provided no medical surveillance program for workers in the isocyanate use area. The company was issued citations for three violations related to deficiencies in its Hazard Communication program related to: informing employees of hazards involved with non-routine tasks, unlabeled containers and unidentified piping systems.

The case was reported in 2007. Three other workers from the same facility had been reported with isocyanate-induced asthma in 1999, 2002 and 2004. There were 17 production workers at the facility. A medical surveillance program was recommended for early detection of symptomatic individuals.

**Case Report #4 (California)**

Seven individuals, six men and one woman, reported shortness of breath, cough, wheezing and chest tightness, three months or less after starting work at a plant that manufactured hand-cast animal sculptures. Five of the seven worked as molder/casters and one worked as a warehouse clerk. Symptoms were reported to often be worse while at work, and in the evening after leaving work. It was reported that a new process had been implemented and that production had been moved away from the open doors, towards the warehouse, where there was no ventilation. The warehouse clerk reported that symptoms began when the Casting Department moved back near the warehouse. Of the seven, five were reached for interview and determined to have confirmed work-related asthma (WRA), among whom four had new-onset WRA.

The hand-cast statues were made of a two part MDI-containing urethane. The molder/casters were exposed to MDI when urethane was injected from an air compressor-operated gun into a mold. The mold was then spun. An opening on the bottom of the mold remained open during the spinning process until the whole statue was solidified, exposing the molder/casters. Personal protective equipment (full-face shields, tyvek suits and half-face respirators with organic vapor cartridges) was worn, however, it was reported to fit poorly. Workers reported only being allowed to change respirator cartridges once per week, and removing respirators to train new workers.

Following report of the cases, the California Department of Public Health conducted an investigation. It found ventilation had been installed and on the day of air sampling, results indicated that there were no overexposures to MDI.

Interviewed workers reported knowing between 2–10 other people at the same plant with similar breathing problems. Other processes in the plant that used MDI included the manufacture of Christmas ornaments. Recommendations included use of airline respirators, implementation of a respirator maintenance program, and improvement of the local exhaust ventilation system.