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How Industry Manages a Hazardous Substance

Working with a Hazardous Substance: One Industry's Workplace Safety Success

How the flexible polyurethane foam manufacturing industry manages the handling of toluene diisocyanate.

By Michele Ostrove

POLYURETHANE FOAM ASSOCIATION

TDI arrives at the plant via rail tank car or liquid transport truck for off-loading by specially trained workers. In this example, a closed-loop vapor recovery system is being installed before off-loading begins.

More than 12 million Americans, or 9 percent of the workforce, are employed directly in manufacturing. According to the Bureau of Economic Analysis, manufacturers in the United States perform more than three-quarters of all private-sector research and development and drive more innovation than any other sector. One place innovation is increasingly relevant is in the safe handling of hazardous substances that are often required in the manufacturing process.

One such chemical is Toluene Diisocyanate (TDI), a known respiratory sensitizer and a necessary raw material for the production of many types of flexible polyurethane foam. For some workers, exposure to even small amounts of TDI could result in occupational asthma, and a worker who develops this condition may not be able to tolerate further exposure to even safe levels of isocyanates, either at work or at home.

Essentially all of the TDI used as a raw material is consumed during the chemical reaction that occurs in the foam-making manufacturing process, so there is no risk of exposure in the finished product. This case study focuses on TDI in an unreacted, raw material form and the effectiveness of the industry's methods for safe handling and exposure reduction. The flexible foam industry's practices may provide guidance for other industries that handle similar hazardous raw materials.

For more than half a century, the flexible polyurethane foam industry has prioritized worker safety and developed mechanical systems and workplace procedures that help to manage TDI handling in accordance with best practice standards at every stage of the receiving, storage, and manufacturing process.

The industry's trade group, the Polyurethane Foam Association (PFA), has facilitated industry-wide information sharing about state-of-the-art technology and processing innovations. Its foam manufacturing members boast an admirable safety track record across an estimated 70 to 80 North American manufacturing plants.

> Results of 24-year tracking surveys show a minimal 2 percent incident rate for self-reported occupational asthma among flexible polyurethane foam manufacturing workers. Rates for medically diagnosed occupational asthma are lower. These rates are far below an estimated 10 percent rate for asthma among the U.S. adult population.

What is Flexible Polyurethane Foam?

First developed in the 1940s, flexible polyurethane foam (FPF) is the cushioning material of choice for a wide range of applications, It's virtually everywhere we turn: in mattresses, seating, and protective panels in vehicles and aircraft; in residential and commercial upholstered furniture; in pillows, apparel padding, air and fluid filtration, office/desk seating, medical braces and restraints; and beneath the carpeting in our homes. It comfortably restrains, supports, and relieves pressure for wheelchair users; allows prostheses to breathe; and provides a medium for collection and absorption in hospitals, laboratories, and testing instruments. FPF protects delicate objects during shipping and helps ink flow in printer cartridges. The list of applications is seemingly endless, driving an annual production of more than 1.6 billion pounds of flexible polyurethane foam in the United States alone.

PFA Executive Director Bob Luedeka explained that, like "plastics," polyurethanes is a broad category with many types of products. Not all polyurethanes and polyurethane foam products are alike. A differentiator for FPF is that this industry's products are always cured before use, and that removes the opportunity for exposure by consumers to raw materials that were used during the reactive manufacturing process.

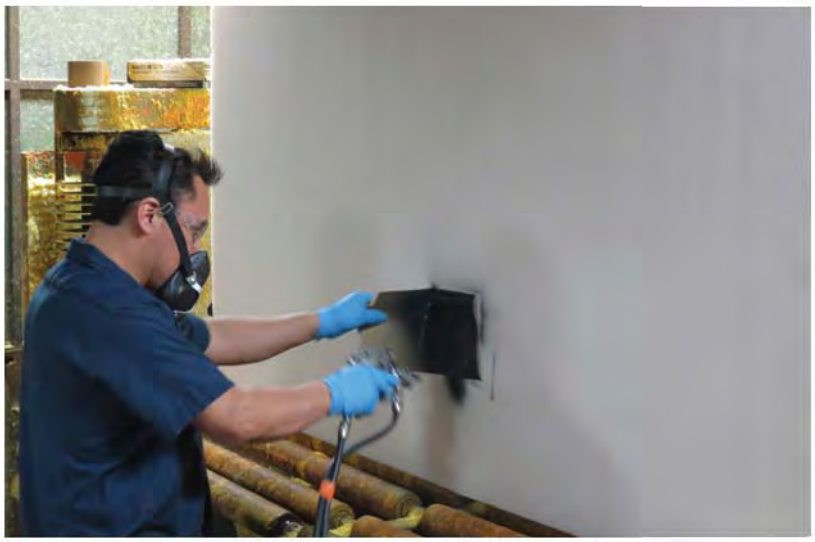
This unique manufactured article is created by combining the raw material TDI with water and polyol to form FPF polymers. With the aid of catalysts and surfactants, this chemical exothermic reaction produces a liquid mixture that quickly gels and expands, forming a flexible cellular structure that, when cured, becomes flexible polyurethane foam.

Modern flexible polyurethane foam production areas may be equipped with negative-pressure exhaust systems to draw fresh air from the outside over the foam-making line. Pressure forces vapors that may include trace amounts of TDI through the factory's exhaust stack that is engineered to prevent unreacted TDI from ever reaching ground level.

To date, no viable alternatives to TDI exist for the manufacturing process. For many FPF products, use of substitute isocyanates imparts significant undesirable physical characteristics. Given no effective substitute raw materials, the FPF industry focused on manufacturing foam products using TDI without compromising the health of its employees. Let's take a look at a few of the safety management steps involved:

The Equipment Side of Manufacturing, from Delivery to Ventilation

As mentioned earlier, the manufacturing of FPF, whether by molding or continuous slabstock process (blocks 9-200 feet long), consumes almost all of the TDI raw material. Testing has shown that for each metric ton, or 2,200 pounds, of foam produced, a maximum of 1.6 ounces, or 0.1 pounds, of TDI remains after the initial reaction. Most of the trace amount of remaining TDI is captured and managed as a stack emission. Remaining traces of



During the unloading process and in production areas where there may be potentially unsafe concentrations of TDI, employees must wear PPE.

TDI are removed during final curing using sophisticated ventilation systems.

What happens to TDI during each step of the manufacturing process? As is true in many industries, safety begins with the mechanics:

1) TDI arrives at the FPF manufacturing plant via rail tank car or liquid transport truck. It is offloaded, often using closed-loop vapor recovery systems, into state-of-the-art steel storage vessels. The tanks are equipped with high-level indicators with automatic detector systems and shut-off capabilities to avoid any possibility of TDI evaporation, leakage, or over-fill.

2) TDI is metered to the mixing chamber of the foam-making machine using stainless steel piping with leak-proof pressure fittings and controlled pressure conditions. In this seal-less feed system, specialized pumps are employed. Within the pumps, all rotating components are encapsulated and joints are sealed with TDI-resistant O-rings. For additional protection, pumps may employ a secondary containment shell or they may be submerged in water, which quickly reacts with TDI to become benign urea.

3) A computer-controlled, closed-

pipe system introduces TDI into the foam-making mixture including polyol, water, catalysts, surfactants, and often performance additives. In the pour-line tunnel, exhaust fans are synchronized to prevent foam production if the ventilation systems are not working properly. There are also automatic shut-off controls to stop raw material feed if pour-line progress malfunctions. Emergency backup generators may be employed to provide emergency power to the foam line conveyors and ventilation.

4) The growing foam block is conveyed through a 75-to-150-foot-long tunnel by moving conveyor belts. Modern foam tunnels are equipped with negative-pressure exhaust systems. Pressure directs vapors that may include trace amounts of TDI up through a tall ventilation stack that is engineered to prevent unreacted TDI from ever reaching ground level. TDI vapors quickly dissipate inside the stack and react with ambient humidity. Some plants also direct air drawn from the production enclosure tunnel and around the growing foam block through activated-carbon chambers that capture TDI vapor for later proper disposal.

The Human Interface: Worker Training and Protection

Production-area workers who are in proximity to TDI during the manufacturing process make up the other critical side of the safety equation. The potential for human error–and human consequence–must be anticipated at every juncture, with utmost care paid to the well-being of everyone involved. Knowledge and preparation are key.

1) If TDI arrives by rail, the cars are "spotted" in specific unloading locations, typically within a spill containment area, and the brakes set. A detailed unloading checklist is followed that includes checking shipping papers against order papers and the car numbers; ascertaining that receiving tanks are able to receive the contents of the car; determining that there is no evidence of tampering, damage, or leakage; checking that all transfer and return hoses are clean and dedicated to TDI service; and ensuring that all seals are new and appropriate for TDI service. The unloading operation is conducted only by a specially trained technician who remains with and monitors the railcar and the receiving tank during the entire duration of the chemical transfer. Spill containment systems are in place during unloading.

2) If TDI arrives via tank truck, the drivers must be informed of on-site access requirements and familiarized with the facility itself. They must be accompanied by an experienced site operator throughout the process, as TDI is offloaded from the bottom of the tank truck via sealed pumps that prevent any vapor from escaping. The plant or site manager is ultimately responsible for the drivers' personal safety and any environmental release that could occur from unsafe handling, which is where the first step of training begins.

3) In compliance with Department of Transportation requirements, tanker trucks and railcars are never left unattended during the unloading process. Training of unloading personnel is also mandatory.

4) During the unloading process and in production areas where there may be potentially unsafe concentrations of TDI, employees must wear personal protective equipment consisting of full-face respirators and full chemical-resistant suits and gloves. Neutralizing solutions must be readily available.

5) As a further safeguard, personal workplace monitoring is conducted periodically and periodic pulmonary exams are provided to ensure that workers are not developing chronic respiratory issues over time.

6) Safe materials handling methods are regularly reinforced through safety training that covers every aspect of handling TDI, from spill prevention to worst case scenario mitigation, including practiced evacuation procedures.

Definitive Data Confirming the Industry's Clean Track Record

How does the industry gauge the effectiveness of its safety measures? TDI sensitization is a respiratory illness having symptoms within the broader category of occupational asthma. Because diagnosing TDI sensitization can be challenging, PFA looked at the industry's history of cases of broader and more easily diagnosed occupational asthma. Through survey techniques, PFA developed a database noting the number of incidences of self-reported and medically diagnosed occupational asthma among foam manufacturing facilities. The occupational asthma database covers a period of 24 years, from 1988 to 2011.

The survey provided historical data for more than 1,300 production-area workers in facilities that collectively produced more than 90 percent of the country's flexible polyurethane foam.

The combined results, reported in a scientific poster and paper entitled "A Survey of the Incidence of Occupational Asthma among Flexible Polyurethane Foam Slabstock Plants," confirmed that incidences of occupational asthma among flexible polyurethane foam workers in the United States were rare. Self-reported cases represented approximately 1 percent of current production workers and a maximum of 2 percent of workers during the 24-year period. The incidence of medically confirmed cases was even lower, with only six cases of occupational asthma reported among the responding plants during the most recent survey period from 2008-2011. The results become more compelling when compared with the 10 percent incidence rate of asthma among the general adult U.S. population as estimated by the Centers for Disease Control and Prevention.

Thanks to an industry-wide focus on workplace safety in receiving, storing, and handling; medical monitoring; and continuous safety training programs, workers in the flexible polyurethane foam industry maintain a much lower rate of asthma than the general population. As PFA's Luedeka said, "That's a track record we are very proud of, and one which everyone in this industry is hardwired to work at maintaining each and every day." OHS

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