

IN-DEPTH REVIEW

Occupational asthma prevention and management in industry—an example of a global programme

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Abstract Isocyanates are widely used in the manufacture of polyurethane foams, plastics, coatings and adhesives, and are known to cause occupational asthma in a proportion of exposed workers. Substitution as a prevention strategy is not currently a feasible option. For this reason, health and safety professionals working together in an automotive coatings business created a proactive global programme to address the known potential effects of isocyanates on its workers. The goals of the programme are prevention, early detection and mitigation of effect of key endpoints, especially asthma and to a lesser degree dermatitis, in people who are occupationally exposed, or potentially exposed, to isocyanates and products containing isocyanates. The surveillance programme for isocyanates has several important components, which include assessment of exposure, pre-placement questionnaire and spirometry, training and education of employees, regularly administered periodic questionnaires, medical assessment for abnormal questionnaire responses, process for early reporting and investigation of symptomatic employees and incidents, group data review and management reporting. Although regional differences exist regarding availability of specialized services, we have successfully implemented this programme in parts of North America, Europe and Latin America, and are currently implementing elsewhere. These simple control measures are relatively inexpensive and can be applied in even small business settings. It is recommended that all employers who manufacture, handle or use isocyanate-containing products consider such a strategy.

Key words Isocyanates; occupational asthma; prevention.

Background

The company described in this article is a science company operating in >70 countries which manufactures a wide range of products and services for markets, including agriculture, nutrition, electronics, communications, safety and protection, home and construction, transportation and apparel. It also produces liquid coatings for automotive original equipment manufacture and repair and refinish.

Isocyanates are widely used in the manufacture of polyurethane foams, plastics, coatings and adhesives. Polyisocyanates have multiple isocyanate ($\text{N}=\text{C}=\text{O}$) re-

active groups that are used as cross-linkers in the coatings industry. They react quickly with amines, hydroxyls and acids to form stable bonds at ambient temperatures. The reaction of an isocyanate, $\text{R1-N}=\text{C}=\text{O}$, with a resin, R2-OH , produces a urethane R1NH-CO-OR2 . The resultant urethane linkage is durable and produces coatings with a number of qualities, including weather, chemical, impact and chip resistance, as well as desirable appearance.

Isocyanates react quickly at temperatures $>10^\circ\text{C}$ (50°F) and have been used since 1970 in air-dry and low-bake coatings. They are not used in coatings where the baking temperature exceeds 250°F as melamine cross-linkers can be used at $>120^\circ\text{C}$ (250°F) to produce equivalent coatings. Hence, they tend to be used in repair/refinish automotive coatings rather than in original equipment manufacture where it is possible to stove the body of the vehicle.

Isocyanates may cause occupational asthma or dermatitis in a proportion of exposed workers. This paper will concentrate on occupational asthma which is asthma that is caused or aggravated by exposures in the workplace.

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The estimated prevalence for occupational asthma has most commonly been reported in the range 5–10% based on studies in the 1970s in one population of isocyanate-exposed workers [1,2]. There is a latent period, with 60% of the cases developing within the first 5 years of exposure. There is no evidence that atopy or smoking influences susceptibility. Isocyanates can trigger asthmatic responses at relatively low concentrations, with some individuals responding to extremely low concentrations (ppm or lower) once sensitization has occurred. Respiratory sensitization to isocyanates also appears to be lifelong [3].

Isocyanates remain the most often reported cause of occupational asthma to well-recognized surveillance schemes such as Surveillance of Work Related Diseases (SWORD) [4] in the UK. Thirty-four percent of those reported cases citing isocyanates as the causal agents give the occupation as spray painting. However, there is evidence, based on small numbers, of an apparent fall between 1991 and 1997 in the proportion of cases attributed to isocyanates. There was also a drop in the number of awards of disablement benefit for asthma due to isocyanates between 1992 and 1997 in UK [5]. Within the company globally over the last 5 years, four individuals have been diagnosed with occupational asthma out of an exposed workforce of ~5000 people. These cases came from a mix of sites that had or had not introduced the described programme.

In the 1980s, as a result of these issues, the coatings industry expended significant technical resources in a search for chemistries that did not require isocyanate cross-linking at low temperatures. Various paint companies developed a number of technologies. They were generally more expensive, not nearly as durable and environmentally more hazardous than isocyanate-based technologies. To this day, coatings companies continue to look at alternate cross-linking methods, but at temperatures <120°C (250°F) nothing has been found to produce equivalent properties with a reduced health risk. For this reason, substitution as a prevention strategy is not currently a feasible option.

The purpose of this paper is to describe the isocyanate occupational asthma prevention and management programme, which is being globally implemented to assist other isocyanate users in developing an effective programme.

The global occupational asthma prevention and management programme

The programme was created as a part of the company's overall philosophy of prevention in health and safety, and its goal of zero occupational injuries and illnesses. It was deemed important by health and safety professionals working together with the business, to create a proactive programme to address the known potential effects of isocyanates on its workers. Until recently, the company

had some site- or region-specific programmes for the prevention and early detection of occupational asthma but lacked a coordinated global approach. For example, there was experience from Ontario, Canada, where a legislated programme had been in place since the early 1980s that showed that such a programme was feasible, manageable and successful [6]. Asthma surveillance has also been a formal process in Europe at some sites since the 1960s.

The goal of the programme is prevention and, if not possible, early detection and mitigation of effect of key endpoints, especially asthma and to a lesser degree dermatitis. In order to prevent the development of asthma and dermatitis in workers as has been reported in other industries [1,2], it was felt that regular assessment of respiratory function and skin condition would detect early changes before they developed into more severe and potentially irreversible asthma or dermatitis. The challenge was to develop tools that would have the right degree of sensitivity and specificity without consuming undue resources. In addition, the business would have to buy into the plan and see the business benefit.

The surveillance programme for isocyanates is designed for people who are exposed, or potentially exposed, to isocyanates and products containing isocyanates. The surveillance programme for isocyanates has several important components.

Assessment of exposure

This is an important part of the programme. This may include industrial hygiene monitoring results of levels in air, but also needs to include documentation of significant skin exposure and personal protective equipment (PPE) use.

Pre-placement questionnaire and spirometry

This is done in addition to any fitness-for-duty requirements that may also be required for the job tasks, respirator wear or other duties. This consists of two parts: a questionnaire and spirometry. An example of a questionnaire that is completed by the employee is included in Appendix 1 (available as Supplementary data at *Occupational Medicine* Online). The questionnaire should include previous occupational and health history, including previous exposure or problems with isocyanates. Spirometry (pulmonary function testing) is performed according to accepted standards, e.g. American Thoracic Society standards, European Respiratory Society or other local/regional standards as appropriate. The questionnaire and spirometry results are reviewed by a health care professional (HCP), normally an occupational health nurse. Abnormalities are referred to an occupational physician for assessment, which may include further clinical assessment and target organ evaluation. In some local jurisdictions, an occupational physician must do all reviews.

Employee training

Training of employees through work site hazard communication training programmes includes understanding safety data sheets and labels, hazards and safe handling of chemicals in the workplace, and other requirements as required by local legislation, e.g. in the USA the Occupational Safety and Health Administration hazard communication standard [7] or the Control of Substances Hazardous to Health Regulations 2002 in the UK [8].

Employees exposed or potentially exposed to isocyanates need to be trained to understand the health effects including routes of exposure, target organs effects and how to report symptoms that might be related to isocyanate exposure. Proper handling includes work procedures, proper use of PPE including respirators, an understanding of the surveillance programme as well as any other training needed to successfully perform the job tasks, including dealing with spills and emergency response. Training must be repeated as required by local legislation; the programme recommends at least annually.

Regularly administered questionnaires at a frequency that is dependent on exposure or local legislation but not to exceed 3 years are reviewed by an appropriately trained HCP.

Medical assessment of all significant abnormalities detected by the questionnaire or spirometry requires follow-up and is described in detail later.

Early symptom reporting by employees is encouraged. These symptoms will be clinically investigated by an HCP. A multidisciplinary team using root-cause analysis techniques investigates incidents such as overexposure or spills.

Group data review and management reporting

Group data review and management reporting by an HCP every 3 years enables identification of patterns that may suggest effects on the group of participants in the surveillance programme. The HCP managing this programme for his/her site or company is encouraged to prepare an annual summary (without names) to site or business management indicating the numbers of cases investigated and reported as per regulatory requirements and voluntary reporting systems (e.g. SWORD in the UK). Individual medical data are kept confidential as per local professional practice.

Investigation of potential occupational asthma

In order to address those circumstances where an abnormality occurs during the routine surveillance, an algorithm was developed to aid site medical staff to investigate abnormalities, especially respiratory, and ascertain whether there actually is asthma and whether it is

work related. Generally, the first indication of a potential work-related respiratory impairment is a history, elicited on the questionnaire, of symptoms (cough, wheeze or shortness of breath) that occur during or after the work shift, and typically improve on weekends or days off. Although physical examination is part of the protocol, it is often non-contributory. Spirometry is the next step and is useful if there is a significant shift (10% or more) in FEV1 or FEV1/FVC ratio over the previous shift. Improvement with inhaled beta agonist, such as salbutamol, will help to confirm a diagnosis of asthma, but will not establish work relatedness. In order to investigate the potential relatedness to work, serial peak flow measurements are undertaken. These are easily performed with minimal training of the employee and should be recorded on an appropriate chart [9]. We recommend readings every 2 hours each day during waking hours, on both working days and days off. The tests are continued for two work cycles, often a 2-week period. Results can be easily plotted and patterns usually readily recognizable (Figure 1). Chest X-rays are of limited value and only ordered to exclude other lung diseases if these are suspected (e.g. pneumonias). Skin prick testing and Radio-Allergo Sorbent Test for isocyanate sensitivity, although useful with some asthmagens, have not been proven to be sensitive or specific for isocyanates and are not part of our protocol [10].

At this stage, if there is still uncertainty, there are two additional tests that are considered. Non-specific bronchial hypereactivity testing, with histamine or methacholine challenge, can be usefully adjunct, but once

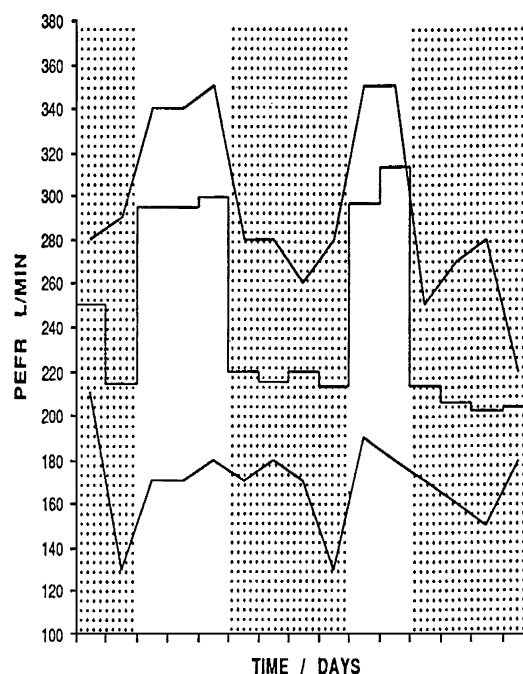


Figure 1. Plot of maximum, mean and minimum peak expiratory flow against time in days. Shaded regions represent days are at work.

again may only indicate asthma but not necessarily work relatedness. Where it is available and well standardized, a specific bronchial challenge with isocyanates can be conducted. In many jurisdictions this is necessary for worker's compensation; however, the availability of this test on a global, and even regional, basis in many countries may be limited and thus is not always a viable option. Although not 100% sensitive and specific, most would agree that this is the 'gold standard' for diagnosing occupational asthma from isocyanates [11].

Specific bronchial provocation tests are required for statutory compensation in Canada and Belgium. They are not required for compensation and therefore not generally available in the UK, Mexico and USA, and so are not typically part of our investigations in these countries.

In the case of a confirmed diagnosis, the site would apply a root-cause analysis technique in an occupational illness investigation to determine the workplace-contributing factors such as a change in the process, PPE or formulation so that improvements can be made to prevent other cases.

This programme is summarized in Figure 2.

Managing confirmed cases in the workplace

Once a diagnosis of occupational asthma is confirmed, the case is reported internally following company procedures for incident reporting. It is also reported externally in line with local legislative requirements. A job search is then undertaken for a suitable alternative role without exposure to isocyanates. This would include making reasonable adaptations to existing jobs to avoid contact with isocyanates. As even small exposures may lead to further attacks and continued deterioration, these individuals continue to have regular medical reviews and lung function testing to ensure that symptoms and signs of occupational asthma are improving. If despite relocation symptoms or lung function continues to decline or suitable alternative work cannot be found, then severance on medical grounds would be considered. This could include workers compensation in some countries.

Roles and responsibilities

Many people have roles in the implementation of a successful surveillance programme. This includes line management, occupational (industrial) hygiene professionals, medical professionals and the employees.

'Line management' has the responsibility to ensure that the people who need to be in the programme are identified, that employees complete training and any required medical questionnaires or tests and that the employees follow work practices, including wearing the

correct PPE when working with isocyanates. This would include regular audits of the workplace.

'Occupational (industrial) hygiene' professionals are responsible for assessing the potential exposure to isocyanate and helping line management develop controls, for example engineering controls, work practice improvements and selecting appropriate PPE.

'Medical professionals' have a key role in the surveillance programme. This includes administering the surveillance questionnaire, including appropriate follow-up, which may involve referrals to outside specialists. In addition, notifying the appropriate people when there is a potential work-related illness so that appropriate investigations and reporting can be done. Typically, the medical personnel and occupational (industrial) hygienist work together to develop the training information on the health hazards of isocyanates.

'Employees' are the key to the programme. In addition to completing the requirements of the programme and following work procedures, they need to report promptly to line management or medical professionals any symptoms which could be related to exposure so that appropriate intervention can be made to minimize potential health effects. They need to follow the procedure and correctly use and maintain PPE.

Product stewardship

The company supports body shop customers with localized on site solutions and response, which promote safe handling of the product. In addition, the company Refinish Training Centers provides relevant, detailed courses and seminars: the training covers understanding not only the technical aspects of the job (new product systems, application techniques, substance preparation) but also the safety, health and environmental requirements. The recommendation is that all automotive paint products should be sprayed only in a properly designed booth or in an effectively ventilated spray enclosure, which prevents spray mist escaping in to the work areas outside the booth. For all spraying operations involving isocyanates, an air fed (supplied air) respirator is recommended. People should not be in the painting area without appropriate respiratory protection and other appropriate PPE. This training does not remove the customer's health and safety responsibility to his/her own workforce, e.g. respiratory protection programme.

Discussion

Isocyanates are recognized as hazardous and can cause occupational asthma. Prevalence of up to 5–10% has been noted in exposed populations [1,2]. This programme indicates that the risk of occupational asthma can be

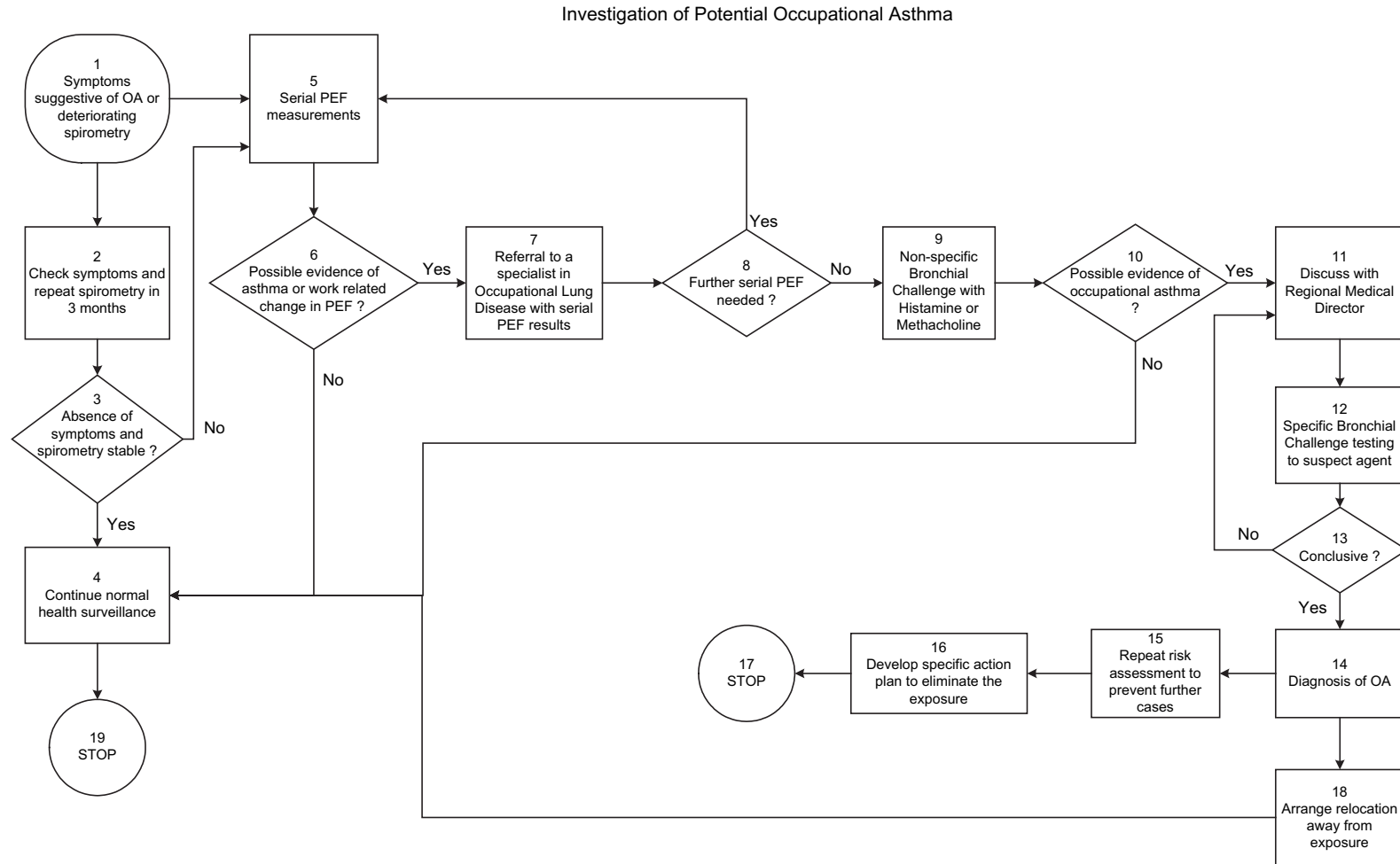


Figure 2. Algorithm for the investigation of suspected occupational asthma.

reduced to low levels with the application of the normal occupational health control measures of reducing exposure, PPE, health surveillance and employee training. These simple control measures are relatively inexpensive and can be applied in many parts of the world, even in small business settings. In addition to being the right thing to do, a business case for such a programme is usually clear given the time, effort and cost involved once a case of occupational asthma is diagnosed. We have found that using root-cause analysis to investigate incidents of overexposure, spills and cases of occupational asthma has been useful in preventing further occupational asthma.

Setting up a global programme has been a challenge, dealing with different cultures, national guidelines and legislation. We have found that the best approach has been to set a minimum standard, which all must follow but allowing variation in what can be added to this to comply with local legislation. The question of who legally (or by custom and practice) carries out assessments and reviews results also varies from country to country and the programme has been made flexible enough to allow this.

Through our customer-training programme we communicate good health and safety practices, so our products can be used safely. It is recommended that all employers who manufacture, handle or use isocyanate-containing products consider such a strategy. This programme could also be applied when other asthmagens are in use.

Conflicts of interest

None declared.

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