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Reducing isocyanate exposure and asthma risk in motor vehicle repair

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Abstract

Purpose – Exposure to isocyanates was the leading cause of occupational asthma in the UK. Motor vehicle repair (MVR) bodyshop paint sprayers were at greatest risk, despite widespread use of air-fed breathing apparatus and ventilated booths. Most paint sprayers work in small and medium enterprises (SMEs). The purpose of the Health and Safety Executive (HSE) project, described in this paper, is to improve exposure control measures in at least 20 per cent of MVR bodyshops, and reduce the risk of occupational asthma. The paper aims to discuss this issue.

Design/methodology/approach – A three-stranded plan consisted of: Safety and Health Awareness Days (SHADs); workplace inspections; and third-party stakeholder communications. The impact of various parts of the project were evaluated.

Findings – Approximately 18 per cent of bodyshops in the UK attended one of 32 SHADs, following which over 90 per cent of delegates expressed an "intention to act" to improve exposure control measures. A local assessment showed that at least 50 per cent of bodyshops improved exposure control measures. An evaluation of 109 inspections found that enforcement action was taken at 40 per cent of visits. Third-party engagement produced a joint HSE-industry designed poster, new agreed guidance on spray booths and dissemination of SHAD material. Knowledge of booth clearance time has become widespread, and 85 per cent of booths now have pressure gauges. Biological monitoring data show that, post-SHAD, exposures were lower.

Originality/value – A sustained national project using clear, relevant, tested messages delivered via different routes, had a sector-wide impact in bodyshops. It is probable that the project has improved isocyanate exposure control in at least 20 per cent of bodyshops. The generic lessons could be applied to other widespread SME businesses.

Keywords Risk management, Occupational health and safety, Spray painting, Workplace health, Spray booths, Behaviour modification, Isocyanates, Key messages, Exposure control, Biological monitoring, Motor vehicle repair, Air-fed breathing apparatus

Paper type Research paper

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Introduction

Exposure to isocyanates has been the leading cause of occupational asthma in the UK for at least two decades (Bakerly *et al.*, 2008). Spray painters, using isocyanate-based paints in the motor vehicle repair (MVR) industry, have been the work-group at greatest risk (HSE, 2010), with 80 times the average UK industry occupational asthma incidence. MVR spray painters were therefore chosen by the Health and Safety Executive (HSE) as a target group for a national awareness project, aimed at reducing the incidence of occupational asthma. Most sprayers work in micro-businesses. There are approximately 12,000 MVR spray painters in the UK, working in approximately 8,000 bodyshops, over half of which have less than ten employees (Broughton *et al.*, 2010).

Throughout the 1990s, HSE targeted the MVR industry to improve isocyanate exposure controls. However, although the risk to sprayers was reduced, the incidence of occupational asthma remained stubbornly high. As most sprayers worked in specialised enclosing spray booths and wore air-fed breathing apparatus it was not obvious how they were being exposed to isocyanates. Research into sources of exposure concluded that activities such as paint mixing, brush application, surface sanding and the spray booth "bake-cycle" for 2-pack paint film curing, emit insignificant amounts of isocyanate (Coldwell and White, 2005a, b). Apart from paint spraying, poorly controlled gun cleaning was the only other potentially significant exposure source identified. This research also characterised the flow of air within spray booths and rooms to better understand how exposure might be taking place. In downdraught booths the formation of recirculatory eddies, against the walls and under light fillets determined the clearance time for airborne isocyanate, whereas in spray rooms this was determined by simple dilution.

This understanding of process and local exhaust ventilation prompted a more detailed exploration of industry control measures, through site visits and discussions with employers and industry suppliers, supported by a review of the relevant occupational hygiene literature. This indicated that the relevant stakeholders, including the suppliers were in the main unaware that:

- high-pressure isocyanate paint spraying creates a fine invisible paint mist;
- airborne isocyanate concentrations created during spraying are high; in the hundreds of micrograms per cubic metre of air ($\mu g/m^3$) in spray booths and often in the thousands of $\mu g/m^3$ in spray rooms (Pronk *et al.*, 2006; White *et al.*, 2006);
- spray booths and rooms have a "clearance time";
- spray booths need to be kept under slightly negative pressure to prevent paint mist leakage; and
- lifting visors to examine the paint quality, or removing their respiratory protective equipment before the booth/room has cleared, can expose sprayers to isocyanates (Williams *et al.*, 1999).

Sprayers' beliefs about the health risk and exposure route were also inaccurate. Sprayers identified the main risk from using 2-pack isocyanate paints as cancer, and the main exposure route as dermal (HSE, 2009).

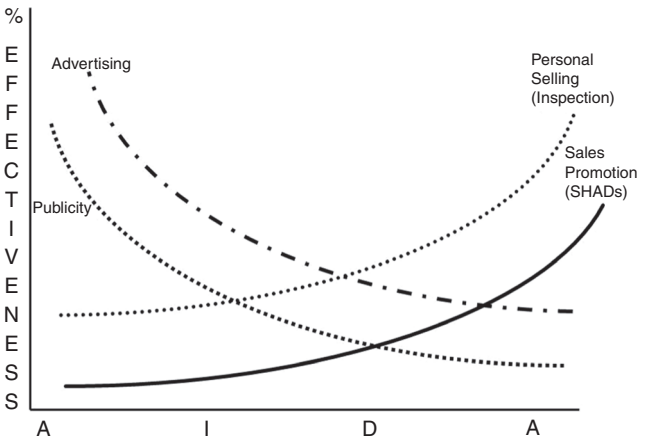
In order to address the apparent misconceptions surrounding exposure control that were likely to have underpinned poor control strategies, HSE embarked on a three year project (2004-2007) designed to influence the exposure control culture of the MVR

industry. The overall aim of this project was to improve the control of isocyanate exposure in 20 per cent of UK MVR premises by creating a change in beliefs, understanding and behaviour in relation to isocyanate paint spraying. The project comprised three interlinked strands designed to target all 8,000 UK MVR bodyshops: Safety and Health Awareness Days (SHADs); on-site visits by HSE inspection staff; and engagement with, and influencing through, third parties (HSE, 2007).

There is evidence that marketing methods can be effective in improving and protecting the health of workers but campaigns need to be sustained to be effective (Mustard and Bielecky, 2007). In addition, creating intention to change does not guarantee actual behavioural change (Webb and Sheeran, 2006). This is more likely to happen where intentions are stable over time, are planned and the circumstances where and when the changes are needed are specified (Gollwitzer and Brandstatter, 1997). Staged approaches to behaviour change (Sutton, 2005) emphasise that change is a dynamic process and different strategies are needed for different audiences according to their receptiveness to change. The staged approach has been successfully applied in the occupational health context (Whysall *et al.*, 2007). This MVR project adopted a simplified, long-standing version, from the world of marketing (Strong, 1925; Fill, 2005).

The AIDA marketing model comprises four stages: awareness/attention, interest, desire and action, which represent the successive stages that individuals move through towards action when confronted with a promotional message. An elaboration of the model (Chartered Institute of Marketing) also indicates which communication methods would have most impact with different methods of communication having more-or-less effect at each stage (Figure 1). The MVR project was concerned with getting bodyshops to take action – the final stage in AIDA. Therefore the communication activities focused on methods known to bring about action, "Sales Promotion" (direct contact with businesses, such as SHADs) and "Personal Selling" (inspection). However, prior to that stage the project sought to generate awareness and interest in the issue of exposure control and a desire to take action, amongst the target population.

This paper outlines the various aspects of the project, and provides details of the evaluation conducted to assess impact and the lessons learned.



Source: Adapted from the Chartered Institute of Marketing

Figure 1.
Likely impact of different communication methods on the four basic stages in behavioural change; awareness, interest, desire and action (AIDA)

Methods

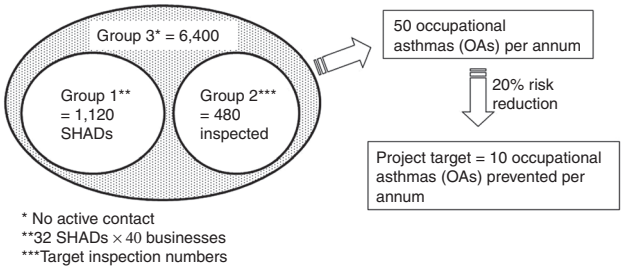
Effective communication relies on defining and understanding the audience, in this case, mainly small micro-businesses distributed across the whole of UK. The approach adopted was shaped by previous HSE work seeking to engage and influence small businesses (Strutt *et al.*, 2004). This included using the SHAD approach previously used by HSE to engage with the farming community and building sub-contractors.

Project target population

A simple potential outcome model informed the overall project plan. The target MVR population was categorised into three groups (sub-populations) in relation to the three project strands: those attending the SHADs (Group 1); those visited by HSE staff (Group 2); and those influenced indirectly by third parties (Group 3). The model is shown graphically in Figure 2 along with group size estimates.

In order to achieve the aim of improved isocyanate exposure control in 20 per cent of UK MVR premises, the anticipated level of impact and target number of bodyshops was calculated for each of the three groups. The SHADs were intended to reach 1,120 of the 8,000 UK MVR bodyshops, which incidence figures would suggest accounts for 7.5 cases of occupational asthma. Based on an estimated impact of 50 per cent, the SHADs were expected to contribute to the prevention of three to four cases of occupational asthma, equivalent to a risk reduction of 7-8 per cent for this strand of the project.

Site visits by HSE staff were expected to have a 90 per cent impact with a smaller proportion of bodyshops ($n = 480$) and the indirect influencing via third parties and publicity was expected to reach a larger number of bodyshops ($n = 6{,}400$) but with a lesser impact of between 2 and 9 per cent. It was clear that the third-party, and other indirect influencing, would need to be highly effective if the project aim was to be achieved as evidence from public health initiatives suggested that this was an ambitious target for the take up of control messages (Hornik, 2002). Given HSE's regulatory role and the statutory requirements underpinning the control of isocyanate exposure, the team were confident of achieving greater impact than that expected for interventions in non-regulatory contexts.



Group	Proportional OA contribution	Assumed control impact	OAs prevented
1	7.5	50%	3.5
2	4	90%	2.7
3	40	~2% (9.5%)†	0.8 (3.8)
Totals	50		~7 (10)

† Percentage impact required to achieve target OAs prevented

Figure 2.
Estimated potential impact on the three motor vehicle repair bodyshop target groups by the project, assuming MVR bodyshops created 50 cases of occupational asthma per year

Understanding and demonstrating the main causes of isocyanate exposure was fundamental to being able to present a small number of clear, simple and practical key messages to the stakeholders. Key messages were identified and refined based on available evidence and expert opinion (Coldwell and White, 2005a, b; White *et al.*, 2006). Additional research clarified the time taken for paint mist to clear from an enclosing spray booth/room (clearance time) and the usefulness of smoke as a way of determining this time (Saunders *et al.*, 2006; HSE, 2008).

Spray painters, bodyshop managers and other industry representatives, as well as HSE and local authority inspectors, were invited to attend a half-day SHAD event. To encourage maximum attendance, an HSE invitation letter explained that the SHAD would provide new and important information on how to control exposure to isocyanates and thus avoid occupational asthma. The letter also stated that inspectors would need to visit workplaces to explain the new information if bodyshop personnel could not attend. Inspectors were also trained using the SHAD materials, and attended local events.

Project design and delivery

Four pilot SHADs were held in the first year of the project. The SHAD final project order and content were modified based on the pilot event feedback (O'Hara *et al.*, 2006). For instance, it was initially assumed that micro-businesses and sprayers would not want to be involved in discussions about how the law applied to their workplace. While this was true, they did want to hear about what would happen if an HSE inspector visited, and what they would be hoping to identify. To maximise impact, a variety of techniques were used to communicate and reinforce key control measure messages (Figure 3).

SHADs included short presentations by HSE and industry speakers. Video clips, schematics and working scale models (of a spray booth and a spray room) were used to show how exposure occurred, could be controlled and simple ways of checking that controls were working and being used appropriately. Checking included the use of biological monitoring by urine analysis (Jones *et al.*, 2013). Smoke, Tyndall lighting (Plate 1) and video-visualisation techniques were used to visualise the hidden

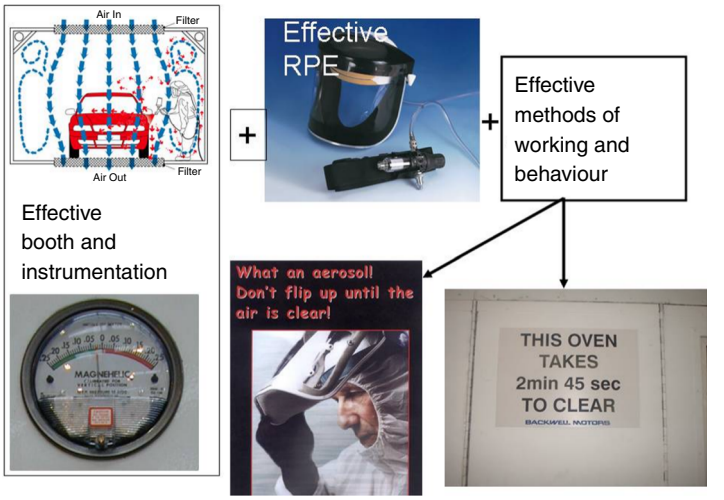


Figure 3.
Summary of motor vehicle repair (MVR) bodyshop 2-pack isocyanate paint exposure control measures

exposure, as isocyanate fine paint mist is invisible to naked eye. Videos were used to describe the health effects of isocyanates, and included an emotive interview with a worker badly affected by occupational asthma. Interactive drama explored issues around the management of risks, and helped to dispel myths. This helped to reinforce the key messages, to challenge behaviour and crystallise what attendees were going to do when they returned to their workplace. A simple two-page action plan, used throughout the SHAD, assisted delegates in formulating "implementation intentions" (Gollwitzer and Brandstatter, 1997). Six posters, reinforcing the key messages were given to every delegate, and were disseminated by HSE inspectors on their visits to bodyshops.

A HSE-industry MVR Forum (HSE, 1999) supported third-party engagement with key trade associations and individuals, and actively promoted the SHADs. The engagement and indirect influencing activities included several articles for *Bodyshop* magazine (distributed throughout the MVR trade) and trade association magazines. A joint poster, developed with the British Coatings Federation, was sent to all the major automotive paint suppliers, and most UK suppliers of spray booths. They attended a briefing meeting and joined a working group to help refine and focus the relevant HSE guidance (HSE, 2003). Over 250 copies of the SHAD presentational material was supplied to delegates and others, including training colleges. HSE manufacturing sector inspectors ran a shortened version of the SHAD for many of the large UK car manufacturers and distributors. HSE inspectors visited bodyshops throughout the project, to disseminate knowledge and improve current practice.

Training colleges were invited to attend their local SHAD event, and were supplied with relevant CD-based training materials, along with an edited video of one SHAD event. Throughout the project, key messages were refined as appropriate based on feedback or tailored to suit specific audiences (e.g. trade bodies, employers, spray painters, trainees). Some of these messages are summarised in Figure 3.

Project evaluation

Evaluation of the project focused on the impact of the project in the short and medium term, primarily in relation to knowledge and behaviour change but also in relation to

Plate 1.
Tyndall lighting (right photo) highlights the fine isocyanate-containing paint aerosol, which is invisible under normal lighting (left photo)

workplace exposure to isocyanate. SHAD events were evaluated using pre and post event questionnaires, initially tested in the evaluation of four pilot events (O'Hara, 2006). The questionnaires were designed to assess any differences in attendees' knowledge in relation exposure control and their intention to make changes. After the event attendees were asked to identify any specific changes they intended to make.

Follow-up site visits were conducted to MVR bodyshops from one SHAD pilot region in order to assess impact on exposure control in those bodyshops that had attended the event. The evaluation of the pilot SHAD events and all of the events in year two provided an indication of the overall likely impact of the events in terms of exposure control knowledge and behaviour. Two years after the project ended, HSE commissioned an evaluation of exposure control knowledge, and behaviour in relation to the use of isocyanate paint spray in the MVR sector. This entailed a telephone survey of 500 bodyshops and 30 site visits (Broughton *et al.*, 2010). Biological monitoring was promoted at the SHAD events, and approximately 4,000 free kits were given away. A significant proportion of the industry now uses this technique to check on exposure control measure effectiveness (Jones *et al.*, 2013).

Results

Between 2004 and 2007, about 4,000 people, from approximately 1,400 bodyshops (about 18 per cent of the UK total), attended one of 32 SHAD events (higher than the 14 per cent (1,120) that had been expected). In the first 15 events evaluated about half of those who attended were paint sprayers (O'Hara and Sanders, 2007). Consistently, across all SHADs, over 90 per cent of delegates expressed an intention to act to improve exposure control measures. In addition, 98 per cent ($n = 723$) of participants at the 2005-2006 events indicated an intention to take improvement action on at least one aspect of health and safety covered in the SHADs (O'Hara and Sanders, 2007). The regional assessment of impact suggests that at least 50 per cent of bodyshops took effective actions to improve controls, after attending a SHAD event (O'Hara, 2006). Questionnaire responses prior to the SHAD event indicated that attendees were overconfident or "unrealistically optimistic" (Weinstein, 1982) about the measures in place to control risks in their workplace compared to their post event responses. This suggests that improved awareness highlighted weaknesses in existing measures and instilled more realistic perceptions of risk.

Almost 25 per cent of biological monitoring kits issued at the SHADs were returned (994 of 4,000). In total, 83 per cent ($n = 826$) of the samples showed no detectable isocyanate exposure. Results were significantly lower than those taken from a comparable population during pre-SHAD, HSE MVR inspection initiatives. For SHAD participants, there was no statistically significant difference in biological exposure monitoring results between sprayers using visor or half-mask air-fed breathing apparatus, or between workers using different enclosures (spray booths and rooms). In cases where the initial sample was above the quantification limit, a repeat sample was submitted, after control measures and working practices were improved. These repeat samples were significantly lower than the initial results (Jones *et al.*, 2013). The project, and the subsequent guidance from HSE (HSE, 2007), has stimulated use of biological monitoring to assess isocyanate exposure of sprayers (Jones *et al.*, 2013), with about 13 per cent of the UK industry now reported to be using the technique (Broughton *et al.*, 2010).

The post project survey of current understanding, knowledge and behaviours amongst 500 bodyshops, with extended visits to a sub-population, provided a picture of MVR bodyshop isocyanate risk perception and understanding of exposure

control measures (Broughton *et al.*, 2010). SHAD attendees responding to the survey (19 per cent of the survey population) reported that they could recall the key SHAD messages years later. The survey reported that 91 per cent of larger bodyshops (68 per cent for sole-traders) knew the clearance time of their spray booths/rooms, and approximately 85 per cent of booths/rooms had a pressure gauge fitted, to check for negative enclosure pressure. Beforehand almost no bodyshop, or supplier, knew that spray booths/rooms had clearance times. Furthermore, 13 per cent of companies surveyed now undertake regular biological monitoring (25 per cent of medium sized (> 15 employees) and ~5 per cent of micro-businesses (less than six employees). These findings suggest that key messages, focused on exposure control, have been received and acted upon more widely than just SHAD attendees or those inspected.

Although there was no formal assessment of the project inspection strand, a sample analysis of 109 bodyshop visits showed that 51 (47 per cent) received some form of enforcement or follow-up action, including 19 letters, 25 improvement notices, seven prohibition notices and 25 follow-up visits.

Discussion

This paper has described the effectiveness of an industry-based campaign, designed to reduce exposure to isocyanates in MVR workers and consequently to aim to reduce the risk of developing occupational asthma. Before the project, the reasons for MVR paint sprayers being at the greatest risk of occupational asthma were not clear – MVR paint sprayers worked in extracted enclosing rooms and, by the 2000s, most wore air-fed breathing apparatus. Research conducted early in the project identified the understanding and behaviours of MVR bodyshop owners, sprayers, suppliers and the control culture within which they worked as important factors. Key messages and appropriate communication approaches were designed within the project to address the factors.

In 2004 it was not well understood in the UK MVR industry (including suppliers), that spray booths and rooms had a clearance time. Almost no one understood that spraying produced a fine, invisible mist, which remained airborne, during the clearance time. Similarly, it was identified that many sprayers were not aware that isocyanates could be harmful when inhaled; believing primarily that the main route of entry was through the skin. In addition, the perceived main adverse health outcome was cancer, rather than asthma, and consequently early signs of asthma were not being thought about or identified. As a result, this project set out to change MVR industry control culture in at least 20 per cent of bodyshops.

Although a formal longer term evaluation of this project was not planned or carried out, certain data are available relating to outcomes after this project was complete. For example, a survey of current practice in 500 MVR bodyshops (IES, Broughton *et al.*, 2010) reported that most bodyshops knew the clearance time of their spray booths/rooms and had a pressure gauge fitted, in order to estimate negative enclosure pressure. Prior to the start of the current project, almost no bodyshop or supplier was aware that spray booths or rooms had clearance times associated with their operation. In order to achieve what is believed to be a successful outcome from this process, a wide range of communication tools was used to deliver key messages directly to workers and employers. The SHAD format was used to deliver these, and these were universally well accepted. Those who attended the SHADs were able in general to recall the key SHAD messages at least one year later (Broughton *et al.*, 2010). These findings suggest that key messages, which focused on control of isocyanate exposure, have been

received and acted upon more widely than just SHAD participants (only 19 per cent of the population surveyed by the IES study) or those inspected.

Additional support of the benefits of this approach include short-term biological monitoring data showing that isocyanate exposures of SHAD attendees were significantly lower than pre-project levels within the sector, albeit in different MVR populations. In the medium term, over 8,000 biological samples have now been analysed since the SHADs, with 80 per cent showing no detectable levels, and only 7 per cent exceeding the current UK Biological Monitoring Guidance Value (Jones *et al.*, 2013).

A simple potential outcome model informed the overall project plan. Although the separate strands were modelled separately, in practice there was considerable overlap and cross-influencing. In relation to anticipated and planned numbers, approximately 300 more MVR bodyshops were represented ($n = 1{,}400$) at SHADs than planned, and although the specific number of MVR inspections was not recorded, actual inspection numbers were probably less than the 480 planned. The concern that they might be inspected encouraged bodyshop owners and sprayers to attend the SHADs. The material, particularly the posters, prepared for the SHADs was also used by inspectors. The priority-third-party influencing, and articles in key trade media reinforced messages given at SHADs, and during inspections. The project therefore functioned as an integrated whole.

The improvements gained during this project have built on previous improvements in MVR exposure control equipment introduced throughout the 1990s, including improved booth design and widespread use of air-fed breathing apparatus. Indeed, it was apparent that most workplaces did not need to invest in new equipment. The improvements seen were also probably a consequence of the simplicity of the messages used, as these were relatively simple for the bodyshops to follow. It is possible that these messages may be transferable to other groups working with isocyanates, and perhaps also to other industrial sectors with persisting health risks, where there are cost, behavioural and perceptual barriers to improving exposure control (Tarlo and Liss, 2010).

Finding the appropriate communication strategy to suit the target population has been highlighted as an essential prerequisite for behaviour change. HSE's MVR project exemplifies the benefits of this approach for improving control of isocyanate exposure and reducing asthma risk in UK MVR workplaces. The project is also consistent with findings from a review of social marketing campaigns in reducing the incidence of work related ill-health (Mustard and Bielecky, 2007). The authors recommend that to be effective social marketing campaigns need to focus on specific hazards and risks, integrate mass media communication with other well designed and resourced activities (e.g. consultation, inspection, enforcement, education and training) and provide sustained exposure to the campaign. The composition of the project team was also integral to the project design and implementation, encompassing a range of relevant disciplines (e.g. occupational hygiene, occupational medicine, psychology and biology) and industrial experience.

Limitations

There are various weaknesses and downsides to our project approach that are worthy of discussion as they may influence the overall interpretation of results. It is not clear how indirect approaches have influenced the 80 per cent of bodyshops not directly contacted during this project (Group 3, Figure 3). Although the findings of the IES

survey suggested a high level of bodyshops (~80 per cent) that were aware of spray booth clearance times, the data also highlighted areas of practice that were less ideal, including poor knowledge of the presence of fine invisible paint mist created during, and remaining after, spraying.

The project was not planned as a formal intervention with a control (non-intervention) group, given its real world nature. Given the relatively small size of the sector, it was a priori felt difficult to isolate such a control group from key messages presented to the SHAD attendees. Also, as part of the HSE Disease Reduction Programme it was important that the project was seen and run as a national project, aiming for a national impact. As a consequence, it is more difficult to attribute improvements directly in all cases to SHAD activity.

Again, improvements in exposure control measures were used as leading indicators of impact, rather than using a reduction in the number of incident cases of isocyanate related occupational asthma. To measure the latter would have required a longer follow-up period, and would have introduced a further set of uncertainties surrounding the clinical diagnosis of occupational asthma. Nevertheless, recent data from the UK national reporting scheme THOR show that occupational asthma incidence for vehicle paint sprayers over the period 2007-2009 was 69 per 100,000 workers (HSE, 2012), compared to an incidence rate of 165 per 100,000 when the project was initiated (2003/2004) (HSE, 2004).

Given the various limitations discussed, it is difficult to be certain that the original aim of the MVR SHAD project (to significantly improve exposure control in 20 per cent of MVR bodyshops) has been achieved, but it is likely from the evidence we have presented. In addition, the available evaluation suggests that there has been a wide-scale improvement in some of the key aspects of MVR bodyshop isocyanate exposure control culture.

Conclusions

This project has indicated a reduction in isocyanate exposure in the MVR industry. This was done by implementing a multi-stranded project involving key stakeholders, an understanding of key exposure sources and being sustained over several years. The project recorded a high level of success; essential to which was a staged approach supported by a research phase testing key exposure assumptions, an understanding of audience risk and exposure perceptions as well as targeted support for behavioural change. The project highlights that to engage, and gain the attention, interest and trust of small and medium enterprises, key messages need to be tested, expressed simply and illustrated effectively so that businesses are motivated to undertake effective control actions.

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