Guidance

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Glove Selection Guidance

"Choosing the correct glove can mean the difference between safety and injury."

Occupational Health and Safety Service
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UNIVERSITY OF CAMBRIDGE

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1. INTRODUCTION

The University owes a moral and legal duty of care for the health and safety of both its employees and others affected by their work. As part of this duty of care risks must be eliminated or controlled as far as reasonably practicable. Potential hazards must be risk assessed, control measures identified and put in place. It follows that wherever reasonably practicable risks should be controlled by engineering practices that protect all those otherwise potentially at risk.

However, due to the nature of work carried out in the University, it can be the case that engineering controls alone are neither reasonably practicable nor in some cases even possible. In these circumstances Personal Protective Equipment (PPE), either alone or in combination with engineering controls, may be the required. In this respect the use of gloves can be a vital line of protection and the selection of the correct gloves for the task a crucial first step (see Appendix 4 before reading on !!).

The guidance below aims to facilitate the glove selection process and to lay down principles that can be used across the University. However, the vast array of potential uses and the ever increasing number of available glove types effectively precludes this document making specific recommendations for individual tasks.

2. WHEN TO USE GLOVES

Whilst gloves can be an effective control measure, it must be remembered that:

- gloves only protect the wearer and they do not remove or reduce the risk to others
- gloves will, if they fail, always ‘fail to danger’ exposing the wearer to the hazard
- gloves used incorrectly may leave the wearer unprotected
- gloves can interfere with the wearer’s sense of touch.
- gloves can give the wearer a potentially false sense of safety
- gloves may reduce dexterity, particularly if
  - the glove material is inflexible
  - the glove material is too thick
  - the glove does not fit the individual
- The wearing of gloves, particularly for extended periods of time, can cause skin problems including allergic responses (ie: latex allergy) and dermatitis.

2.1 Factors to Consider

There are four principle factors to consider when deciding whether gloves are required and when selecting which glove would then be suitable for the task

- Type of hazard (ie: mechanical, thermal, biological or chemical)
- Task being undertaken
- User (ie: size and fit, state of health)
- Workplace conditions (ie: ergonomics, temperature, humidity, hot, cold etc….)

All of these factors should be considered together in the risk assessment, and not in isolation, as their interaction may determine the suitability of the glove. The risk assessment should specify which type of glove has been selected and why. It should also detail any specific requirements necessary to ensure the protection provided by a glove is maintained ie: specifying circumstances in which gloves should be changed and any emergency procedures necessary if a glove fails to prevent exposure to the hazard.

3. TYPE OF HAZARD

This guidance will focus on four categories of hazard that can put a person's health and safety at risk via exposure of the hands to those hazards:

3.1 Chemical

- metal working fluids
- petrol / oils
- Solvents / degreasers
- acids / bases
- detergents / soaps
- cement
- tar / adhesives / resins
- paints / inks
- pesticides / herbicides (weed-killers)
- bleach / descalers
- irritant or harmful chemicals
- toxic and very toxic chemicals
- Schedule 1 poisons
- carcinogens / mutagens / substances toxic to reproduction / sensitisers
- water ! (excessive immersion)

3.2 Biological

- animal tissue / bone / urine / faeces / blood / body fluids etc
- human tissue / bone /urine / faeces / blood / body fluids etc
- pathogens / bacteria / viruses / certain proteins etc.

3.3 Thermal

- hot tools / apparatus / utensils / work pieces
- steam
- hot pipework / components
- hot tar / oil / liquids
- cold weather
- cold tools / workpieces
- cold pipework / components
- cryogens (liquid nitrogen, oxygen or argon etc)

3.4 Mechanical

- sharp objects / components
- heavy or sharp tools / saws
- power tools / chainsaws
- wire / rope
- friction
- wood / trees / branches
- bricks / blocks
- trimmers / guillotines
- presses / rollers
- broken glass / needles / sharps
- nail guns / staplers
- knives / graters
- manual handling

These lists are not exhaustive but do serve to highlight the range of potential hazards the hands can face in the workplace.

3.5 Incidental versus Intentional Contact

The difference between incidental and intentional contact will often determine the degree by which the hazard is likely to translate into a risk of contamination or harm. It is second only to the nature of the hazard itself in the hierarchy of selection when choosing the correct glove to control the risk.

3.5.1 Incidental contact

Incidental contact refers to tasks where there is no intended direct contact with the hazard and the task is such that contact is considered unlikely under normal operation. For example, the appropriate disposable gloves can offer reasonable protection against incidental contact on the hand by a small splash of a hazardous substance provided that the gloves are changed immediately after the splash occurs. However, this is **not true for all chemicals**, since some aggressive and some extremely toxic chemicals can pass very quickly or even ‘instantly’ through certain glove materials (see Appendix 4). Always check the manufacturers data for the suitability of any glove under consideration.

3.5.2 Intentional contact

Intentional contact refers to tasks where contact with the hazard is likely or inevitable ie: immersing hands in liquids, direct handling of a substance rather than its container, handling of materials coated or saturated with a hazardous substance (i.e. cleaning cloth / rag), handling hot or cold items, handling/carrying sharp objects or handling potentially pathogenic biological material.
Under these circumstances there may therefore be relatively lengthy contact with the hazard. For example, when selecting a glove for protection against intentional contact with chemicals, it is necessary to select a glove made from a material that offers good resistance to attack or permeation from the specific chemicals in use. This will often require a ‘reusable’ rather than a ‘disposable’ glove (see below). Whilst in the case of biological material double gloving with good quality disposable gloves and appropriately frequent changes of gloves maybe the appropriate control measure.

4. TASKS AND WORKPLACE CONDITIONS

Whilst the hazard will usually be the key factor determining the choice of glove material, the task and the environment in which it is performed may influence the choice of the material and the style of glove.

4.1 Temperature

Temperature can affect comfort. Prolonged exposure to sweat inside a glove can provoke rashes or dermatitis. Gloves may need to be changed frequently and hands dried before donning a fresh pair or a cotton liner used inside the glove to absorb the sweat. Temperature can also affect the performance of gloves (see section 7.1.2).

4.2 Grip and Wet work

The amount of grip a glove provides is influenced by the material it is manufactured from and its surface texture. A textured surface providing a more secure grip in dry or wet conditions. Generally natural latex has better grip qualities than many nitrile, or other artificial rubber gloves, although manufacturers are making improvements with non-latex gloves. It is worth noting that butyl gloves may become ‘sticky’ when wet which can be misinterpreted as degradation.
Long cuffs and a good wet-grip are particularly important for wet or oily work.

4.3 Repetitive movements

A task that involves repetitive movements requires a glove with good flexibility and elasticity. A good quality nitrile or neoprene glove should meet most requirements.

4.4 Dexterity

The thicker the glove material the greater the resistance to chemicals, mechanical damage and thermal stress, however thick gloves can impair grip and dexterity and can themselves compromise safety. Thinner gloves generally do not offer a high degree of protection against physical hazards and may reduce chemical resistance. If different components of the work have greatly differing requirements, you may need to use more than one type of glove in the course of the work.

4.5 Cuff Length

The cuff of a standard disposable glove protects only a small area of the wrist. There may be a gap between the sleeve of protective clothing, overalls or laboratory coat, and the top of a glove. This is particularly important if the work involves reaching forwards causing the protective clothing to ‘ride up’ the arm. Disposable gloves are generally offered in either standard lengths of 24 cm ie: ‘medical devices / examination gloves’ or 26 cm ie: PPE, and alternatively in the longer length of 30 cm. Consideration should always be given to the consequences of splashes to the wrist when selecting the length of disposable gloves. Longer cuffed gloves are essential if you have to ensure protection of the wrist and lower arm during handling of highly irritant chemicals, handling of some high grade pathogens or dealing with large volumes of liquid which may spill or splash over the top of a standard length glove.

4.6 Physical Resistance

Resistance to physical damage such as abrasion, puncture, snagging, tearing and cuts will be dependent upon both the nature of the glove material(s) used and its thickness. Single use disposable gloves do not offer a high degree of protection against physical hazards. Thicker re-usable or specialised gloves may be required (see section 7.4 below).

5 DISPOSABLE VERSUS RE-USEABLE GLOVES

Disposable gloves are only intended for small splash / incidental contact with a limited range of hazardous substances, whilst reusable gloves may be more suitable for direct exposure to a hazard. The risk assessment should consider these aspects before selecting the best glove for the given task. Disposable and reusable gloves are often characterised by their thickness, which can be in either millimetres / mms (EU) or mils (US), the ’mil’ is one thousandth (0.001) of an inch, also known as a ‘thou’. Note: 10 mils = 0.25 mm.

5.1 Disposable Gloves

Disposable gloves are usually thin, generally being only 0.1 to 0.4 mms thick. They allow the user to retain good touch sensitivity and dexterity, however may consequentially have relatively poor chemical and mechanical resistance; tearing or puncturing easily if snagged. They are only intended to protect against incidental rather than intentional contact with chemicals and are unsuitable for some highly hazardous chemicals (see Appendix 4).

Disposable gloves are designed for single use only (logo), should be changed after any contamination is suspected, and should NEVER be re-used.

5.1.1 Pinholes / Faults in Gloves

Disposable gloves for chemical and biological hazards should be manufactured to the BS EN 374 and/or BSEN455 standard and may be assigned an Acceptable Quality Level (AQL) after testing by the manufacturer or independent testing centre.

Where tested the AQL number identifies the average number of allowable defects (aka pinholes) per 100 units ie: gloves with an AQL of 1.5 must have fewer than 1.5 defects per 100 gloves. However because 800 gloves are tested and the nature of the sampling regime used in assigning the standard, the maximum allowed defects within a box could be as high as 3% (twice the AQL).

A lower AQL number represents a higher quality product. !

Medical grade gloves will have AQLs of 1.5 or less i.e. 0.65. However lower quality gloves can have AQLs of 4 or may never have been tested (i.e. no AQL assigned).

More simply……

An AQL number is the percentage of gloves that might have pinholes!

Remember

Never use disposable gloves for immersion in any hazardous liquids!

Disposable gloves without a quoted AQL value could have unknown levels of pinholes and should be treated with suspicion unless the AQL can be established.

5.1.2 Double Gloving

Double gloving, ie: wearing two pairs of disposable gloves can in certain circumstances offer several potential benefits:

- When handling biological pathogens or particularly toxic chemicals, especially ones readily absorbed through the skin, it significantly reduces the risk of contamination through pinholes. The chance of two pinholes being in close enough proximity to each other to allow a splash to contaminate the hand through both is very low.
- Double gloving can approximately quadruple the duration of protection.
- It may offer some protection against physical damage if only the outer glove is penetrated /breached.
- It allows the top pair to be removed quickly in a contamination emergency without completely sacrificing all protection.
- It can allow two gloves of differing material to be worn thereby:
    - Potentially offering protection against two substances / hazards.
    - Allowing the risk of accidental contamination to be reduced when all the available data on a hazardous substance(s) fails to unequivocally identify the best choice of glove material.
    - Allowing a thin disposable glove to be worn under a thicker outer reusable glove. As well as offering additional protection it can prevent the re-useable glove becoming contaminated with sweat.
    - Allowing a non-latex glove to be worn next to the skin whilst a latex outer glove is used for its qualities ie grip or chemical resistance.

If the outer glove starts to degrade or tears open, the inner glove continues to offer protection until the gloves are removed and replaced. The best practice is to check the outer glove frequently, watching for signs of damage or degradation (change of colour, change of texture, etc.). With the first sign of damage or degradation remove the outer glove and re-glove.

5.2 Re-usable Gloves

Re-usable gloves are generally 0.5 to 1.0 mms thick. They offer greater protection than disposable gloves against abrasion and other physical hazards. They are less likely to tear in use and will resist chemical attack for longer. However, they generally reduce dexterity and touch sensitivity. They can still be damaged or penetrated by many chemicals and they need to be looked after to prolong their useful life. Re-usable gloves usually have a longer cuff length than standard disposable gloves made of the same material, and so may offer better protection against liquid slopping over the top of the glove. The longer cuff also allows protective clothing, ie: overalls or laboratory coat sleeves, to overlap the glove cuff.

Re-useable gloves need to washed and dried after work to avoid accidental skin contamination when next using them. This is particularly important if the work has involved immersion or handling of chemicals that can permeate the glove material whilst in use or storage (see 7.1.1 above). Volatile solvents such as acetone, toluene and xylene, readily penetrate many of the polymers used in glove manufacture and the non-volatile solvents, such as alkylated napthalenes and petroleum oil, are very difficult to remove from gloves. Therefore, under certain conditions safety may dictate that what might otherwise be considered as reusable gloves are in practice treated as disposable.

Always carry out a visual inspection of any gloves before using them. Of principal concern are cuts, tears, punctures, stiffness, cracking, or discoloration which indicates damage to the glove material or chemical attack resulting from previous use or storage. Gloves should be should be discarded if any damage is found or if the inside becomes contaminated with a hazardous substance.

Re-usable gloves can be checked for holes by filling them with water and tightly rolling the cuff toward the fingers, sealing the glove and applying pressure to the water at the same time, whilst examining for leaks. The gloves will require drying before reuse. Alternatively the glove could be 'filled' with air and then held under water whilst examining for air bubbles emanating from any leaks. Gloves showing any signs of damage or chemical degradation should be disposed of immediately.

If frequently re-used the gloves should periodically be turned inside out and the inner surface washed, rinsed and dried. However no gloves used for handling hazardous substances should be reused indefinitely, they should be subject to a regular replacement program.

6. USER

Factors related to the individual glove user include:

6.1 Size

Gloves are generally supplied as small, medium and large although some are available as extra small and extra large. These sizes are often equated to a numerical scale based either on the distance across the hand from the base of the thumb in centimetres or the circumference around the hand at the same point in inches (XS/6, S/7, M/8, L/9, XL/10, XXL/11). However sizes can in fact vary between manufacturers and between different styles of glove since the shape / fit of the glove will be dependent upon the original shape of the mould used to make it.

Gloves made from ostensibly the 'same material' from different manufactures may in fact differ in their suitability for an individual user.

Gloves that are too small can be difficult to put on, may bind and cause undue hand fatigue. A tight glove may restrict blood flow and cause skin rashes. A tight glove will be stretched, thinning the glove material and potentially exaggerating otherwise minor imperfections, possibly resulting in failure. Tight gloves are also difficult to remove safely, especially in emergencies. Conversely gloves that are too large are uncomfortable, interfere with the precision of grip and can snag.

The cuff length will also determine the level of protection, a standard length glove of 24 to 26 cm may not fully protect the wrist, whereas a 30 cm glove should.

Ideally there should be a range of gloves of differing sizes available in the workplace since using the correct size of glove is almost as important as using the correct type.

6.2 Allergy

Wearing any gloves for extended periods of time can result in adverse skin reactions including allergies and dermatitis. Type 4 allergic responses can develop where the skin is irritated by a substance in the material of the glove itself or as an added component of its manufacture.

Chemical accelerators / promoters are a common component of glove manufacture and residual amounts of these chemicals have been implicated in type 4 allergic responses from a number of glove materials including latex and more recently nitrile. However, different manufacturers may use different cocktails of chemicals and therefore their products may exhibit different allergenic responses, for example SHIELDSkin nitrile gloves from Shield Scientific are currently manufactured using only carbamates, which they claim reduces their allergenic potential.

Typical accelerators can include:

- Thiurams - Tetramethylene thiuram tetrasulphide (TMTD) at 2 to 16.1 %
- Carbamates - Zinc diethyldithiocarbamate (ZDEC) at 0.4 to 4.4 %
- Thiazoles - 2-Mercapto benzothiazole (MBT) at 0.7 to 2.3 %

Gloves lacking accelerator chemicals, may be a viable alternative where problems of allergic reaction have been identified in individuals ie: 'accelerator free' N-Dex nitrile gloves from Best Manufacturing or similar.

6.2.1 Latex Allergies

The use of latex gloves must be specifically justified in light of the risks associated with type 1 and type 4 latex allergies. Type 1 allergies, caused by residual latex proteins in the glove, can be life threatening and **may have far reaching consequences for the individual and the working environment**. Where latex gloves have been identified in a written risk assessment as the safest option for a task their use should be restricted to **minimise exposure time** and they must be powder free and low protein, **powdered latex gloves must not be used.**

Anyone with known latex allergy **must** be provided with and use suitable alternatives to latex gloves. If the person is highly sensitised ie: latex exposure provokes asthma attacks, anaphylactic reactions, or widespread urticaria (rashes) then all those working in the area will have to avoid using latex gloves to prevent any inadvertent exposure of the allergic person to traces of latex on shared equipment, door handles etc.

NB: The life threatening consequences for a person highly sensitised to latex extend far beyond the workplace as latex rubber products are common place in daily life.

Anyone who suspects they may have symptoms of latex allergy **must** report this to their manager/supervisor and to the University's Occupational Health Service immediately. The Occupational Health Service can provide confidential health advice on minimising symptoms and the necessary control measures as well as referring on to specialist clinics for accurate diagnosis.

See Policy and Guidance for the Use of Latex Disposable Gloves on HSD website: http://www.admin.cam.ac.uk/offices/safety/

6.3 Pre-existing skin problems

Some pre-existing skin conditions can effect selection or use of gloves. Anyone with a relevant pre-existing skin condition should contact the University's Occupational Health Service for specific advice.

Any unhealed cuts and skin abrasions should be covered with a waterproof dressing before donning gloves.

7 GLOVE SELECTION

The selection of the correct glove for the task being undertaken is critical to minimising the risk of exposure to the hazard.

It should always be remembered that the purchase of cheap low quality gloves for safety critical tasks is a false economy, with potentially serious consequences.

Before you put on protective gloves, even new ones, check them for holes, tears, and other defects, such as softening or deformation, which indicate that physical or chemical degradation has occurred. Latex gloves are extremely sensitive to storage conditions (e.g. high temperatures, sunlight and ozone).

The incorrect choice of gloves could in certain circumstances be more detrimental than failing to use gloves at all ie:

- Using a damaged glove could allow chemicals to leak through and then trap them next to your skin
- Using an inflexible glove that provides no real protection against a sharp blade could result in a serious injury through 'over confidence' or loss of dexterity when cutting or guillotining.
- Using an 'open weave' thermally insulating glove could result in a severe cold burn from a spill of liquid nitrogen being absorbed into the glove.
- Using a glove without sufficient dexterity could result in a sharps injury and infection when handling pathogens.
- Using a glove made of the wrong material for a particular chemical could result in the **chemical contaminating the skin through the glove**. Possibly without the wearer's knowledge (see Appendix 4).

The type of hazard is the key starting point for any glove selection.

7.1 Gloves for Chemical Hazards

Nitrile

Accelerator Free Nitrile

Norfoil laminate

Neoprene

Butyl Rubber

Latex

Many chemicals can cause skin damage or provoke allergic reactions and some toxic and highly toxic chemicals can be readily absorbed through the skin. Gloves are therefore second only to eye protection as key pieces of personal protective equipment in many chemical laboratories, however:

No single glove material can offer complete protection from all chemicals.

All gloves are liable to damage and failure by degradation or permeation through the chemical action of certain substances. Different materials may behave differently with the same chemical / mixture of chemicals and each glove type has its own advantages and disadvantages (Table 1 below summarises the key characteristics offered by a range of gloving materials).

In many cases where the protection is against incidental contact or small splashes, a disposable nitrile glove will be the best choice. However care must be taken to choose the right nitrile glove. Nitrile disposable gloves can vary in quality, thickness, dexterity and grip (the latter two being potential weaknesses in some nitrile gloves).

Traditional latex disposable gloves offer little or no protection against many common laboratory chemicals, particularly organic chemicals / solvents (Appendix 4). They should only be used with very dilute, aqueous solutions of hazardous chemicals below 1% or below 0.1% if it is a known or suspected carcinogen, mutagen or substance toxic to reproduction.

If the task involves direct contact with chemicals or you are working with chemicals classed as toxic, harmful on skin contact or capable of absorption through the skin you should always consult the material safety data sheets for the chemicals used, or a chemical resistance chart to select the most suitable type of glove.

Gloves for protection against chemicals should comply with the requirements of BS EN 374:2003 and the EU's directive on Personal Protection Equipment, including CE marking and categorisation as either category 1 - simple design; 2 - intermediate design; or 3 - complex design (see Appendix 3).

7.1.1 Chemical Resistance

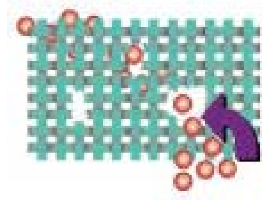
Many glove manufacturers provide chemical resistance charts on their websites or in catalogues giving test data on their gloves with a limited number of pure chemicals, but only rarely for mixtures of chemicals.
Manufacturers usually provide information on both degradation rating and permeation performance (rate and 'breakthrough times'). Specific data is only directly relevant for the specific brand and type of glove used in the test. However the data could be used as a rough guide to how a similar glove (of the same material and same thickness) **might** perform, in the absence of specific data on the glove in use.
Some Material Safety Data Sheets may contain recommendations on the most suitable gloves for specific chemicals.

(See Appendix 2. Glove Selection Guidance for Some 'Common' Chemicals).

7.1.1.1 Penetration

Penetration is the movement of a chemical, hazardous substance or micro-organism through porous materials, seams, pinholes or other imperfections in a protective glove material at a non-molecular level (see section 4.5.1 below).

7.1.1.2 Chemical Degradation

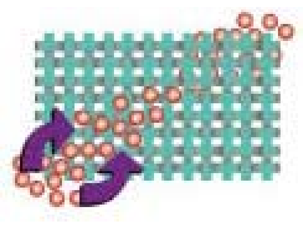


Chemical degradation of a glove occurs where exposure of the material to a chemical agent causes the loss of one or more of its original physical qualities.

Signs of chemical degradation may include softening, swelling, brittleness, loss of flexibility, weakness, tackiness, disintegration etc.

Resistance to degradation is measured as a loss of tensile strength. The loss of 30% tensile strength upon exposure to a chemical defines the maximum useful life of the glove. Resistance to degradation is usually rated on a five point scale from excellent to not recommended.

7.1.1.3 Permeation of Chemicals



Permeation occurs where a chemical or hazardous substance passes through an intact glove by diffusion, this can occur even if the glove is undamaged. Permeation is inversely proportional to thickness and is often expressed as a qualitative rate ie: fast, medium, slow and zero in addition to the breakthrough time.

Breakthrough time is the time it takes for a chemical or hazardous substance to pass through a glove and be detected on the inside surface of the material. It is measured in minutes and is derived from static tests carried out on a specimen cut from a glove. The test is carried out according to a standard method in EN 374-3.

Thicker gloves made from the same material will have a longer break-through time since breakthrough time is directly proportional to the square of the thickness. Breakthrough times are specific to the glove tested and gloves of the same material and thickness from different manufacturers can have different breakthrough times. This can be as a result of numerous factors including, differences in raw materials and their content in the finished product, as well as the degree of cross-bonding.

Breakthrough times are therefore effectively only ‘guides’, not hard and fast exposure times. Contaminated reusable gloves should always be washed and contaminated disposable gloves changed as soon as reasonably practicable. It is particularly important that re-usable gloves are thoroughly washed after use since residual chemicals may continue to permeate through the material in storage between ‘uses’.

Where contact with chemicals has occurred gloves of any description should always be disposed off before the breakthrough time has been reached or if there is any reason to suspect the gloves integrity. In some cases gloves may even need to be discarded before the total in-use-time exceeds the breakthrough time, if permeation through to the inner surface can continue after the glove is washed.

Never rely on the skins sense of touch to detect breakthrough. Skin exposure will occur long before any perceptible feeling of wetness on the inner surface of the glove. Therefore, whilst permeation is an important factor when determining the adequacy of gloves, its use should be tempered by the realization that the skin is unable to detect subtle breakthrough during the use of the glove. In addition gloves will often not display any visible signs of breakthrough, such as puckering or degradation, even after permeation occurs. With the exception of corrosives and primary irritants, the human skin is ill-equipped to detect skin exposures when wearing gloves.

In most laboratory environments gloves are worn to protect against small incidental contamination / splashes. If the chemicals have a known toxicity to humans, but unknown breakthrough times, it would be reasonable to make an informed choice of glove based on the best available current knowledge when the risk assessment is carried out. With the caveat that a glove change regime is built into the procedure to mitigate any degradation and permeation issues (see case study Appendix 4). In this case the risk assessment might include reasonable extrapolations based on chemical groupings and known strengths and weaknesses of glove types (see Appendix 1).

However if the methodology were to involve deliberate contact with or immersion in chemicals having a known toxicity to humans, but unknown breakthrough times, then this approach might not be suitable or sufficient. In the first instant the risk assessment should identify the need to **change the method and avoid deliberate contact / immersion** wherever reasonably practicable. If changing the method is not reasonably practicable then the risk assessment should consider, in light of current knowledge, whether it is necessary to carry out degradation and permeation tests in accordance with the standards, by an approved laboratory.

Many chemicals and most chemical mixtures will not have published breakthrough times.

7.1.2 Temperature Effects

Degradation, permeation rates and breakthrough times will be adversely effected by increasing temperature. The tests used to produce the published data are carried out at 25ºC, however when worn gloves will quickly warm to nearer 37ºC.
One study tested the effect of a range of temperatures from 25 to 50ºC, on the permeation of N-methylpyrrolidone, a solvent used at elevated temperatures in industry. There was a 3-fold decrease in breakthrough time and a 2.5-fold increase in permeation rate between testing at 25ºC and 37ºC, whilst at 50ºC, the breakthrough time decreased 9-fold and the permeation rate increased 6-fold.

The decreased protection afforded by gloves at body temperature and in hot environments must be considered when estimating the duration of effective glove protection

7.1.3 Physical Effects

The effects on a glove of pressure, stretching, and abrasion can all adversely effect degradation, permeation rates and breakthrough times, however the standard static tests take no account of these factors.

A practical study comparing laboratory and workplace permeation of an aromatic amine epoxy resin demonstrated the importance of these considerations in glove selection. Laboratory glove tests performed under static conditions did not detect amine breakthrough for more than 1 week. Actual workplace testing of glove performance showed significant breakthrough of the amine after 20 minutes using an amine contaminated screwdriver with normal exertion.

7.1.4 Mixtures of Chemicals

Since most chemical mixtures will not have published break through times, choosing gloves for work with mixtures of chemicals can be a complex task. Each chemical in the mixture needs to be assessed to determine which glove material should be used. Where different chemicals have different recommended glove materials the one that best withstands the chemical with the fastest breakthrough time may be the best choice. However if one chemical is significantly more toxic than the others then this may dictate which glove material to choose. This is further complicated because one chemical may facilitate the permeation of others or act synergistically with them.

The limited data available on breakthrough times for mixtures of chemicals shows that breakthrough times <u>can</u> be reduced by orders of magnitude below the shortest published individual breakthrough time of an individual chemical in the mixture.

It may be necessary to purchase specialist composite gloves or in some cases more simply to double glove with two pairs of differing glove materials.

7.1.5 Composite Gloves for Chemicals

For those materials that are **"extremely toxic"** and which are also easily absorbed through the skin, the best choice of glove material maybe **Norfoil** (Silver Shield by North Hand Protection, 4H by Safety4, or New Barrier™ brand by Ansell Edmont). Norfoil is a thin, multi-layer laminate with each layer made of a different polymer. Norfoil gloves are chemically resistant to a wide range of materials that readily attack other glove materials, but lack the dexterity of close fitting ‘molded’ gloves. It has been reported that dexterity my be partially regained by wearing a ‘tighter fitting’ heavier weight glove over the loose fitting composite glove, although care would be required to ensure the norfoil is not compromised.

7.1.6 Nanoparticles

There is currently no standard for nanoparticle penetration through gloves, however the viral penetration test in ASTM F1671 uses a bacteriophage of 27 nm diameter and may be indicative of their performance with nanoparticles down to this size.

Table 1. Gloves for Chemical Hazards include:

GLOVE TYPE	GOOD	POOR
NITRILE	**Good** for wide variety of solvents, oils, greases, some acids and bases.	**Poor** for oxidising acids, ketones, organic compounds containing nitrogen, DMF, benzene, chloroform, ethyl acetate, aniline, phenol…..
NATURAL LATEX RUBBER	**Good** for incidental contact with phenol, dilute aqueous acids / bases, inorganic chemicals.	**Poor** for oils, greases, organics. Generally poor chemical protection. Hard to detect physical damage.
NEOPRENE / CHLOROPRENE	**Good** for acids and bases, peroxides, fuels, alcohols hydrocarbons, phenols.	**Poor** for halogenated and aromatic hydrocarbons.
BUTYL RUBBER	**Good** for many organics, acids, ketones, esters, vapours/gases, oxidising chemicals. Remain flexible at low temperature	**Poor** for aliphatic, aromatic hydrocarbons, halogenated hydrocarbons, petrol. Expensive, ‘thick’ and only available as re-usable
POLYVINYL CHLORIDE (PVC) – ‘*Vinyl* ’	**Good** for acids and bases, some organics, oils, fats, amines, and peroxides	**Poor** for most organic solvents, ketones. **Not recommended for most laboratory work**
POLYVINYL ALCOHOL (PVA)	**Good** for aromatic and chlorinated solvents	**Poor for all water-based solutions: *gloves dissolve !***
VITON™ Synthetic rubber - fluoroelastomer	**Good** for chlorinated and aromatic solvents, aniline, benzene, chloroform **Good** resistance to cuts and abrasions**.**	**Poor** for ketones. Expensive, ‘thick’ and only available as re-usable
Silver Shield™ (Norfoil)	**Good** for wide variety of toxic and hazardous chemicals; provides high level of chemical resistance. Flexible laminate glove	**Poor fit** – two dimensional – use an over glove for improved dexterity
Ansell Barrier LLDPE (Polyethylene)	**Good** resistance to many chemicals; better dexterity than Silver Shield™.	**Poor fit** – use over glove for improved dexterity

7.2 Gloves for Biological Hazards


Neoprene


Nitrile


Latex


Vinyl for food


Virus resistant nitrile


Chloroprene

Gloves are frequently used as barriers against potentially pathogenic material and therefore they must conform to the BS EN 374-1: 2003 micro-organisms. However ‘micro-organism resistance’ in this context applies to fungi and bacteria, but not to viruses. Therefore gloves tested to BS EN 374-1 **may** not have been tested for resistance to viruses (check manufacturer’s data).

For work with blood, blood products and/or at Containment Levels 2 and 3 the gloves should have been tested to BS EN 374-1 and **also** tested for virus penetration in accordance with ASTM F1671, using the bacteriophage Phi-X174 (diameter 27 nanometres).

A few examples of gloves currently tested to both BS EN 374-1 and ASTM F1671 include N-DEX and N-DEX Free from Best, Esteem from Allegiance, SHIELDSkin from Shield Scientific and Ansell’s DermaPrene Ultra, Microtouch Nitrile as well as others (always check manufacturer’s data).

Gloves intended for medical use must conform to BS EN 455-1 as medical devices.

It must be remembered that biological work can involve handling both biological and chemical hazards. **Latex, nitrile and neoprene/chloroprene disposable gloves** can provide adequate splash protection against both biological and certain chemical hazards (see section 7.1 above), however double gloving may be required.

Vinyl gloves are sometimes used in food handling operations but are of less value against biological / infectious hazards than latex, nitrile or neoprene. It should also be noted that PVA and the specialised composite chemical resistant gloves on their own are **not suitable** for biological work unless further protection is provided by double gloving using one of the above, as appropriate. If a glove is to be used for food handling, its packaging should carry either the words 'for food use' or the symbol: 

Whilst latex disposable gloves have been the traditional choice, the risk of allergenic reactions to latex proteins (particularly in the presence of the lubricating powder) has resulted in a range of alternative gloves coming onto the market place. These include extra thin nitrile gloves as well as chloroprene (aka neoprene) disposable gloves which are marketed as having improved dexterity and grip akin to latex.

Some tasks such as manipulating cultures or micro-surgery require a high degree of flexibility, grip, sensitivity and dexterity, and latex disposable gloves have almost unique abilities in these areas. If a risk assessment identifies latex gloves as the safest choice **only hypoallergenic, low protein, non-powdered latex gloves should be used** (see University Guidance on Latex Gloves on the HSD website). Those required to wear latex gloves should receive information, instruction and training on the potential health effects related to latex.

During handling of cultures or clinical specimens pinholes or glove failure could create infection risks therefore, when handling certain pathogens, double gloving would be recommended (see section 4.6.1.2 above).

For further information on biological work see the University's – 'Safe Biological Practice (SBP) for Prevention and Control of Exposure to Biological Agents in the Laboratory' (HSD028B) on the Safety Office web site at:

http://www.safety.admin.cam.ac.uk/publications/biological/hsd028b-safe-biological-practice-sbp-prevention-and-control-exposure

7.3 Gloves for Thermal Hazards

Leather

Polyamide

Nitrile

Cotton

PVC / Cotton

Polyamide

Hands can be damaged / burned by both hot and cold extremes of temperature. In either case the principle of protective gloves utilises the insulating properties of certain materials. These materials are often woven fabric and therefore rely on the air trapped in the weave to act as insulation and protect the wearer from the effects of contact with hot or cold solids. These gloves could be suitable for handling items from -80ºC freezers, autoclaves, drying ovens and furnaces for relatively short periods of time. When selecting the appropriate gloves both the type and period of exposure to the hazard should be considered.

However, open weave gloves are not effective against direct contact with hot or cold liquids, such as boiling water or liquid nitrogen, that can penetrate the weave following a spillage or accidental immersion. Work with hot or cold liquids, including liquefied gases / cryogens should utilise gloves that are appropriately 'liquid resistant', however even these have their limitations. They are not suitable for immersion in liquid cryogens and often have large open cuffs that could inadvertently 'collect' a spill of cryogenic liquid.
Whilst double gloving with an impervious glove over a 'thin' thermal glove may protect against immersion in some hot liquids, it is not generally recommended as it will fail to danger.

Double gloving will NOT protect against immersion in cryogenic liquids because:

Non-woven glove materials will quickly become very brittle at low temperatures and are therefore not suitable for cryogens

Gloves for thermal hazards include:

Cotton a natural material, cotton provides only moderate resistance to heat or cold. To give adequate protection, the material has to be thick which may impede dexterity.

Leather generally provides good protection against heat and cold, so long as the glove does not get wet. Leather is used in the composition of heat resistant gloves because it does not melt or burn unlike some synthetic materials.

Aluminised gloves help reflect heat and can be used in areas where radiant heat is the main hazard and products reach extremely high temperatures.

Kevlar fibre is an effective heat resistant material for gloves, having been developed to resist the heat of re-entering the earth's atmosphere, it does however degrade in UV light.

Nitrile, PVC or Rubber coated fabric gloves, providing thermal insulation with a wet resistant outer surface

Polyamide fabric gloves with insulating material ie: the classic blue cryogen gloves.

Remember that some gloves, especially disposable gloves, are combustible

i.e. gloves can burn if ignited

7.3 Gloves for Mechanical Hazards

Rubber / Kevlar

PVC / Kevlar

Nitrile / Cotton

Kevlar

Leather / Cloth

Chain-mail

A range of glove types can be used to protect the wearer from mechanical hazards. However by their nature they are all subject to a balance between protection and the loss of sensitivity / dexterity.
Typically these gloves will be made from robust materials and frequently be of a composite construction often including breathable fabric upper surfaces and cuffs supporting an abrasion resistant palm of rubber, leather, nitrile or kevlar. Where both chemical and mechanical resistance are required disposable puncture resistance nitrile or kevlar lined nitrile or gloves are available.

Where the open fabric material could become contaminated double gloving with an inner disposable glove may be appropriate.

Gloves for protection against mechanical hazards are tested against BS EN 388 with numbers assigned to the level of protection against abrasion, cut, tear and puncture.

Gloves for mechanical hazards include:

Nitrile (on a fabric liner) provides excellent abrasion and puncture resistance whilst retaining flexibility and comfort.

Kevlar$_{\mathbf{tm}}$ (para aramid fibre) a specialist man-made yarn from which gloves and sleeves are knitted. Kevlar has excellent tear, abrasion and cut resistance, it does however degrade in UV light.

Latex (on a fabric liner) natural rubber is an extremely elastic and flexible material with good physical properties. Depending on the formulation of a particular glove, natural rubber can offer abrasion, tear and cut resistance.

Polyvinyl Chloride (PVC) (on a fabric liner) PVC can offer abrasion and puncture resistance, if thick enough it can afford some cut protection. However generally its tear resistance is poor.

Leather a natural material modified by tanning to give a range of properties. Leather gloves come in a vast range of thickness and styles which vary widely in their protective capabilities

Chain-mail a glove made of interlinked metal wire that is highly resistant to abrasion and cuts. On its own is not a barrier to hazardous substances due to its open weave.

8. SIMPLE RULES FOR GLOVE USE

- Select gloves which are resistant to the hazards you may be exposed to.
- Select gloves of the correct size and fitting.
- Before use, check gloves (even new ones) for physical damage such as tears or pin holes: this is especially important when dealing with dangerous materials such as hydrofluoric acid (HF).
- When working, it may be advisable to wash the external surface of the gloves frequently with water.
- Some gloves, especially lightweight disposables, may be combustible: keep hands well away from naked flames or other high temperature heat sources.
- When removing gloves, do so in a way that avoids the contaminated exterior contacting the skin i.e. use the 'surgical technique' of glove removal.
- Wash hands after removing gloves.
- Dispose of contaminated gloves properly.
- Do not attempt to re-use disposable gloves.
- **Never wear possibly contaminated gloves outside of the laboratory or to handle telephones, door handles, computer keyboards, *etc*.**

9. Further Information:

The following links can be used to find more information on chemical compatibility:

Ansell: http://www.ansellpro.com/specware/guide.asp a very useful site, listing many chemicals, with selection options for splash or immersion. For virus penetration see http://www.anselleurope.com/medical/index.cfm?page=birdflu&lang=EN

Kimberly Clarke: http://www.kcprofessional.com/us/safety_home.asp

Marigold industrial: http://www.marigoldindustrial.com/GB/index.html

Best: http://www.bestglove.com/aspx/region-language-select.aspx?ctry=CA+&lang=EN+&returnpath=http://www.bestglove.com/aspx/products/gloveselector.aspx

North:
http://www.northsafety.com/ClientFormsImages/NorthSafety/CorpSite/E8D15F2E-1F59-454F-B8F0-147FA2B9D81D.pdf

Shield Scientific http://www.shieldscientific.com/

Links via Michigan State University: http://www.hazmat.msu.edu:591/glove_guide/

Oklahoma State University: http://www.pp.okstate.edu/ehs/hazmat/gloves.htm%20

NB: Remember break through times and permeation rates quoted by manufacturers are specific to the glove actually used in the static test!

Beware: Occasionally different glove compatibility databases may appear to contradict each other on the best glove material for a particular chemical!

10. Definitions

Breakthrough is the time elapsed between the initial contact with a chemical and its detection inside a glove. Breakthrough time is directly proportional to glove material thickness for most materials.

Butyl rubber see Appendix 1.

Co-polymer - a long chain molecule synthesized by reaction of more than one monomer species with each other. Copolymers often have cost and/or performance advantages over polymers made from one monomer.

Degradation is a change in one or more of the physical properties of a glove due to chemical contact. Some of these changes, such as discolouring, swelling, shrinkage or stiffness, may be visually detected but others are invisible. Degradation almost always results in a loss of performance of a glove and is an indicator of how long a glove will last. Degradation is usually detected by a change in weight of a glove and degradation ratings are often based on % change in weight over time.

Dermatitis

Two types of allergic health problems may occur; latex allergy - type 1 reaction and contact dermatitis - type IV reaction

> **Immediate Hypersensitivity (type 1 reaction)** also known as latex allergy is a reaction resulting from the formation of IgE (allergic antibody) to the protein in the natural rubber latex (NRL). This type of reaction generally produces symptoms that occur within 5-30 minutes of latex exposure. A variety of symptoms may occur including local or general erythema and urticaria, angioedema, rhinitis, conjunctivitis, asthma, laryngeal oedema, hypotension and collapse. The severity of reactions vary. Severe reactions are called anaphylaxis and can be fatal.
>
> **Delayed hypersensitivity (type IV reaction)** also known as allergic contact dermatitis, is a reaction to a sensitivity to the chemicals used in the rubber production process, mostly accelerators. The chemicals most likely to cause a reaction are thiurams, dithiocarbamates and mercaptobenzthiazoles (MBT). This cases an eczematous rash at the site of contact with rubber, usually on the hands. The reaction longer exposure than a type 1 reaction and is delayed in onset, beginning several hours after contact, reaching a maximum of 24-48 hours, and then subsiding. With repeated exposure to the chemicals in the gloves a persistent rash may occur. Although the severity of the rash can vary, this reaction is usually mild and is not potentially dangerous.
>
> **Irritation** it is important to distinguish between the reaction associated with a type IV reaction and that from irritation, which is mild and a non-allergic condition. When gloves are used a dry itchy rash may occur on the back of the hands. It is important to note that a wide range of substances e.g., skin cleansers and disinfected agents may cause skin irritation. This is not an allergy to the glove components, but still requires advice from Occupational Health.

Double gloving is the use of two layers of gloves to provide improved hand protection when using certain hazardous substances. This affords a double layer of protection since if the outer glove starts to degrade or tears open, the inner glove continues to offer protection until the gloves are removed and replaced.

Finish refers to the surface texture of a glove material. Most laboratory gloves have a smooth finish. Textured surfaces are added to glove materials to provide a better grip on objects being handled.

Flock lining is a natural or synthetic shredded fibre that covers the inside of a glove to provide comfort by absorbing perspiration and providing ease in putting on and removing the glove.

Gauge or thickness of gloves is generally measured in millimetres or mils (thousands of an inch). Higher gauge (thicker) gloves generally offer more protection. Generally speaking, doubling the thickness halves the permeation rate.

Hypalon is a synthetic polymer that offers superior resistance to oxidizing agents and ozone. It is frequently used for glove box gloves.

Lower detection limit (LDL) is the minimum level detected with analytical test equipment, measured in parts per million (ppm) detected at breakthrough time.

Mil is the standard unit for measuring the gauge or thickness of glove materials in the USA. A mil is one-thousandth of an inch or 0.001". A millimeter is 39.37 mils; a mil is .00254 mm.

Natural rubber (or latex), produced from the sap of tropical rubber trees (*Hevea brasiliensis)*; see Appendix 1.
Neoprene, see Appendix 1.

Nitrile, see Appendix 1.

Norfoil, see Appendix 1.

Over-glove is a glove worn over another glove (under-glove) when double gloving to provide multiple layers of resistance to hazardous chemicals. The over-glove protects the under-glove from chemical degradation and permeation. It is changed when it begins to be chemically attacked to protect the under-glove.

Penetration is the nonchemical transport of a chemical through a glove, usually by pinholes or microscopic tears or cracks resulting from degradation.

Permeation is the process by which a chemical passes through a glove's protective film. Permeation occurs at the molecular level and often leaves the appearance of the glove unchanged. The rate of permeation of a chemical through a glove is one of the determining factors in the effectiveness of a glove for use with a particular chemical. Generally speaking, the permeation rate is inversely proportional to thickness (gauge), although the length of time of exposure and temperature can be important factors for some glove materials. Permeation is an indicator of how long gloves are safe to wear.

Permeation breakthrough is the time in minutes it takes for a chemical to permeate through a glove. Generally speaking, doubling the thickness of a glove quadruples breakthrough time.

Permeation rate at steady state is the maximum rate at which a chemical passes through a glove material, usually expressed in milligrams per square meter per second ($mg/m^2/sec$).

Polymer - a substance formed by the union of small molecules of the same kind (monomer); also see co-polymer above.

Powdered gloves have an interior coating of cornstarch or other absorbent material. Powdered gloves are usually easier to take on and off and are often more comfortable for the wearer, but the powder can carry allergens into the air may contribute to allergic responses in some individuals.

Supported means that the polymer of the glove is a coating over a fabric liner. This two- component glove style offers more durable hand protection. Very few gloves for laboratory use are supported.

Under-glove is a glove worn under another glove (over-glove) when double gloving to provide multiple layers of resistance to hazardous chemicals.

Unsupported means that a glove is made only of a pure polymer or mix of polymers. Unsupported gloves tend to offer greater dexterity and tactile sensitivity but less protection from physical damage.

Appendix 1: Summary of Commonly Available Glove Materials

NITRILE (synthetic acrylonitrile-butadiene rubber: properties depend on composition ratio, the more acrylonitrile in the polymer the higher the resistance to oils but the lower the flexibility i.e. properties of nitrile gloves can vary by its composition).

• Good for solvents, oils, greases, hydrocarbons, animal fats, some acids and bases
• Good alternative to latex for biochemical work
• Maintains integrity over a range of temperatures from approx −40°C to +120°
• Less elastic than latex, but gives clear indication of tears and breaks
• Better snag, puncture, abrasion and cut resistance than neoprene or PVC
• **Avoid:** intentional contact with ketones, oxidizing acids and organic compounds containing nitrogen
• Regarded as current best choice for general splash protection against chemicals

NEOPRENE (synthetic rubber- polychloroprene - chloroprene rubber)

• Good for acids, bases, alcohols, fuels, peroxides, hydrocarbons, and phenols
• Poor for halogenated and aromatic hydrocarbons
• Latex like properties without allergenic proteins
• Maintains integrity over a range of temperatures from approx −20°C to +150°
• Resistant to snags, puncture, abrasions and cuts
• Nitrile like chemical resistance claimed

LATEX (natural rubber)

• **Can cause or trigger latex allergies -** justify use by written risk assessment
• Good snag, puncture, abrasion and cut resistance
• Good dexterity
• Good for biohazard protection (infection risks)
• Good for inorganic chemicals
• Maintains integrity over a range of temperatures from approx −20°C to +150°
• **Poor for organic solvents**
• **Avoid:** Oils, grease and hydrocarbon derivatives
• Hard to detect small puncture holes

BUTYL RUBBER (synthetic rubber, a butylene and isoprene copolymer)

• Good for acids, ketones (MEK, MIBK, acetone) and esters
• Poor for petrol, aliphatic / aromatic, and halogenated hydrocarbons
• **Good for water, vapours, gases** and many toxic / oxidising chemicals
• Good resistance to weathering
• Flexible, dextrous at low temperatures
• Relatively expensive
• Only available as re-useable – poor touch sensitivity
• Inherent 'stickiness' when wet, which may be misinterpreted as degradation

VITON (chemically resistant fluoroelastomer - synthetic rubber)

• **Good for chlorinated and aromatic solvents** ie: benzene, PCB's, aniline, chloroform
• Low surface tension repels most liquids
• Good resistance to cuts and abrasions
• Poor for ketones
• Expensive but long lasting
• Only available as re-useable - poor touch sensitivity

POLYVINYL ALCOHOL (PVA)

• Good for aromatic and chlorinated solvents ie: chloroform
• **Unsuitable for water and water-based solutions** (dissolves in water)
• Only available as re-useable - poor touch sensitivity

POLYVINYL CHLORIDE (PVC) - the standard 'vinyl' glove

• Good for acids, bases, oils, fats, peroxides, and amines
• Good resistance to abrasions
• Poor for most organic solvents.
• Plasticizers in glove may contaminate solvents
• **Avoid:** intentional contact with ketones, aldehydes and aromatic solvents
• **OK** for protection against soiling, low hazard chemicals, or for food hygiene
• **Not generally recommended for laboratory work**

NORFOIL (Silver Shield / 4H) – PTFE laminate

• Good for aromatics, esters**,** ketones and chlorinated solvents
• **Resist permeation and breakthrough against a wide range of chemicals**
• Good for bulk handling of chemicals in laboratory or process area
• Good flexibility, but may require over gloving to improve dexterity and robustness
• **Poo**r puncture and cut resistance

Appendix 2. Glove Selection Guidance for Some 'Common' Chemicals:

NB: These notes are for guidance only when selecting gloves for further evaluation; always consult manufacturers data on their breakthrough times and permeation rates for the gloves you select before using them.

Acetaldehyde: double glove with neoprene for incidental contact and remove/replace gloves at once if exposed.

The only gloves for possible extended contact with acetaldehyde are butyl or norfoil* gloves.

Acetaldehyde is a suspected carcinogen, is easily absorbed through the skin and breaks through nitrile gloves instantaneously.

Acetic acid: nitrile gloves for incidental contact with dilute acid. Neoprene or butyl rubber gloves are recommended if contact with acetic acid above 10% is possible.

Acetic anhydride: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use heavier nitrile gloves.

Acetic anhydride is very corrosive to human tissues (skin, eyes, mucus membranes) and a poison by inhalation. For handling larger quantities of pure material only heavier weight butyl rubber or neoprene gloves are recommended.

Acetone: heavier weight natural rubber or neoprene for incidental contact; for extended contact with acetone the only recommended glove type is norfoil* or butyl rubber gloves ie: Ansell ChemTek 38-520 gloves have a breakthrough time of > 8 hours for acetone.

Note: Natural rubber gloves and neoprene have about 10 minute breakthrough times and are for incidental contact only, whilst nitrile gloves are **not** recommended for acetone.

Acetonitrile: nitrile gloves or double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed.

For large scale use of acetonitrile use heavier weight butyl rubber or polyvinyl acetate (PVA) gloves. Acetonitrile permeates though disposable latex exam gloves in a matter of seconds and latex gloves should never be used to handle this material.

Acrylamide: nitrile gloves or double glove with nitrile gloves for incidental contact; butyl rubber gloves are recommended for extended contact.

Acrylamide is readily absorbed through unbroken skin and disposable latex gloves. It is a cumulative potent neurotoxin, carcinogen, mutagen, and teratogen so adequate hand protection is essential. Once polymerised it is no longer hazardous, however polyacrylamide gels can still contain residual amounts of acrylamide monomer which may then wash out into and also contaminate stain and destain solutions.

bis- Acrylamide: nitrile gloves

bis- Acrylamide (N,N'-dihydroxy-ethylene-bis- acrylamide) does not share the more extreme toxic characteristics of acrylamide. However, its toxicological properties have not been fully investigated and it should be treated as a hazardous material.

Acryllic acid: double glove with nitrile for incidental contact and remove/replace outer glove at once if exposed. For extended contact use viton, butyl or norfoil*.

Acrylonitrile: double glove with nitrile for incidental contact and remove/replace gloves at once if exposed.

The breakthrough time for nitrile gloves is only about 5 minutes. For extended contact use only butyl or norfoil*.

Ammonium hydroxide: nitrile gloves for incidental contact, for extended contact heavier weight neoprene, viton or butyl rubber gloves are superior to nitrile gloves.

Aniline: double glove with nitrile for incidental contact and remove/replace outer glove at once if exposed or use a neoprene glove. For extended contact use butyl or norfoil*.

Benzaldehyde: double glove by wearing a latex glove over a nitrile glove for incidental contact. Nitrile gloves on their own are not recommended and even latex has a short breakthrough time with benzaldehyde.

Viton, PVA or butyl gloves are recommended for extended use.

Benzene: double glove by wearing a latex glove over a nitrile glove for incidental contact. Nitrile gloves on their own are not recommended and even latex has a short breakthrough time with benzene.

Viton, PVA or norfoil* gloves are recommended for extended use or possible contact.

Benzotriazole, 1,2,3-: nitrile gloves.

Butyl acetate: double glove with nitrile for incidental contact and remove outer glove at once if exposed or use heavier nitrile gloves.

Most nitrile gloves have short breakthrough times for butyl acetate. For large quantities use, PVA, norfoil* or for short periods butyl gloves (max 2 hrs then dispose).

Carbon disulfide: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use heavier nitrile gloves.

Most nitrile gloves have a breakthrough time of only 8 to 20 minutes for carbon disulfide and offer little protection. For large quantities use viton, PVA or norfoil*.

Carbon tetrachloride: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use 15 mil or heavier nitrile gloves

For operations involving the use of large amounts of carbon tetrachloride viton, PVA or norfoil* gloves are recommended since carbon tetrachloride is a poison, mutagen, carcinogen and teratogen which is readily absorbed through unbroken skin. Alcohol and acetone are known to enhance the toxicity of carbon tetrachloride. If you can find a suitable substitute for carbon tetrachloride it is recommended that you use it.

Catechol: nitrile gloves.

Chloroform: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use 15 mil or heavier nitrile gloves.

Disposable nitrile, neoprene or latex gloves have a short breakthrough times and thus offer little protection against chloroform. For operations involving the use of large amounts of chloroform viton, PVA or norfoil* gloves are recommended.

Cobalt Chloride: See Heavy Metal Salts**.**

Copper (Cupric) Sulfate: nitrile gloves.

Cyclohexane: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use 15 mil or heavier nitrile gloves. For large quantities use viton or norfoil* gloves but not butyl.

Cyclohexanol: nitrile gloves, for extended contact use heavier nitrile.

Cyclohexanone: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed since the breakthrough time for nitrile is quite short. For extended exposure use buyl or norfoil* gloves but not viton.

3,3'-Diaminobenzidine (DAB): nitrile gloves for incidental contact; double glove with nitrile gloves when handling the pure material or concentrated stock solutions.

Diazomethane in Ether (a derivatizing reagent): double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use 15 mil or heavier nitrile gloves.

For extended contact the only recommended glove would be a norfoil* glove, due to the extreme hazards associated with this material. Diazomethane is an extreme poison, a suspected carcinogen, extremely flammable, easily detonated and has an autoignition temperature of 100° C. (an ordinary light bulb would cause a sufficient quantity of the vapour in air to autodetonate). If you can substitute another material for diazomethane in ether it is strongly recommended that you do so.

1,2-Dichloroethane: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed since the breakthrough time for nitrile is quite short. For extended exposure use viton or norfoil* gloves. Note: butyl gloves have a shorter breakthrough time than viton or norfoil.

Dichloromethane: See Methylene Chloride.

Diethyl pyrocarbonate: nitrile gloves for incidental contact and double glove with nitrile gloves when handling the pure material or concentrated stock solutions.

Dimethyl sulfoxide (DMSO): double glove with nitrile or neoprene for incidental contact and remove outer glove at once if exposed or use heavier nitrile gloves.

Nitrile is not generally recommended for extended contact with DMSO because it degrades and the breakthrough time is short.

Only butyl rubber gloves are recommended for extended contact with DMSO.

DMSO freely penetrates through the skin and may ‘carry’ dissolved chemicals with it into the body, so hand protection is very important if you are working with any hazardous materials dissolved in DMSO.

1,4-Dioxane (dioxane): double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed, or use 15 mil or heavier nitrile gloves.

Dioxane is a listed carcinogen, mutagen and teratogen and most nitrile gloves have short breakthrough times with dioxane. Dioxane is readily absorbed through unbroken skin so hand protection is very important when working with this material. Nitrile gloves have short a breakthrough times when exposed to dioxane; for potentially extended contact use butyl rubber or norfoil* gloves.
Note: Dioxane is one of the few common lab chemicals that readily degrades viton.

Dithiothreitol (Cleland's Reagent): nitrile gloves.

Ethanol: nitrile gloves.

Ethidium bromide (EtBr): nitrile gloves (incidental contact); double glove with nitrile gloves when handling the pure material or concentrated stock solutions.

Note: Nitrile gloves are also effective barriers to the UV radiation used in most transilluminators, long (30cm) gloves should be used to cover the wrists. (however disposable vinyl and latex are not suitable).

Ethyl acetate: double glove with nitrile for incidental contact and remove/replace outer glove at once if exposed. For extended exposure use butyl or norfoil* gloves.

Ethylene Glycol: nitrile gloves.

Ethyl Ether (diethyl ether, ether)**:** double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use 15 mil or heavier nitrile gloves.

Ether degrades most glove materials. It permeates through viton, butyl rubber, neoprene, nitrile and natural rubber in a matter of minutes. The only recommended glove materials for extended contact are PVA and norfoil*.

Formaldehyde: nitrile gloves.

Formamide: nitrile gloves for incidental contact, however butyl rubber gloves are the only gloves recommended for direct contact with the pure material.

Formic acid: double glove with nitrile gloves for incidental contact.

Formic acid is very corrosive to human tissues (skin, eyes, mucus membranes). For handling larger quantities of pure material only use butyl rubber or neoprene gloves.

Furfural: double glove with nitrile for incidental contact and remove/replace outer glove at once if exposed. For extended exposure use butyl or norfoil* gloves (viton has a shorter breakthrough time).

Gallic acid: nitrile gloves.

Glutaraldehyde: nitrile gloves for incidental contact and butyl or viton can also be used for extended contact.

Heavy Metal Salts (especially those that are easily soluble in water): nitrile gloves and double glove in some cases*.

For most inorganic salts of heavy metals the human skin is usually an effective barrier against absorption of heavy metal ions. However, if there are cracks, areas of inflammation, insect bites or cuts in the skin, heavy metal ions can pass directly through the skin. The salts of many heavy metals are toxic or highly toxic/poisonous i.e. **arsenic, bismuth, cadmium, chromium, cobalt, lead, mercury, nickel, osmium, silver and uranium**. Some of these materials are also corrosive (chromium trioxide), inhalation hazards (osmium tetroxide), known or suspect carcinogens and mutagens (lead and lead salts, mercury and its salts, etc.) or radioactive (uranium).

Disposable nitrile gloves are generally acceptable for incidental contact with the common salts of the above metals (i.e. acetates, chlorides, sulfates, nitrates, anhydrides, oxides, hydroxides, etc. However several heavy metal salts are more easily absorbed by the skin than others i.e. **osmium tetroxide** is readily absorbed by the skin and is very toxic, **lead acetate** is absorbed more easily than other lead salts, and **mercuric chloride** can be absorbed fairly easily. It is recommended to double glove with nitrile gloves when using these materials.

Heptane: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed, or use 15 mil or heavier nitrile gloves. For extended contact use heavier weight nitrile (35 mils or thicker), viton or PVA gloves.

Hexamethylenediamine (1,6-diaminohexane): double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed, or use 15 mil or heavier nitrile gloves. Use a heavier weight neoprene glove when handling the pure material or concentrated stock solutions.

Hexane: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed, or use 15 mil or heavier nitrile gloves.

For extended contact use heavier weight nitrile (35 mils or thicker), viton, PVA or norfoil* gloves.

Hydrochloric Acid (concentrated and strong solutions): nitrile gloves for incidental contact.

A heavier weight neoprene or butyl rubber glove would be superior for long-term use with more concentrated solutions.

Hydrofluoric acid (HF): double glove with nitrile gloves for incidental contact with very dilute solutions; using heavier nitrile or butyl over-gloves when handling more concentrated solutions (>2%).

Note: All HF users must be familiar with and follow the University policy and guidance for working with HF.

Isobutanol (isobutyl alcohol): nitrile gloves.

Isopropanol (isopropyl alcohol): nitrile gloves.

Kerosene: nitrile or neoprene gloves.

Lactic acid: nitrile gloves.

Laser dyes: nitrile gloves (check the nature of the dye used).

Lead Acetate: See Heavy Metal Salts.

Maleic acid: nitrile gloves.

Mecuric Chloride: See Heavy Metal Salts**.**

Mercury: nitrile gloves.

Methanol (methyl alcohol): nitrile gloves.

Methanol should never be allowed to make contact with the skin, as it is poisonous and fairly easily absorbed by the skin.

Methylene Chloride: double glove with nitrile gloves for incidental contact.

Methylene chloride will break through thin nitrile gloves in four minutes or less. If you splash or spill methylene chloride on your gloves, stop what you are doing and change the outer glove immediately. If you allow methylene chloride to remain on the outer nitrile glove for more than a few seconds you must discard both sets of gloves and re-glove. Methylene chloride permeates disposable latex exam gloves in a matter of seconds and latex gloves should never be used to handle this material.

For use of methylene chloride where contact with the glove is anticipated only viton, PVA or norfoil* gloves are recommended.

Methyl sulfonic acid, ethyl ester (EMS) (ethyl methanesulfonate): nitrile gloves for incidental contact; double glove with nitrile gloves when handling the pure material or concentrated stock solutions.

Monoethanolamine: nitrile gloves.

Naptha: nitrile gloves.

Nickel chloride: See Heavy Metal Salts.

Nitric acid: nitrile gloves for incidental contact.

A heavier weight neoprene or butyl rubber glove would be superior for long-term use with more concentrated solutions.

Nitrobenzene: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed. For extended contact use viton, butyl or norfoil* gloves.

N-Methylethanolamine: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed.
Viton, neoprene or butyl rubber gloves are recommended for extensive use of N-methyl-thanolamine such as working with the pure material or making solutions.

Oil: nitrile gloves for incidental contact. For extended contact use neoprene or butyl gloves.

Organophosphorous compounds: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use heavier nitrile gloves.

Osmium Tetroxide: See Heavy Metal Salts.

Oxalic Acid: nitrile gloves for incidental contact and use heavier nitrile glove for extended contact.

Paraformaldehyde: nitrile gloves.

Perchloric Acid: nitrile gloves.

Perchloroethylene: nitrile gloves for incidental contact
For extended contact, use viton or norfoil.

Petrol (gasoline): nitrile gloves.

Phenol: double glove by wearing a latex glove over a nitrile glove for incidental contact. Nitrile gloves have a short breakthrough time and poor degradation rate with phenol compared to latex.

Neoprene or butyl rubber gloves are recommended for extensive use of phenol such as working with the pure material or making solutions.

Phenol-chloroform mixtures: double glove with nitrile gloves for incidental contact and remove outer glove at once if exposed or use heavier nitrile gloves. (Neoprene is not recommended for chloroform).

Viton or norfoil* gloves are recommended for work with phenol-chloroform mixtures when probable exposure to the mixture exists. (see phenol and chloroform entries).

Phenylmethylsulfonyl fluoride (PMSF): nitrile gloves for incidental contact and double glove with nitrile gloves when handling the pure material or concentrated stock solutions.

Phenylmethylsulfonyl fluoride is corrosive (causes burns) on contact with the skin, eyes and mucus membranes. It is also a highly toxic cholinesterase inhibitor and central nervous system poison. Avoid all contact.

Phosphoric acid: nitrile gloves.

Picric acid: nitrile gloves for incidental contact and use heavier nitrile glove for extended contact

Polychlorinated biphenyls (PCBs): For weighing out of pure or concentrated materials, double glove by wearing a nitrile glove over a neoprene glove.

Polyoxyethylenesorbitan monolaurate (Tween 20): nitrile gloves.

Potassium hydroxide (50%): nitrile gloves.

Psoralen: nitrile gloves for incidental contact; double glove with nitrile gloves when handling the pure material or concentrated stock solutions.

Psoralen is corrosive (causes burns) on contact with the skin, eyes and mucus membranes. It is anticipated to be a carcinogen, it is a mutagen and a strong photosensitizer. Avoid all contact.

Pyridine: double glove with nitrile gloves for incidental contact.

Pyridine will break through thin nitrile gloves in a few minutes at the most. If you splash or spill pyridine on your gloves, stop what you are doing and change the outer glove immediately. If you allow pyridine to remain on the outer nitrile glove for more than a few seconds you must discard both sets of gloves and re-glove.

Only butyl gloves are suitable for extended contact.

Silane based silanization or derivatization compounds: double glove with nitrile gloves for incidental contact or use heavier nitrile gloves; remove glove(s) at once if signs of degradation occur.

Silver nitrate: See Heavy Metal Salts.

Sodium azide: nitrile gloves or double glove with nitrile gloves for incidental contact.

Sodium dodecyl sulfate (SDS): nitrile gloves.

Sodium hydroxide (50%): nitrile gloves.

Sulfuric acid: nitrile gloves for incidental contact with dilute solutions (<50%) and double glove for concentrated solutions or use heavier weight nitrile. Use neoprene or butyl rubber gloves for extended contact.

Tetrahydrofuran (THF): double glove with nitrile gloves for incidental contact or use heavier nitrile gloves; remove glove(s) at once if THF contacts glove.

For extended contact only norfoil* gloves are recommended. Note that the permeation time for THF through disposable nitrile and latex gloves is almost instantaneous.

3,3',5,5'-Tetramethylbenzidine (TMB): nitrile gloves for incidental contact; double glove with nitrile gloves when handling the pure material or concentrated stock solutions.

N, N, N', N'-Tetramethylethylenediamine (TEMED): nitrile gloves for incidental contact; double glove with nitrile gloves when handling the pure material.

TEMED is corrosive (causes burns) on contact with the skin, eyes and mucus membranes.

Toluene: double glove with nitrile gloves for incidental contact, removing outer glove at once if exposed or use heavier nitrile gloves.

For extended contact, only viton or polyvinyl acetate (PVA) gloves are recommended. Note that the permeation time for toluene through 4 mil nitrile gloves is less than 4 minutes and through latex exam gloves is less than that; subsequently, these gloves are not recommended for use with toluene.

Trichloroacetic acid (TCA): nitrile gloves.

Trichloroethylene: double glove with nitrile gloves for incidental contact , removing and replacing gloves at once if exposed.

Nitrile gloves have short breakthrough times for Trichloroethylene, therefore with extended contact only viton and norfoil* gloves are recommended.

Triethanolamine (TEA): nitrile gloves for incidental contact , removing and replacing gloves if exposed. Use thicker nitrile, PVA, PVC or butyl for extended contact.

Triton-X100: nitrile gloves.

Turpentine: nitrile gloves for incidental contact. For extended contact use thicker nitrile, PVA or butyl gloves

Tween 20: (polyoxyethylenesorbitan monolaurate): nitrile gloves

Xylene: double glove with nitrile gloves for incidental contact , removing outer glove at once if exposed or use heavier nitrile gloves.

For use of xylene where contact with the glove is anticipated only viton, PVA or norfoil* gloves are recommended.

* Norfoil is a PTFE laminate glove material i.e. North’s Silver Shield gloves.

Appendix 3: Glove Standards

BS EN 374:2016

This standard specifies the requirements of gloves for protection against chemicals and/or micro-organisms. In order to comply with the standard gloves are tested using the standard test for permeation against the following list of chemicals:

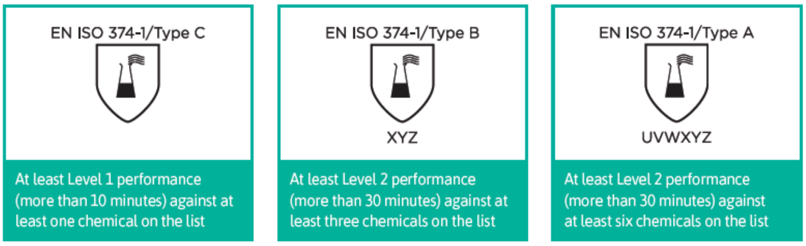
	Codeletter	Chemical	CAS Number	Class
OLD	A	Methanol	67-56-1	Primary alcohol
	B	Acetone	67-64-1	Ketone
	C	Acetonitrile	75-05-8	Nitrile compound
	D	Dichloromethane	75-09-2	Chlorinated hydrocarbon
	E	Carbon disulphide	75-15-0	Sulphur containing organic compound
	F	Toluene	108-88-3	Aromatic hydrocarbon
	G	Diethylamine	109-89-7	Amine
	H	Tetrahydrofuran	109-99-9	Heterocyclic and ether compound
	I	Ethyl acetate	141-78-6	Ester
	J	n-Heptane	142-82-5	Saturated hydrocarbon
	K	Sodium hydroxide 40%	1310-73-2	Inorganic base
	L	Sulphuric acid 96%	7664-93-9	Inorganic mineral acid, oxidizing
NEW	M	Nitric acid 65%	7697-37-2	Inorganic mineral acid, oxidizing
	N	Acetic acid 99%	64-19-7	Organic acid
	O	Ammonium hydroxide 25%	1336-21-6	Organic base
	P	Hydrogen peroxide 30%	7722-84-1	Peroxide
	S	Hydrofluoric acid 40%	7664-39-3	Inorganic mineral acid
	T	Formaldehyde 37%	50-00-0	Aldehyde

Note: Chemicals listed as ‘old’ in the table above were used in the 2003 standard and those listed as ‘new’ were added to this list in 2016.

The 2016 standard also changes the way boxes of gloves are labelled, see below:

How will the new tests be represented in glove pictograms?

- There is a new three tiered system to report chemical performance against a specific number of chemicals.
- It is reported with a new pictogram icon and a marking above each that describes its performance. For example, the Type A glove is the most versatile chemical glove as it was tested for more than 30 minutes against at least six chemicals on the test list. Refer to the diagrams here.
- The type of chemical glove you need is dependent on the type and number of chemicals you frequently use.



Note:

The beaker icon (low chemical resistance/ waterproof) has been eliminated.

Each chemical tested is classified in terms of breakthrough time and assigned a performance level:

Measured breakthrough time (minutes)	Permeation performance level
>10	1
>30	2
>60	3
>120	4
>240	5
>480	6

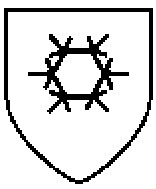
The ‘Micro-organism’ pictogram is used when the glove conforms to at least a performance level 2 for the penetration test with bacteria and fungi.

BS EN 455:2000 - 2009

Gloves that have been tested according to this standard are assessed for suitability for use in health care. They are Medical Devices and are often referred to as ‘exam’ or ‘examination’ gloves.

BS EN 511:1994

This standard specifies the requirements for gloves giving protection against convective and contact cold down to –50 °C



abc

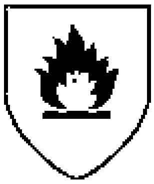
The ‘cold hazard’ pictogram is accompanied by a 3-digit number:

a. Resistance to convective cold (performance level 0 - 4)
b. Resistance to contact cold (performance level 0 - 4)
c. Permeability by water (0 = water penetration after 30 minutes of exposure or 1 = no water penetration

All gloves must achieve at least Performance level 1 for abrasion and tear.

BS EN 407:2004

This standard specifies thermal performance for protective gloves against heat and/or fire.



abcdef

The nature and degree of protection is shown by a pictogram followed by a series of six performance levels, relating to specific protective qualities.

a. Resistance to flammability (performance level 0 - 4)
b. Contact heat resistance (performance level 0 - 4)
c. Convective heat resistance (performance level 0 - 4)
d. Radiant heat resistance (performance level 0 - 4)
e. Resistance to small splashes of molten metal (performance level 0 - 4)
f. Resistance to large splashes of molten metal (performance level 0 - 4)

Resistance to flammability: based on the length of time the material continues to burn and glow after the source of ignition is removed. The seams of the glove shall not come apart after an ignition time of 15 seconds.

Contact heat resistance: based on the temperature range (100-500 °C) at which the user will feel no pain for at least 15 seconds. If an EN level 3 or higher is obtained, the product shall record at least EN level 3 in the flammability test. Otherwise, the maximum Contact heat level shall be reported as level 2.

Convective heat resistance: based on the length of time the glove is able to delay the transfer of heat from a flame. A level of performance shall only be mentioned if a performance level3 or 4 is obtained in the flammability test.

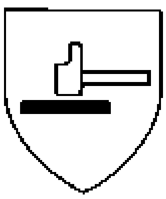
Radiant heat resistance: based on the length of time the glove is able to delay the transfer of heat when exposed to a radiant heat source. A performance level shall only be mentioned if a performance level 3 or 4 is obtained in the flammability test.

Resistance to small splashes of molten metal: the number of molten metal drops required to heat the glove sample to a given level. A performance level shall only be mentioned if a performance level 3 or 4 is obtained in the flammability test.

Resistance to large splashes of molten metal: the weight of molten metal required to cause smoothing or
pin-holing across a simulated skin placed directly behind the glove sample. The test is failed if metal droplets remain stuck to the glove material or if the specimen ignites.

BS EN 388:2003

This standard applies to gloves that protect against physical and mechanical hazards. It specifies requirements for resistance to damage from abrasion, blade cut, puncture and tearing.



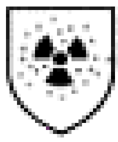
a b c d

Protection against mechanical hazards is expressed by a pictogram followed by four numbers (performance levels), each representing test performance against a specific hazard.

a. Resistance to abrasion: based on the number of cycles required to abrade through the sample glove (0 - 4).
b. Blade cut resistance: based on the number of cycles required to cut through the sample at a constant speed (0 – 5).
c. Tear resistance: based on the amount of force required to tear the sample (0 - 4).
d. Puncture resistance: based on the amount of force required to pierce the sample with a standard sized point (0 - 4).

BS EN 421

This standard lays down test methods and performance criteria for gloves offering protection against ionising radiation and radioactive contamination.



BS EN 420:2003

General requirements and test methods for gloves

Appendix 4: Case Study

Fatal Failure of a Disposable Latex Glove to Protect a Laboratory Worker

Karen E. Watterhahn, Ph.D., Professor of Chemistry and the Albert Bradley Third Century Professor in the Sciences at Dartmouth College, **died at the age 48** on June 8th 1997 at the Dartmouth-Hitchcock Medical Center (Lebanon, NH).

In a letter to *Chemical & Engineering News* shortly before Dr. Wetterhahn's death, Michael B. Blayney, director of environmental health and safety at Dartmouth, and two other Dartmouth authors, said her **severe mercury toxicity was the result of a single exposure to one or several drops of dimethylmercury through a disposable latex glove**.

Dimethylmercury belongs to a class of organic alkyl mercury compounds, used primarily in research. It is a colourless liquid described as having a weak, sweet odour. Dimethylmercury is readily absorbed through the skin. Many materials, including several plastics and rubber compounds, have been shown to be permeable to this chemical. It is highly reactive and flammable. Because of its high vapour pressure (50-82 mm Hg at 20°C), the inhalation route of entry into the body is also potentially significant.

Case Report:

Research notes, interviews, hair analysis, and statements made by Dr Watterhahn established the circumstances of the incident:

In hindsight it was about three months after the incident/exposure before Dr Watterhahn began to experience episodes of nausea and vomiting spaced weeks apart. Five months after the incident/exposure, the professor noted the onset of numbness and tingling in both lower extremities, difficulty with walking/balance (ataxia), slurred speech (dysarthria), loss of vision, and loss of hearing. Medical evaluation at this time revealed a whole blood mercury concentration of 4,000 µg/l i.e. 80 times the usual toxic threshold of 50 µg/l and markedly above the expected normal range of 1 to 8 µg/l. Similarly the mercury concentration in the urine was 234 µg/l against background levels in unexposed populations of only 4-5 µg/l.

Full diagnostic evaluation confirmed organometallic toxicity as a result of exposure to dimethylmercury as the cause. Analysis of the mercury content along a 15-cm length of the professor's hair revealed a large exposure to mercury in mid-August 1996, in accord with a review of research notes and interviews with colleagues. The hair analysis was consistent with a single or short exposure, mercury levels in hair reflecting the blood mercury levels at the time the hair was formed. The mercury concentration peaked at 54 days post the spill incident followed by a subsequent slow decline.

When informed that her symptoms were due to mercury poisoning, Dr Watterhahn recalled spilling “one or several drops” on the back of a disposable latex glove on her left hand. The incident took place during a transfer of dimethylmercury to another container while preparing a mercury nuclear magnetic resonance standard. Dr Watterhahn stated that she had removed the gloves promptly and did not think any more about the incident. As a result, there was no medical monitoring or other follow-up until the diagnosis five months after the exposure.

The size of the spill onto the latex glove is estimated to have been between 0.1 to 0.5 ml of dimethylmercury. A toxic dose of 100 to 200 mg of mercury requires absorption of less than 0.1 ml of the liquid dimethylmercury (density 3 g/ml). The incident took place in a fume cupboard and the possibility of inhalation exposure is considered unlikely given the brief time the material was handled, the use of the fume cupboard, and the high concentration found subsequently in Dr Watterhahn body.

Dr Watterhahn symptoms progressed rapidly to cognitive deficits and coma. Aggressive chelation treatment increased the rate of elimination of mercury from the body, but without clinical improvement.

Dr Watterhahn died 10 months after the exposure, with the diagnosis at the time of death being encephalopathy as a result of mercury intoxication.

Many workers in her field thought this could not happen, but it did. In keeping with other reported cases, the delayed onset of symptoms is not completely understood, although the intense lipophilia (affinity for fat/solubility in lipids) of the compound may play a role.

Whole blood and urine testing of family members and laboratory co-workers revealed no other abnormal mercury levels. Air and surface samples from Dr Watterhahn's laboratory, office, car and home only revealed detectable levels of mercury near the sealed mercury waste can in the laboratory fume cupboard, containing the residual dimethylmercury.

There were seven brands of thin-latex or PVC disposable medical type gloves used in the Dartmouth laboratories at the time. All types were tested by an independent testing services using ASTM (American Society for Testing and Materials) methodology. The testing service established "maximum permeation at 15 seconds, the quickest time they could sample". In effect, Dr. Wetterhahn didn't have any protection from her disposable latex gloves, the dimethylmercury simply passed trough the glove as water would through a sieve.

A highly resistant laminate glove (Silver Shield or 4H) should be worn under a pair of long-cuffed, unsupported neoprene, nitrile, or similar heavy-duty gloves. Latex or PVC gloves have an important role in many laboratory activities, but they are not suitable for significant, direct contact with aggressive or highly toxic chemicals. Medical surveillance measuring mercury concentrations in whole blood or urine should be considered for repeated or extended use of alkyl mercury compounds. In all cases, the potential hazards associated with dimethylmercury and related alkyl mercury compounds must not be underestimated.

Recommendations

1. Consider the use of less hazardous substances unless dimethylmercury is specifically required.

2. Work with dimethylmercury must be carried out in a fume cupboard whilst wearing impervious long cuffed gloves, a laboratory coat with disposable plastic apron and a face shield to prevent any skin potentially being exposed to splashes.

Latex, neoprene and butyl gloves **do not** provide suitable protection for direct contact with dimethylmercury as it migrates through plastics and rubber.

Permeability tests have shown that Silver Shield laminate gloves are impermeable to dimethylmercury for at least 4 hours (OSHA). The Silver Shield glove should be worn under an outer glove that would be resistant to abrasion and tears. The vial containing the dimethylmercury should be carefully secured and the contents drawn up by means of a glass syringe and cannula. All gloves that may have been in contact with dimethylmercury should be considered contaminated and disposed of as hazardous waste and not reused.

3. Anyone using organometallic compounds such as dimethylmercury must be trained and aware of the extremely toxic properties of these materials. MSDSs must be read with the understanding that they may not provide adequate guidance on glove selection.

4. All spills of this material or even suspected contact must be reported and medical attention sought immediately. Dimethylmercury evaporates rapidly and nearby workers could be quickly exposed to toxic levels.

5. Medical surveillance consisting of periodic blood and urine testing of all individuals who work with this chemical on a routine or frequent basis should be provided by the Occupational Health Service.

"Sometimes it’s hard to predict the long-term consequences of doing something. You don’t always have the knowledge you need. You have to make your best judgment."

Karen Wetterhahn, 1995

Appendix 5: Signage indicating that gloves should be used -

UNIVERSITY OF CAMBRIDGE

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Greenwich House
Madingley Road
Cambridge
CB3 0TX
Tel: 01223 333301
Fax: 01223 330256

HSD059C (rev3)

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www.safety.admin.cam.ac.uk/