Commentary

Gloves as Chemical Protection—Can They Really Work?

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Gloves are probably the commonest form of personal protective equipment used to protect workers against damage to health from workplace skin exposure. It has been estimated that around £30 million is spent annually in the UK alone for this purpose. Unfortunately, studies suggest that many of these gloves will not actually provide the protection that both employer and user believe is being obtained. This is illustrated by the results of a study of dermatitis in printers. In this study, in which a questionnaire was returned by over 1000 respondents working in the printing industry, 26% reported a skin problem at the time of responding. When these workers were clinically examined by a consultant dermatologist, all were found to be correct. The highest prevalence was in workers involved in actual printing, although over 90% of them wore personal protective equipment, such as gloves. The conclusion from these statistics can only be that the gloves were not protecting the users.

This is not surprising. There are many reasons why gloves do not protect workers against chemical hazards. In this commentary I propose to consider some of these and try to suggest how a system for the selection and use of gloves might be structured so as to provide the highest probability that workers will be effectively protected.

In the first place, awareness of the complex way in which gloves used as chemical protection work and fail is often simply missing. In courses on occupational skin management this often appears to surprise those participating, who, it seems, have been of the opinion that it is simply a matter of referring to a supplier’s catalogue and selecting the glove that is recommended therein. Others seem to believe that the CE marking on a glove is a guarantee that the glove will provide adequate protection. Neither assumption is true.

However, to start at the beginning, the British COSHH regulations are quite specific that the provision and use of gloves as protection against chemical hazards must be regarded as a last resort, when all practicable technical measures to eliminate or control exposure have been implemented and where there is still a residual exposure that cannot be controlled by other means. Gloves may only then be used in conjunction with the other measures introduced to control exposure. Article 6 of the EU Chemical Agents Directive has a similar requirement. Simply providing gloves as a first line of protection does not constitute compliance with regulations such as COSHH. The exceptions are as follows:

(i) The provision of gloves as a temporary measure whilst other methods of exposure control are identified and introduced.
(ii) In an emergency situation where there is no time to take other action.

As this commentary will illustrate, there are very good reasons for adopting this approach.

A basic rule of all exposure control should be that this is, so far as possible, independent of the worker. This is what technical control measures attempt to achieve. Since gloves are dependent upon the wearer to don, use and remove correctly, we immediately introduce an element of uncertainty. Furthermore, when controlling exposure by technical methods, it is frequently possible to structure these so that the control is ‘fail-to-safe’, i.e. should the control measure fail, this will not result in worker exposure. In practice, this is unachievable with personal protective equipment such as gloves. Any failure will result in worker exposure. Thus, where the consequences
of glove failure are acute, severe and irreversible damage to health, it is questionable whether gloves should ever be considered as primary protection. The exception, again, would be an emergency, where there is no practicable alternative but to rely upon gloves.

HOW RELEVANT IS CE MARKING?

All chemical protective gloves in the European Union must now be appropriately CE marked. Unfortunately, there is a common misconception that this enables the appropriate glove to be selected and can also be taken to indicate how well the glove will perform.

Under European Standard, EN374-1 (CEN, 2003a) protective gloves are divided into three categories as follows:

Category I: Gloves suitable for minimum risk.
Category II: Intermediate use.
Category III: Gloves for protection against high risks, i.e. where skin exposure would result in irreversible damage to health or possibly death.

The different categories require differing amounts of information to be marked on each glove. In the category III, there will also be one or more pictograms, indicating the risk for which the glove is suitable, and including the pictogram for chemicals. The pictogram will also indicate against which of the EN standards the glove has been tested. In the case of gloves used as protection against all but the most minor of chemical hazards, this will be EN374. It is not always realized that the CE marking is neither a guarantee of quality nor of the suitability of a glove for a particular purpose.

To decide which glove should be used and how often it should be changed requires first an understanding of how gloves work, or more particularly, why they fail.

REASONS WHY GLOVES FAIL

Whilst gloves can provide extremely effective protection, this is often not achieved in practice. There are basically four reasons why gloves can fail:

Misuse.
Physical damage.
Degradation.
Permeation.

In many situations, it will be a combination of these that results in the user being exposed to the chemical, often without realizing it.

Misuse can be first the selection of completely the wrong glove. It is still not uncommon to see what is termed a ‘riggers glove’ being used where a chemical protective glove is really required. This type of cotton glove with a leather palm provides no protection against chemicals and may actually increase exposure, as the chemical will be held in contact with the skin.

Even where apparently the correct glove has been chosen, skin contamination is common, simply due to the fact that the user has not donned or removed the glove properly. In one study on internal contamination of gloves Rawson et al. (2005) concluded:

Without training 9 out of 10 volunteers had internal contamination of their gloves when they reused them but if they were trained this reduced to 1 out of 10.

Similar findings were reported by Ramwell et al. (2002) when they studied internal contamination of gloves by those spraying pesticides.

Physical damage may be obvious, where, for example, a glove has split. However, minute punctures may not easily be detected and can result in quite extensive contamination inside the glove. A further complication arises where the worker requires protection from a combination of both physical hazards, e.g. cuts or abrasion, and chemical hazards. Those gloves that protect against physical hazards but at the same time have some form of chemically resistant coating always have the coating on the outside. Thus, any physical damage to the coating completely removes the chemical protection provided. In practice there will be little alternative but to consider double-gloving, i.e. wearing a glove that affords the physical protection needed outside the appropriate glove for the chemical protection required.

Degradation is where the chemical actually attacks the material from which the glove has been manufactured. The glove may become brittle and split, may swell and lose its mechanical strength or simply dissolve. Unfortunately, there is currently no EN standard for degradation. Different manufacturers use different test methods to determine the level of degradation that will occur with their gloves in contact with different chemicals. As a result it can be extremely difficult to compare glove performance.

Permeation is where the chemical is absorbed into the external glove surface, migrates through the glove at a molecular level, then emerges as a vapour from the internal surface. Since this does not, of itself, result in any apparent change to the glove it is undetectable by the wearer. There is a standard test for permeation included in EN374-2 (CEN, 2003b). This divides gloves into six different classes, depending upon the time taken in the test for the chemical to migrate through a sample of the glove, as shown in Table 1.

Note that the standard assumes that each person will use a fresh pair of gloves each working day.
Glove manufacturers publish tables showing a list of chemicals against which their gloves have been tested, indicating the permeation breakthrough time for their different gloves. It must be realized that this is only an indication of the suitability of the glove for use as protection against that particular chemical. It is not an indication of the length of time over which the glove will provide protection.

There are several reasons for this. In the first place, the standard provides for the test to be conducted at room temperature, specified as 23°C. Hands tend to be warmer than this. A thermometer placed against the skin inside an occlusive glove may well show a temperature of ~35°C. This can have a significant effect on the actual permeation breakthrough time, as Table 2 demonstrates.

As can be seen, the variation follows no pattern and cannot be easily determined, other than by testing at the appropriate temperature.

In addition, many other factors will influence the glove’s performance. For example, one glove exhibited in excess of 8 h permeation breakthrough time against 75% nitric acid. However, degradation due to contact with nitric acid was such that within 30 min the glove had become so brittle that it split. Factors that must be included in any assessment as to the useful life of the glove are shown in Table 3.

Since there is no simple way of correlating these factors to determine the actual performance that will be achieved in a given workplace situation, it may well be necessary to test the gloves for that task. There are several ways in which this can be done. One method is to use colour change pads underneath the glove. Another, that can also provide quantitative data, is to use activated carbon pads. Placed underneath the working glove and replaced at predetermined intervals, these are then analysed for the contaminant. This will indicate at which point in time chemical was detected inside the glove and thus allow the employer to decide how frequently the gloves should be changed.

In a pilot study using this technique we found that the performance of gloves bore little relationship to the data provided by the manufacturer. A major influence on glove performance was the nature of the task being performed and the type and extent of contact. Glove performance was found to vary widely. For example, a nitrile glove, used to protect against xylene (and with a manufacturer’s permeation breakthrough time of 36 min) showed no permeation breakthrough in one task after 2 h, but a breakthrough of the xylene in another task after just 5 min.

A further complication arises from the fact that most manufacturers provide data for individual chemicals, whereas in practice what most workers will be using will be some form of mixture. How mixtures permeate is complex, depending upon several factors, in particular, concentration. One constituent may act as a vehicle, taking others through the glove. At present the only practical approach is to consider each constituent on its own, then attempt to find the optimum glove. That this is not always simple is illustrated by the example of the mixed, reclaimed solvent that was being used to clean paint spray guns.

Table 1. Classes of gloves according to EN 374

<table>
<thead>
<tr>
<th>Measured breakthrough time (min)</th>
<th>Class (protection index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10</td>
<td>1</td>
</tr>
<tr>
<td>&gt;30</td>
<td>2</td>
</tr>
<tr>
<td>&gt;60</td>
<td>3</td>
</tr>
<tr>
<td>&gt;120</td>
<td>4</td>
</tr>
<tr>
<td>&gt;240</td>
<td>5</td>
</tr>
<tr>
<td>&gt;480</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 2. Breakthrough times at a test temperature and at a typical glove temperature

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Breakthrough time (min) at 23°C</th>
<th>Breakthrough time (min) at 35°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Butanol</td>
<td>&gt;480</td>
<td>&gt;240</td>
</tr>
<tr>
<td>Diethylamine</td>
<td>60</td>
<td>6</td>
</tr>
<tr>
<td>Dipentene (d-limonene)</td>
<td>&gt;480</td>
<td>36</td>
</tr>
<tr>
<td>Isobutanol</td>
<td>&gt;240</td>
<td>&gt;240</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>&gt;1440</td>
<td>&gt;240</td>
</tr>
</tbody>
</table>

Table 3. Factors affecting the safe maximum use time (SMUT) of gloves

<table>
<thead>
<tr>
<th>Reduce the duration of protective effect</th>
<th>Increase the duration of protective effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degradation</td>
<td>Intermittent or incomplete contact</td>
</tr>
<tr>
<td>High temperature</td>
<td>Volatility</td>
</tr>
<tr>
<td>Flexing and stretching</td>
<td>Low temperature</td>
</tr>
<tr>
<td>Mechanical damage, including abrasion</td>
<td>Frequent glove washing</td>
</tr>
<tr>
<td>Poor maintenance</td>
<td>Mixture strength</td>
</tr>
<tr>
<td>Ageing</td>
<td></td>
</tr>
<tr>
<td>Mixtures</td>
<td></td>
</tr>
</tbody>
</table>

It is clear that only one glove actually performs at all with this mixture, namely the butyl rubber glove. However, this is only a class 1 glove, i.e. permeation breakthrough somewhere between 10 and 30 min. Furthermore, xylene degrades butyl, reducing the permeation breakthrough time. Given the relatively high cost of butyl rubber gloves, it is unlikely that any paint shop will invest in these and change them at the appropriate frequency.
CREATING AN EFFECTIVE GLOVE MANAGEMENT SYSTEM

As can be seen, the selection of gloves for chemical protection and the development of a system that will ensure workers are adequately protected is not simply a matter of referring to manufacturers published data. The flow chart (Fig. 1) illustrates some of the elements that we will need to include in any such system. The whole subject is more extensively covered by Boman et al. (2004).

So can gloves work?

Returning to the question at the head of this commentary, gloves can work, but the development and maintenance of an effective glove system is not simple. Nor, given the fact that gloves may have to be changed frequently, is the provision of gloves usually the most cost-effective solution to the reduction of risk from dermal exposure.

Furthermore, gloves can actually cause skin problems. This is due mainly to the occlusive effect resulting in the development of irritant contact dermatitis, and, occasionally, to an allergic reaction to the chemicals used in glove manufacture. (In Germany, if gloves have to be worn for more than a quarter of a normal working shift of 8 h, then this is considered equivalent to wet work conditions and a special regulation applies (Technische Regel für Gefahrstoffe Nr. 531).

My own experience has been that in all too many workplaces, reliance has been placed (or rather misplaced) on gloves that are probably not adequately controlling exposure, whereas had attention been directed at changing the actual way in which the work was done, the exposure could have been prevented, or minimized to a level where the risk could be considered insignificant.

REFERENCES


