IN-DEPTH REVIEW

Reducing occupational exposure to chemical carcinogens

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Abstract

Strategies for controlling occupational exposure to chemical carcinogens are set out in the European Union Carcinogens Directive and in national legislation such as the British Control of Substances Hazardous to Health Regulations. While such legislative requirements must apply to all occupational chemical carcinogens, it is argued that priority should be given to controlling those agents that contribute most to the cancer burden. Examples of possible strategies to reduce exposure to two agents (diesel exhaust particulate and paint emissions) are discussed. It is concluded that there are no real technical difficulties in controlling exposures to chemical carcinogens; however, for many of the key agents, we need to change attitudes to the potential risks and clearly demonstrate to employers and employees how to reduce the exposures.

Key words

Cancer; chemicals; workplace.

Introduction

Occupational cancer deaths in Great Britain are still at an unacceptable level. Rushton et al. [1] estimate that there are >7000 deaths attributable to work-related carcinogens for the six cancers that they assessed, 4.9% of the total cancer deaths. In comparison, there are just >3000 people who lose their lives in road traffic accidents in Britain and ~240 died as a consequence of accidents at work.

There are >170 chemicals or exposure circumstances that have been classified by the International Agency for Research on Cancer (IARC) as known or probable human carcinogens (Groups 1 and 2a, respectively). In addition, there are ~250 substances or circumstances that are classified as possibly carcinogenic in humans (Group 2b). Details are available on the IARC website (http://monographs.iarc.fr/ENG/Classification/index.php). A large proportion of these substances may be found in workplaces, either because they are used in processes or because they are emitted during the operation of processes. They range from asbestos, which has been a confirmed human carcinogen for many decades, to Zidovudine (AZT), a drug used in HIV treatment that was classified as an IARC Group 2b substance in 2000.

The basic approach to protect workers from occupational carcinogens is either to eliminate the use of the material, as has been done in a small number of instances, or to control exposure to a level where the risk is acceptably small, where the maximum exposure level that is considered acceptable is usually defined by an Occupational Exposure Limit (OEL). This paper discusses the strategies that are open to reduce exposure to occupational chemical carcinogens and attempts to identify which substances require priority action and what barriers need to be overcome to ensure exposure is controlled.

Strategies for reducing exposure to chemicals

The European Union Carcinogens Directive (2004/37/EC) provides minimum standards for the protection of workers from risks related to exposure to carcinogens and mutagens at work. The Directive is implemented in each European Union (EU) country under national legislation; for example, in Great Britain, it is brought into force through the Control of Substances Hazardous to Health (COSHH) Regulations. Article 5 of the Carcinogens Directive sets out the strategy for controlling exposure and risks; first, that the carcinogen be eliminated and if this is not technically possible, it should be handled in an enclosed system. Where this is not possible, the employer shall apply the control measures seen in Table 1.

In all cases, the OELs specified in the Directive (benzene at 3.25 mg/m³, vinyl chloride monomer at 7.77 mg/m³ and inhalable hardwood dust at 5 mg/m³, all over an 8-hour reference period), although national authorities or other...
Table 1. Carcinogens Directive measures for controlling exposure

- Minimizing the quantities of a carcinogen used
- Minimizing the number of workers exposed
- Design the work to minimize the release of carcinogens
- Use local ventilation or general ventilation to reduce exposure
- Use appropriate procedures for the measurement of carcinogens in the work environment, particularly to detect accidental releases from work processes
- Application of suitable working procedures and methods to minimize exposure
- Provide individual protection measures, such as personal protective equipment (PPE)
- Undertake regular cleaning of floors, walls and other surfaces
- Provide information for workers
- Provide demarcation of risk areas and use of adequate warning signs
- Draw up emergency plans for circumstances where high exposure may occur
- Provide means for safe storage, handling and transportation
- Provide means for safe waste disposal

organizations within the EU may set limits for other occupational carcinogens.

In Britain, there is an obligation on employers to first attempt to reduce exposure by means other than personal protective equipment (PPE) before resorting to the use of respirators or other PPE to achieve adequate control.

In 2004, the British authorities introduced the concept of ‘Good Control Practice’ into the requirements of the COSHH Regulations. These good practice guidelines are encapsulated in eight generic principles, which must all be applied to obtain effective and reliable control (Table 2). They are not ordered in terms of priority or effectiveness, although the ordering provides a logical approach that can be adopted when seeking effective controls. The Good Control Practice approach is linked to a simple online risk assessment tool known as COSHH Essentials, which is available at www.coshh-essentials.org.uk. This tool provides general advice about the control approach that should be taken in specific situations where hazardous substances are used and provides access to control guidance sheets for specific processes (see http://www.hse.gov.uk/pubns/guidance/). For example, there are >60 guidance sheets available for processes involving exposure to crystalline silica, including tile pressing and the use of hand-held rotary tools in stonemasonry.

Good practice should also dictate that the ease of workers complying with the control measures should be considered, and while respirators are generally efficient at reducing inhalation exposure, there is often considerable resistance on the part of workers to use them for prolonged periods.

Priority substances for risk reduction measures

There is little consensus about which carcinogens should have a priority for risk reduction. In 2006, the British Health & Safety Executive (HSE) Working Group on Action to Control Chemicals (WATCH) published a list of substances that it considered as ‘carcinogens of high priority’ (http://www.hse.gov.uk/aboutus/meetings/acs/acts/watch/091106/p7annex1.pdf). It is not clear how the list was devised but it included aromatic amines such as 4,4'-methylene bis(2-chloroaniline) (MbOCA), beryllium and compounds, nickel and compounds, hexavalent chromium and compounds, as well as wood dust and other substances. Explicitly identified as ‘carcinogens of low priority’ were diesel exhaust particulate, arsenic, cadmium, vinyl chloride monomer and other substances that are still widely used. The European Commission has published a different list of priorities, which it is planning to consult with stakeholders about before considering possible amendments to the Carcinogens Directive (http://ec.europa.eu/employment_social/calls/2008/vt_2008_063/tenderspecifics_en.pdf). This consultation contains proposals in relation to 25 substances, including diesel engine exhaust particulate, wood dust, crystalline silica and vinyl chloride monomer, but not MbOCA or nickel.

Perhaps the most logical way to choose occupational carcinogens for priority intervention would be on the basis of the population risk arising from current exposure, i.e. estimates of the number of people expected to die in the future from cancers or the number of life years lost from current exposure at work, assuming that it continued into the future. There is currently no assessment of future cancer burden, although the British assessment of current occupational cancer burden from past exposure [1] probably provides a good ranking of priority substances for intervention—based on the assumption that relative changes in exposure level and prevalence have

Table 2. Guidelines for ‘Good Control Practice’ in the COSHH Regulations

The guidelines are as follows:
1. Design and operate processes and activities to minimize emission, release and spread of substances hazardous to health
2. Take into account all relevant routes of exposure—inhalaation, skin absorption and ingestion—when developing control measures
3. Control exposure by measures that are proportionate to the health risk
4. Choose the most effective and reliable control options which minimize the escape and spread of substances hazardous to health
5. Where adequate control of exposure cannot be achieved by other means, provide, in combination with other control measures, suitable PPE
6. Check and review regularly all elements of control measures for their continuing effectiveness
7. Inform and train all employees about the hazards and risks from the substances with which they work and the use of control measures developed to minimize the risks
8. Ensure that the introduction of control measures does not increase the overall risk to health and safety
been similar for each substance. Cherrie et al. [2] suggest that for most substances used at work, the population average level of exposure decreases similarly over time, typically by between ~5 and 10% per year. However, for some substances, this may not be the case and particularly for diesel engine exhaust particulate and radon, where there may have been no change or some increase in the population cancer risk over the last 20–30 years, mostly because of increased prevalence of exposure. In contrast, the increased use of highly refined mineral oils with much reduced polycyclic aromatic hydrocarbon (PAH) content may have produced a more dramatic reduction in the cancer risk from mineral oil exposure.

Table 3 shows the top 10 chemical carcinogens in terms of current occupational cancer burden, based on cancers where it is either established or suggestive that the exposure causes the specific tumour for which the mortality estimate was produced [1]. Five of the top 10 substances on the list are all commonly found in construction and other related activities (asbestos, crystalline silica, diesel engine exhaust particulate, painting and welding). The total number of predicted deaths from these agents/circumstances comprises ~98% of the total occupational cancer burden. Following the crude approach to estimate future burden outlined by Cherrie et al. [2] and allowing for reductions in exposure for most of these carcinogens at ~8% per year, with the key exceptions of radon, diesel exhaust particulate and painting where there is little evidence of much of an effective reduction in exposure levels, suggests that the future burden from current exposure could be about a third of the current burden, i.e. ~2000 occupational cancer deaths per year in ~20–30 years time.

In the future, it is important that we have a much better understanding of the number of people exposed to occupational carcinogens in Britain and levels of exposure in different jobs and industries. This could be achieved by a series of periodic national surveys undertaken by the HSE to document the exposure prevalence and intensity of those agents contributing most to the cancer burden.

### Examples of how to implement effective controls

Two examples are used to illustrate how we could effectively control exposure to occupational carcinogens: working as a painter and exposure to diesel engine exhaust particulate.

The cancer risk associated with being a painter was recently reviewed by IARC and confirmed as a Group 1 carcinogenic circumstance [3]. A meta-analysis of lung cancer data, carried out by the IARC Working Group, from population-based case–control studies using smoking-adjusted estimates, showed a significantly increased risk of ~50%. There was also an increased mortality from mesothelioma, which may point to the lung cancer risk being, at least partly, as a result of exposure to asbestos. However, increased risk of urinary bladder cancer in painters was also noted, and this risk was maintained after adjusting for cigarette smoking. There is no indication of exactly what aspect of exposure from painting is associated with the bladder cancer risk, although it is clear that the risk is still present in epidemiological studies that have recently been carried out; not knowing the substance or substances associated with painting that are responsible

<table>
<thead>
<tr>
<th>Substance/circumstance</th>
<th>Occupations/uses</th>
<th>Estimated deaths in 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Asbestos</td>
<td>Maintenance or demolition work on buildings containing asbestos</td>
<td>3840</td>
</tr>
<tr>
<td>2 Crystalline silica</td>
<td>Construction, certain industrial process, brick making, ceramic manufacture, foundry work, quarries, stonemasonry</td>
<td>850</td>
</tr>
<tr>
<td>3 Diesel engine exhaust particulate</td>
<td>Professional drivers, garage workers, tollbooth attendants, ferry workers, railway workers</td>
<td>676</td>
</tr>
<tr>
<td>4 Mineral oils—metal workers and printers b</td>
<td>Metal workers, printers</td>
<td>530</td>
</tr>
<tr>
<td>5 Radon</td>
<td>Office workers and others in buildings where radon contamination is present</td>
<td>370</td>
</tr>
<tr>
<td>6 Painters</td>
<td>Commercial, industrial and artistic painters</td>
<td>296</td>
</tr>
<tr>
<td>7 Welders</td>
<td>Process and maintenance welders</td>
<td>152</td>
</tr>
<tr>
<td>8 Dioxins</td>
<td>Coal power station, waste incinerators, metal reprocessing, chemical plants</td>
<td>120</td>
</tr>
<tr>
<td>9 Arsenic</td>
<td>Manufacture of special gasses, semiconductor manufacture</td>
<td>116</td>
</tr>
<tr>
<td>10 Cobalt</td>
<td>Metal alloy production and use, magnets, cemented carbides, particularly with tungsten carbide, catalysts</td>
<td>115</td>
</tr>
</tbody>
</table>

*Except environmental tobacco smoke (ETS), which has been all but eliminated (though still 1.2 million people who have some exposure to ETS as a result of their work activities in the UK) as an occupational exposure in Great Britain.

*bWhile other groups of workers may be exposed to mineral oils, these are the only two groups Rushton et al. considered there was sufficiently good evidence for them to derive cancer burden estimates.
for the risk means that it is necessary to control all emissions from painting.

To design an appropriate control strategy for painters, we must consider the actual circumstances of work, and the approach adopted will differ, for example, depending on whether the workers are based at a fixed paint spray facility in a factory or are peripatetic house painters. For a factory-based painter, there is no reason why the work cannot be adapted to reduce the emission of aerosols or vapours by modifying the process or using some form of local ventilation system. For example, it may be possible to use a high-volume low-pressure spray gun to minimize aerosol emissions or to use a downdraught ventilated booth where clean air enters through a diffuser covering the ceiling and is then exhausted through the floor. The downdraught booth, which is widely used in spraying cars and other vehicles, has the advantage of drawing the paint aerosol and vapours away from the operator and this minimizes exposure. Even with these engineering controls, it may still be prudent to require the painter to wear appropriate PPE such as a high-efficiency respirator, with disposable coverall and gloves, the latter providing protection from dermal exposure.

For house painters, there are greater difficulties than in factories in implementing engineering controls because of the nature of the work. However, it is practicable to minimize exposure by using brush or roller application methods rather than spraying, although this is probably commonly done, and to try to maximize the general ventilation by using fans to exhaust air from the room. In addition, it would be appropriate to require painters to wear respiratory protective equipment, coveralls and gloves to minimize inhalation and dermal exposure. Ideally, the respiratory protection should protect against both aerosols and vapours, although this type of equipment is expensive and problematic to use and it might be more practicable to focus on reducing the aerosol exposure with a filter respirator.

Use of a high level of control for painting in factories and motor vehicle repair is not uncommon because of the use of isocyanate compounds and the consequent risk of asthma, but the types of controls proposed in other painting situations will require a considerable change in attitude among painters and their employers. Most people are unaware of the cancer risk associated with painting and implementing these control measures will take a concerted effort to make people aware of the dangers associated with this type of work and to change their attitudes.

The second exposure control example concerns diesel exhaust particulate, which may occur for a diverse range of occupations and so the appropriate control strategy will differ depending on the circumstances. Here, by way of example, we discuss the controls that could be put in place for a tollbooth attendant and a professional driver. In the case of the tollbooth attendant, the best strategy is probably to provide fresh filtered air into the cabin where he or she works and to ensure that the room is overpressurized, i.e. that an excess of air is supplied into the space so that it flows out through windows and doors minimizing the ingress of vehicle emissions. In the case of the professional driver, the approach is broadly similar although in this case the air drawn into the vehicle should be filtered to a much higher standard than is normally the case using a high-efficiency particulate arrestor filter. It is probably not necessary to wear respiratory protective equipment in these situations; although for some occupations exposed to diesel exhaust particulate, this may be the only practicable option, e.g. traffic wardens. As with the painting scenarios, it is likely that there will need to be some considerable change in attitude to diesel exhaust particulate exposure before these strategies become widely adopted.

There are a number of excellent publications available to assist in selecting appropriate controls measures. For example, the HSE have produced helpful guides on local ventilation [4] and respiratory protective equipment [5].

Discussion

Setting priorities for intervention to prevent occupational cancer should logically be based on the projected future burden from current and future exposure to carcinogens at work. In this way, the control strategies adopted can be targeted to produce the greatest reduction in expected deaths. For some agents, such as benzene, beryllium and formaldehyde, the projected number of deaths from historic high exposure levels is so low (six, seven and six deaths per annum, respectively, from [1]) that it is not appropriate to focus substantial additional resources on further reducing risks. Rushton et al. are currently developing a methodology to estimate future burden. However, in the absence of good information about the future occupational cancer burden from current exposure it is probably reasonable to use estimates of current burden from past exposures to set priorities for action. This is based on the assumption that exposures, on average, decrease at a fairly consistent rate year-on-year [6], and so although the future burden will be lower than the current burden the relative importance of most carcinogenic exposures should be similar to that of the past.

On the basis of this the top-ten targets for intervention were identified, with the most important being asbestos, crystalline silica and diesel exhaust particulate. Many of these priority substances/exposure circumstances are associated with the construction industry and it would be appropriate to target the message for improved control to this sector in particular. For some agents there may have been greater reductions in risk than might be expected on average, particularly in the case of mineral oils where there has been efforts to reduce the PAH content by carefully refining the mineral oils sold on the market. There are only a few manufactured chemicals in the
top–ten. In fact, it is probable that most chemicals classified as IARC Group 1 or 2a that are manufactured and/or used in industrial processes are mostly handled within enclosed systems, as is advised by the European Union Carcinogens Directive. Therefore, exposure and risk in these situations is probably already well controlled.

For many of the situations where further interventions are required there is a serious problem in terms of awareness of the risks and the control measures that would be required to reduce the population occupational cancer risk. There are currently no steps taken to reduce the risk from diesel exhaust particulate emission for most exposed groups and no particular priority is given to this by regulatory authorities. Most people are unaware of the cancer risks associated with being a painter and so no effective controls are generally put in place. Despite there being good advice available about how to remediate buildings where there may be elevated radon levels there is no evidence that there has been any substantial reduction in population occupational exposure to radon over the last 10 or so years. Poor awareness of occupational cancer risks will hamper efforts to introduce effective interventions. Tomatis cites the example of the occupational cancer risks from historic exposure to ionizing radiation exposure, where there were early reports of tumours associated with its use but the scientific evidence was ignored in the rush to exploit the benefits arising from its diagnostic potential [7]. There were consequent tragedies from this lack of awareness although now the risks from ionizing radiation are tightly controlled (Rushton et al. [1] estimate that only one cancer death occurred in 2004 from past exposure to ionizing radiation, excluding radon).

Niewöhner et al. [8] identify a number of factors that influence communication in relation to hazardous substances at work and propose a theoretical model describing the necessary components to change behaviour and reduce risks. They argue that the intention to behave in a safe way, and hence the actual safe behaviour, is dependent on attitudes, subjective norms, perceived control over the actual behaviour and the perceived difficulty in following through with the appropriate behaviour. Unless each of these is aligned with the intention to act in a safe way, the actual behaviour will not take place. So for example, they note that users relate to chemical risks through their work practices and their perceived exposures, and these help to shape their attitudes towards any consequent health risks; materials that are generally handled without much caution may therefore be perceived as not carrying any significant risk. Most workers do not perceive the potential risks associated with long-term low-level exposure to chemicals. The general safety culture within the work environment and attitudes of others towards risks are also important in shaping intentions to act safely with it being difficult for individuals to take actions different from the prevailing norm. So if most painters take little or no precautions to avoid exposure to paint emissions, then it is difficult for any individual to act in a different way from the norm.

Perceived difficulty in working safely is related to the ease or difficulty in performing a specific behaviour, and Niewöhner et al. [8] note that in many situations, workers consider the difficulty in complying with a specific action to be high, for example wearing impervious gloves. In addition, the perceived control over exposure is often considered to be low because the worker often looks to the management to take the initiative to change working practices. These authors suggest that communication on its own will not change attitudes, and they suggest that there needs to be regulatory change, technical innovations and training interventions to ensure occupational risks from chemicals are reduced. This is almost certainly the case if we are to reduce the risk from occupational chemical carcinogens.

Action is needed to reduce exposure and risks to occupational carcinogens and this needs to be particularly focussed on those substances/circumstances where there is poor recognition of the risks.

Conflicts of interest

None declared.

References