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Automotive industry

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16.1 Introduction

The production of automobiles and trucks is a major worldwide industry. There are approximately 4 million auto and truck production workers worldwide with major growth in the industry occurring in Asian–Pacific countries. Historically vehicle production was vertically integrated within one company. That company would manufacture most of their own metal and plastic parts and then assemble them into vehicles. This business model has shifted in the last couple of decades, with in-house parts manufacture being spun off as independent companies so that now 75% of autoworkers work for companies that produce vehicle parts and 25% work for companies that assemble the final vehicles. Since vehicle production is a worldwide industry, the percentage of workers in vehicle assembly vs vehicle parts production in any given country varies. Of the 1 million autoworkers in the USA, 75% are in vehicle parts manufacturing facilities; in contrast, in Belgium almost 90% of vehicle workers work in assembly facilities. This distribution between vehicle assembly and parts manufacturing is important from the health care provider's perspective. Vehicle parts manufacturing has significantly more respiratory hazards since it involves processes such as casting metal parts in foundries, machining metal parts, manufacturing foam products and extruding and injecting plastic into molds. In contrast, vehicle assembly requires a great deal of material handling as the various parts are assembled into the final vehicle. Accordingly the major health concern in vehicle assembly facilities involves musculoskeletal conditions. However, there are respiratory concerns in assembly facilities. Important activities in vehicle assembly that generate respiratory hazards are welding, painting and the use of adhesives. Another contrast between parts manufacture and assembly is that vehicle assembly facilities are more likely to be larger corporate entities: six corporations produce 75% of the world's vehicle

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production while just in the USA there are 5000–8000 vehicle parts manufacturers. This difference in corporate structure would suggest that the larger assembly facilities will have more expertise and resources to address health and safety issues than many of the smaller vehicle parts manufacturers.

This chapter will examine the respiratory hazards in vehicle assembly and parts manufacturing. The respiratory hazards of car maintenance and repair are discussed in Chapter 15. Table 16.1 summarizes by vehicle manufacturing industry type (vehicle assembly vs vehicle part manufacturing) and activity (casting, welding, etc.) the possible exposures (isocyanate, silica, etc.) and the respiratory conditions (silicosis, asthma, etc.) that have been associated with these exposures in the vehicle manufacturing industry.

Table 16.1 Work processes, exposures and respiratory conditions in the automotive manufacturing industry

Vehicle parts manufacturing	Work process	Exposure	Respiratory condition
Metal parts	Casting	Silica Asbestos Benzo(a)pyrene	Asbestosis COPD Lung cancer Silicosis
	Chipping/grinding	Silica	COPD Lung cancer Silicosis
	Core/mold production	Silica Isocyanates	Asthma COPD Lung cancer Silicosis
	Machining	Metal working fluids	Asthma Hypersensitivity Pneumonitis
	Forging/stamping	Drawing compounds	Asthma Hypersensitivity pneumonitis
Polyurethane foam	Foam production for seats, arm rests, etc.	Isocyanates	Asthma
Plastic parts	Extrusion/injection molding	Styrene Polyvinyl chloride Polyethylene	Asthma Bronchitis
Carpeting/liners	Flocking	Nylon flock	Interstitial fibrosis
Vehicle assembly			
Body shop	Welding	Welding fumes NO_x, ozone, particulates	Asthma COPD
Paint line	Painting	Isocyanates	Asthma
Assembly	Gluing	Isocyanates Epoxies	Asthma

16.2 Respiratory hazards and disease

Both obstructive and restrictive diseases occur from exposures in the vehicle manufacturing industry. With increased automation, substitution with alternative materials and better engineering and ventilation controls, restrictive lung disease such as asbestosis and silicosis have become less common. One restrictive lung disease in the vehicle manufacturing industry whose incidence is not decreasing is hypersensitivity pneumonitis. The increase in the use of water-based synthetic metal-working fluids has caused repeated outbreaks of hypersensitivity pneumonitis. The association between metal-working fluids (MWFs) and hypersensitivity pneumonitis was first recognized in the mid 1990s. Although the same microbial agent has been identified in the MWF in a number of the outbreaks from different facilities, this agent has not always been identified during outbreaks and it has also been identified in facilities without outbreaks. A lack of understanding of what are the other important factors that initiate these outbreaks has limited the ability to reduce the respiratory hazard from MWFs. Additionally, the introduction of new technology has caused recognition of a new restrictive lung condition, nylon flock disease.

Most new cases of respiratory disease currently being identified in the vehicle production industry are obstructive: asthma, chronic obstructive pulmonary disease (COPD) and chronic bronchitis. The use of chemical sensitizers such as isocyanates, chronic exposure to irritants such as during welding and the occurrence of obstructive changes with repeated exposure to substances classically associated with restrictive disease such as silica are all causes for these obstructive lung conditions.

Lung cancer is increased among foundry workers making vehicle parts. Historically, there has been exposure to three carcinogens in the foundry environment: asbestos, benzopyrene from the fumes of the molten metal and silica. There are studies reporting a cancer risk from exposure to natural (straight) metal-working fluids (mineral oils), with the best evidence of an association between MWFs and cancer being for laryngeal cancer and the nonrespiratory cancers of bladder, pancreas, rectal, scrotum and skin.

Vehicle manufacturing workers, as other blue collar workers, generally have a higher prevalence of cigarette smoking than the general population. This increased prevalence of smoking in conjunction with workplace exposures such as silica or welding will increase the likelihood of lung cancer, COPD, chronic bronchitis and irritant symptoms more so then if the group only smoked cigarettes or only had the workplace exposures.

16.3 Vehicle parts manufacturing

16.3.1 Foundries

Foundries produce metal parts by pouring molten metal into molds, which traditionally have been made from sand. In order to create internal cavities in the metal pieces being produced, cores made from sand are produced and placed in the mold prior to pouring in the molten metal. A common binder used in making sand cores is methylene

Figure 16.1 An individual chipping and another grinding an engine block. Both workers are wearing respirators because air levels are above the permissible exposure levels

diisocyanate (MDI). After the metal hardens the mold and core must be removed and the metal smoothed. The activity of removing the mold and core is conducted in the 'finishing' or 'clean' room. Activities there include knocking off the sprue (hardened metal from where the pour goes into the mold), shake-out and chipping and grinding. Figure 16.1 shows a picture of an individual chipping and another grinding an engine block. Both workers are wearing respirators because air levels are above the allowable OSHA permissible exposure levels. During pouring, the molten metal heats the silica. Because heated silica is transformed into more fibrogenic forms, tridymite and cristobalite, and the removal of sand generates a large dispersion of particulates, the 'cleaning' area of a foundry is the location with the highest risk for silica exposure. Silica exposure is also significant in the mold and core areas and among any workers responsible for handling and cleaning up spilt sand. Asbestos exposure has occurred among workers maintaining furnaces, pipes and cupolas (the latter being the containers in which molten metal from furnaces are transferred to the molds). The workers who maintain and repair furnaces and pipes are in some facilities classified as 'skilled trades': insulators, electricians, plumbers and millwrights. Removal of fire bricks in furnaces and cupolas is a high-risk job for both asbestos and silica exposure. Furnaces are typically relined on a regular basis and, in the USA until the 1980s, workers on overtime from throughout the facility would on weekends and downtime throughout the year work in the furnaces chipping away the firebrick and asbestos insulation without adequate respiratory protection.

There is substantial data that the mineral dusts, particularly silica, cause obstructive as well as restrictive disease. These obstructive changes are more prevalent in workers who also have smoked cigarettes. Silica exposure also increases the risk of active tuberculosis and silica is considered a risk factor, like diabetes or steroid use, when considering the indications for treating latent tuberculosis or the number of medications needed when treating active tuberculosis. Other conditions increased in silica-exposed workers are chronic renal failure and connective tissue diseases, particularly scleroderma and rheumatoid arthritis. Even in the absence of clinical disease, markers of connective disease including antinuclear antibody and rheumatoid factor are more prevalent in patients with silicosis.

There are multiple methods for forming sand molds and cores. A common method involves the mixture of TEA gas (tetraethylamine) and MDI. Ruptured or disconnected hoses, causing acute exposure, are not uncommon in this work setting. Acute exposure after such a rupture or spill may cause an acute chemical pneumonitis. With recovery from the acute episode, the worker may be left with persistent shortness of breath and wheezing. On testing these patients may have a positive methacholine challenge test and meet the diagnostic criteria for reactive airway dysfunction syndrome. Exposure to TEA gas is associated with difficulty in vision, particularly being able to see at night. MDI is a common cause of sensitization and work-related asthma. This method is a 'cold' method. An alternative method is a hot process involving a phenolic–formaldehyde resin. Formaldehyde exposure from this process is a cause of work-related asthma.

Alternative foundry processes, such as lost wax casting, or lost foam casting, that do not use silica or use less silica and do not use known sensitizers, have become more common in recent years. The risk of silicosis is also less in aluminum foundries.

The International Agency for Research on Cancer has classified iron and steel founding as a group I human carcinogen: sufficient evidence of carcinogenicity in humans. Similar group I classifications have been given for asbestos, benzo(a)pyrene and silica, to which foundry workers have been commonly exposed. The US National Toxicology Program does not classify work processes such as foundries but has classified asbestos and silica as 'known human carcinogens' and benzo(a)pyrene as 'reasonably anticipated to be a human carcinogen'. Asbestos and silica exposure in foundries is described above; benzo(a)pyrene is one of the polynuclear aromatic compounds produced with combustion and is formed when metal is heated, so that workers in the pouring areas of a foundry would have the potential for the greatest exposure.

16.3.2 Metal machining

Metal pieces need to be cut, drilled, shaped and smoothed. In order to facilitate this machining, MWFs are used. These substances are commonly called 'coolants', but their primary properties are actually to remove metal particles, protect or treat the surface of the metal being machined and prolong the life of the machining equipment. Figure 16.2 shows a machining operation with an MWF being used. There are four types of metal-working fluids, straight (natural, mineral oil), emulsified, semi-synthetic and synthetic fluids. Straight fluid, as the name implies, is 100% mineral oil and generally is what was used prior to the 1970s. Water-based oils are now more commonly used; emulsified oil is an emulsion of mineral oil and water; semi-synthetic contains smaller amounts of mineral oil than the emulsified oils; and synthetic oils contain no mineral oils. Since these are water-based products, corrosion inhibitors as well as dyes and biocides to inhibit microbiological growth are found in the three types of nonstraight MWFs. Typically these fluids are collected in sumps around the machining operations and repeatedly reused in the machining process after the metal particles are filtered out. Specific personnel are designated to check the pH, assess the biological content and put in additives in response to the sampling results. Work around water-based MWFs is

Figure 16.2 A machining operation with metal-working fluids being used

associated with a higher prevalence of respiratory symptoms, chronic bronchitis and doctor visits than work around the straight fluids. Individual components of water-based metal-working fluids, such as ethanolamine compounds, have been shown by specific antigen bronchoprovocation testing to cause work-related asthma, while microbiological contamination of nonstraight MWFs has been associated with outbreaks of hypersensitivity pneumonitis.

Historically there have been a few case reports of lipoid pneumonia among individuals working around straights MWFs. Cūrrent exposures are usually too well controlled to cause this condition. Another condition of historical interest is Pontiac fever, an influenza-like condition that was reported in an engine manufacturing plant using water-based MWFs. Patients had antibodies to a species of *Legionella* but no evidence of pneumonia. Although theoretically possible, there are no studies that indicate an increased risk of either upper respiratory infections or pneumonia among individuals who work with MWF contaminated with microbiological agents.

Hypersensitivity pneumonitis (HP) from exposure to MWF was first reported in the mid 1990s in a facility that manufactured vehicle parts. A dozen or more outbreaks have subsequently been reported in the literature. The initial outbreak involved six patients. Antibodies to *Pseudomonas* were identified in the cases of this initial report. In subsequent outbreaks, *Mycobacteria immunogenum* has been the most common suspected etiologic microbiologic agent, although *Mycobacteria immunogenum* has been found in MWFs in facilities without cases of HP. Patients are usually nonsmokers, have symptoms of cough, dyspnea and fever, have ground glass opacification on their HRCT and have restrictive changes on spirometry and plethysmography and decreased diffusing capacity. Respiratory symptoms and radiograph changes will clear and pulmonary function changes will markedly improve over a period of months if the patient is removed from exposure soon after the onset of symptoms. If the patient is not removed from exposure, then fibrosis and increased respiratory symptoms are increasingly likely to occur as the exposure continues and the symptoms and radiographic changes are less likely to clear after removal from exposure. The sporadic nature of these outbreaks has remained perplexing. Are there truly outbreaks associated with overgrowth of certain microbiological species or are there endemic, ongoing cases that are misdiagnosed as atypical pneumonia? If during the time the patient is off work, changes are made to the worksite such as cleaning tanks, replacing all the MWF with new unused MWF or adding a biocide so that when the patient returns to work the causal biological agent is not present or is present in a much lower concentration, the fact that the patient was misdiagnosed with atypical pneumonia may never be recognized. Typically when an outbreak is identified, changes in the use of the metal work fluid as described above are instituted as well as improvements in ventilation controls. The actual workplace changes that cause the outbreak to end have not been identified since multiple interventions are typically instituted at the same time. Increased automation of machining with faster machines causing more aerosolization and increased used of water-based MWFs is the presumed reason why HP was not recognized in association with this work process until the 1990s. Microbial growth does not occur in straight oil and HP has not been reported in machining operations where only straight oils are used. The current US OSHA standard for oil mist of 5 mg/m^3 is not sufficiently protective to prevent HP when emulsified or semi-synthetic MWFs are used nor relevant to machining operations involving synthetic MWFs.

Work-related asthma has been identified in the same facilities where outbreaks of HP have been recognized. In a recent report of an outbreak of HP in an automotive engine manufacturing facility, work-related asthma was more common than HP. In the state of Michigan with its large vehicle manufacturing industry, MWFs are the second most common cause of work-related asthma.

Case reports of work-related asthma documented by specific antigen bronchoprovocation testing have been reported with both used and unused emulsified MWF. Studies of cross-shift changes in FEV_1 have reported the largest response among workers exposed to the semi-synthetic and synthetic MWFs. Amine compounds, which are common additives in the water-based MWFs, have also been documented by specific antigen bronchoprovocation testing to be the cause of work-related asthma.

Routine elicitation from a patient concerning the onset of their respiratory symptoms and whether there is a temporal association with work is important for all adults with asthma. Studies have shown that such questioning is only documented in a minority of charts of adult asthmatics. Positive responses are important indicators of the need for further testing. A history of a temporal relationship is sensitive but nonspecific. Objective pulmonary testing is important to make the diagnosis of work-related asthma since medical restrictions or departure from work has serious socioeconomic consequences. Use of more specific testing and not relying on history alone is highly advised. Given the unavailability of specific antigen bronchoprovocation testing, which is the gold standard, other breathing tests using the patient's actual workplace as the bronchoprovocation have been recommended.

16.3.3 Forging/stamping

Similar to machining, MWFs, called drawing compounds, are used when cold rolled steel is stamped out into metal parts (stamping) or compressive force is used on heated metal to form metal parts to conform to the shape of dies (forging). Both processes use drawing compounds, since forging generally involves heated metal, and pyrolysis and volatization of the drawing compound are likely to increase the potential for exposure.

The potential for the development of asthma and hypersensitivity pneumonitis in forging and stamping would be similar to machining.

16.3.4 Carpeting/liners

In one process to make vehicle carpeting, and interior lining, short nylon, rayon or polyester fibers (flock) are glued to a cotton-polyester fabric substrate. In the early 1990s, outbreaks of interstitial disease were first noted in facilities making nylon flock. By 1998, 20 of 500 potentially exposed workers were reported with lung disease from four facilities in Canada and the USA. Symptoms were cough, both productive and nonproductive, two of the 20 cases had arthralgias, two had weight loss and eight had asthma. No temporal association was noted in the short term with work (i.e. improvement on the weekend), but with prolonged removal from work of weeks to months some individuals improved. These individuals had reoccurrence of their symptoms on return to work. Half of the reported cases had decreased total lung capacity and/or forced vital capacity, and 13 had decreased diffusing capacity. Although several of the cases had normal chest radiographs, their high resolution CT scan (HRCT) showed ground glass opacities with a peripheral predominance. A distinctive histology was described that showed 'lymphocytic bronchiolitis and peribronchiolitis with lymphoid hyperplasia represented by lymphoid aggregates'. Transbronchial biopsies and/or bronchial lavage did not provide sufficient tissue in relation to the pulmonary lobular architecture for diagnosis. There is one reported case of interstitial fibrosis occurring in this industry outside of North America – a case report from Spain, after exposure to polyethylene flock.

16.3.5 Polyurethane foam

Isocyanates are commonly used in vehicle parts manufacture to make seat cushions, inner padding such as arm rests and bumpers and fascias. Figure 16.3 shows an auto

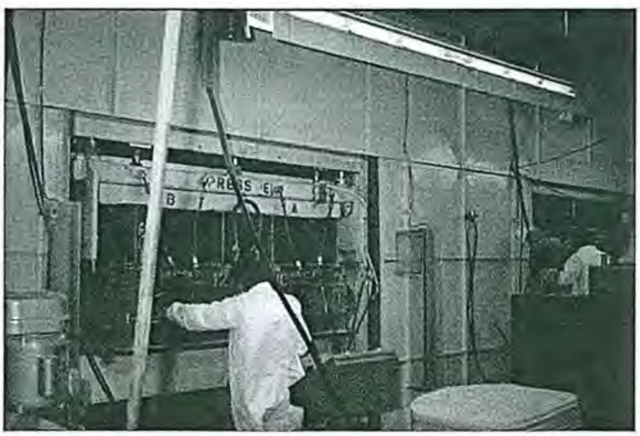

Figure 16.3 An auto part being made from MDI. The hoses bring the MDI and the catalyst, an amine compound, into the mold where the two chemicals mix in the mold. The chemicals react and assume the shape of the mold and then the worker removes the product from the mold

part being made from MDI. The hoses bring the MDI and the catalyst, an amine compound, into the mold where the two chemicals mix in the mold. The chemicals react and assume the shape of the mold and then the worker removes the product from the mold.

Across all types of industries, isocyanates are the most common etiologic agents of occupational asthma. The most common type of isocyanate used has been changing over time. MDI and more recently polymeric forms of the isocyanates are being used more frequently than toluene diisocyanate (TDI). A health benefit of this switch is that MDI and the polymeric foams are less volatile and human exposure should be decreased. However, the generation of heat in some of the processes involving isocyanates and limited data that respiratory sensitization can occur after skin exposure have meant that sensitization to isocyanates remains an ongoing issue. Clearly workers in the area where the isocyanate is mixed with the catalyst are at potential risk. Generally day-to-day exposure measured by the 8-hour time-weighted average of exposure is below the regulatory standard, which is in the thousandth of a part per million. However, spills and leaks and clean-up of these spills without proper protective equipment causes increased exposure that has been associated with the onset of isocyanate-induced asthma. For example, the US National Institute for Occupational Safety and Health recommends air-supplied respirators when cleaning up isocyanate spills. Studies on skin exposure show the potential for skin exposure even after mixture of the amine catalyst and the isocyanate during the time the material is 'curing'.

The diagnosis of work-related asthma from isocyanates is similar to the diagnosis of work-related asthma from other chemicals and the health care provider should not rely on the history alone to make the diagnosis. A temporal association of symptoms during the day or at night after work with improvement on weekends and vacations is a sensitive but nonspecific finding. Unfortunately, however, this sensitive screening for work-related asthma is overlooked. It has been consistently reported that physicians fail to document and presumably fail to ask about their patient's work and whether their patient's symptoms are associated with work. Collecting pulmonary function testing in conjunction with the patient's work allows the clinician to perform a natural challenge test, given the general unavailability of a laboratory which will perform specific antigen bronchoprovocation testing. With chronic exposure the patient may have lost the temporal pattern or the patient may be on long-term leave from the facility. In these situations return to the workplace after a prolonged absence and documenting changes in spirometry or peak flows may be useful to confirm the clinical history. There are both IgE and IgG antibody testing for hexamethyldiisocyanate (HDI), MDI and TDI available from commercial laboratories. IgE has a low sensitivity (10–15% range) and IgG as a marker of exposure has a low specificity for disease. Research is underway for better assays and a limited number of research laboratories may have a test with better sensitivity and specificity parameters. A positive specific antigen bronchoprovocation test to an isocyanate has been reported in patients with a negative methacholine challenge test. This has occurred in individuals who are no longer being exposed to isocyanates. The absence of a positive methacholine challenge in a patient currently exposed to isocyanates is highly suggestive that the patient has an alternative diagnosis such as irritative symptoms, or vocal cord dysfunction but not asthma.

Case reports of HP have also been reported after acute exposure to an isocyanate. HP is much less common than asthma after isocyanate exposure.

16.3.6 Plastic

Plastic has been substituted for many metal parts that historically were used in vehicles. The ability to manufacture strong but relatively cheap plastics, and their lighter weight in comparison to metal, which improves fuel economy, have all led to this switch.

The two common manufacturing processes for plastic parts are injection molding and extrusion. In injection molding, plastic granules or powders are heated to fluid, which is then forced into a metal mold where it hardens and assumes the shape of the product. In extrusion, heating softens the plastic and then the softened plastic is forced through a die and on cooling assumes the shape of the die.

Since heat is involved in both processes, plastic fumes may be released into the air. In most facilities multiple injection molding or extrusion machines will be in the same room. A machine may be dedicated to a particular plastic; more often the same machine is used for multiple different types of plastic and the machine needs to be 'purged' when the plastic is switched. The highest exposures occur during purging. During purging, the machine is superheated and residual plastic in the machine is burnt off. With multiple machines in the same area a worker may be exposed to fumes from purging even though the machine they are operating is not being purged.

Identification of the plastic used in the machine when the patient has respiratory problems is important in evaluating the cause of the patient's respiratory problem. Some plastics contain ingredients that have caused sensitization and work-related asthma. These include styrene and formaldehyde, and a single case report with a positive specific antigen bronchoprovocation test for polypropylene. In addition to determining the type of plastic and eliciting a temporal relationship between the patient's respiratory symptoms and particular work exposures, it is important to determine the patient's medical condition before deciding whether and if medical restrictions are indicated. Patients can develop asthma, have aggravation of existing asthma or COPD, bronchial irritation or polymer fume fever. Spirometry with determination of hyper-responsiveness by pre/post bronchodilator or methacholine challenge as indicated by the FEV_1 results on baseline spirometry with lung volumes and diffusing capacity are typically needed to reach a clinical diagnosis before delving into the even more complicated area of documenting causality. Clearly patients cannot have work-related asthma if they do not have asthma. Similarly medical restrictions will be different for a patient having irritative symptoms than for a patient with work-related asthma.

A self-limited condition associated with manufacturing plastic parts is 'polymer fume fever' after exposure to polyvinyl chloride or polytetrafluoroethelyene. Here an individual will develop flu-like symptoms in the evening after work with fever, headache, chills and myalgia that typically resolves in 24–48 h. Symptoms typically occur on return to work when the individual has not been exposed for a period of time, i.e. after a vacation, and will not reoccur the rest of the week. The condition is similar to metal fume fever from exposure to zinc oxide fumes given off when galvanized (zinc coated) metal is burnt or cut.

16.3.7 Vehicle assembly

Generally healthcare providers involved with assembly workers need to address musculoskeletal issues, and respiratory conditions are relatively uncommon. However, the parts of the assembly facility where the greatest potential for respiratory exposures exist are in the body shop and on the paint line, including the touch up area.

16.3.8 Body shop

In a typical car over a thousand welds are necessary to assemble the vehicle. Worldwide, in modern facilities the vast majority of welds are performed by robots with individual workers placing and removing various parts in position for the robot welding. In less automated facilities thousands of workers may be performing welding. This work is performed in the 'body shop' where hundreds of robots will be performing welding. The area is typically noisy from the manipulation of so many metal parts and the movement of these metal parts along the line. Workers are required to wear hearing protection and special gloves to reduce cuts from handling the sharp metal pieces. Even though the workers in an automated body shop are not doing the actual welding, they are in close proximity to where the welding is performed and are potentially exposed to welding fumes. In limited areas workers themselves continue to perform spot welding.

There are approximately 80 different types of welding. Electric arc and resistance welding are the most common types used in the vehicle assembly facility. Ozone and nitrogen oxide and particulates are produced during the welding. Studies of workers in vehicular 'body shops' have reported increased respiratory symptoms. There is good documentation that stainless steel welding with exposure and sensitization to chromium causes work-related asthma. Although welding in the vehicle manufacturing industry is not done on stainless steel, workers in this industry develop new-onset asthma. Although not documented by specific antigen testing or work-related pulmonary function testing, welding is the fifth most common cause of work-related asthma (90% new onset) reported by physicians to the SENSOR surveillance program in Michigan, a state with a large vehicle manufacturing industry.

16.3.9 Paint line

Vehicular paint or a clear protective coat sprayed over the paint usually contains the isocyanate HDI, a well-recognized cause of work-related asthma. Vehicular painting is performed in assembly facilities and in many facilities is well contained, with separate ventilation and exhaust systems from the rest of the assembly operations. Historically, such ventilation controls will not have been as extensive. The paint area has a limited number of workers who wear airline respirators and complete skin protection or the spraying of the paint or clear coat is performed by robots, thus markedly reducing the likelihood of exposure to workers on the paint line. Limited access to the paint line by non-paint line workers is the other factor limiting exposure. One reason access is limited to the paint areas in addition to health concerns is the concern about the off-gassing of perfumes, colognes and shampoo that are worn by individuals which affect the bonding of the paint to the vehicles. The potential for adverse health effects is greatest either during spills, leaks and maintenance or when touch-up work is performed as compared with routine operations. The levels of protective equipment provided and work practices during spills, leaks, maintenance and touch-up activity are important factors affecting the level of risk. Cars that are damaged after painting during handling will have touch-up painting performed. This touch-up is performed in a similar manner to procedures used in auto body shops (Chapter 15). Potential exposure to the isocyanates both via inhalation and skin will be greater in this work situation, although the number of employees in an assembly plant involved with touch-up is small.

16.3.10 Assembly

During assembly some of the adhesives used may contain chemicals that cause asthma, isocyanates and/or epoxies. For example, an isocyanate adhesive is used to attached the front and rear windows in a car. Exposure, however, is limited as the adhesive has a low volatility and is applied by a robot which limits the potential for skin exposure during routine work. Inadequate protection during clean-up of spills or leaks or during maintenance will determine if there is exposure potential for developing asthma.

Further reading

Antonini, J.M., Lewis, A.B., Roberts, J.R., Whaley, D.A. (2003) Pulmonary effects of welding fumes: review of worker and experimental animal studies. *Am. J. Ind. Med.* **43**: 350–360.

Beach, J., Rowe, B.H., Blitz, S., Crumley, E., Hooton, N., Russell, K., Spooner, C., Klassen, T. (2005) Evidence report/technology assessment no. 129. (prepared by the University of Alberta Evidence-based Practice Center, under contract no. 290-02-0023). AHRQ publication no. 06-E003-2. Agency for Healthcare Research and Quality: Rockville, MD. Available from: http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=hstat1b.chapter.25934 (accessed 3 March 2008).

Eschenbacher, W.L., Kreiss, K., Lougheed, M.D., Pransky, G.S., Day, B., Castellan, R.M. (1999) Nylon flock-associated interstitial lung disease. *Am. J. Respir. Crit. Care Med.* **159**: 2003–2008.

Hnizdo, E., Vallyathan, V. (2003) Chronic obstructive pulmonary disease due to occupational exposure to silica dust: a review of epidemiological and pathological evidence. *Occup. Environ. Med.* **60**: 237–243.

Nicholson, P.J., Cullinan, P., Taylor, A.J., Burge, P.S., Boyle, C. (2005) Evidence based guidelines for the prevention, identification, and management of occupational asthma. *Occup. Environ. Med.* **62**: 290–299.

Robertson, W., Robertson, A.S., Burge, C.B.S.G., Moore, V.C., Jaakkola, M.S., Dawkins, P.A., Burd, M., Rawbone, R., Gardner, I., Kinoulty, M., Crook, B., Evans, G.S., Harris-Roberts, J., Rice, S., Burge, P.S. (2007) Clinical investigation of an outbreak of alveolitis and asthma in a car engine manufacturing plant. *Thorax* **62**: 981–990.

Tarlo, S.M., Balmes, J., Balkissoon, R. *et al.* (2008) Diagnosis and management of work-related asthma. American College of Chest Physicians Consensus Statement. *Chest* 134 (suppl.): 1S–41S.