DISPOSABLE GLOVES IN THE WORKPLACE

YOUR FIRST LINE OF DEFENCE

For many applications in the workplace we wear disposable gloves, to the extent that for many people they have become an everyday feature of working life. Disposable gloves come in all sorts of colours, while the different materials they are made of also seem to be growing. For a product that shares such a high level of intimacy with our working life, it may come as a surprise that few of us take the time to understand their purpose. This article will therefore review glove barrier properties in the workplace and why gloves really are our first line of defence.

In terms of purpose, disposable gloves are often expected to provide personal protection against chemical splashes and biohazards, plus provide protection to the process from human-borne contamination. To assess these different needs, we will first look at glove materials, then discuss in greater detail how disposable gloves satisfy the need for chemical splash and biohazard protection.

How glove materials impact barrier effectiveness

An understanding of the barrier effectiveness of glove materials is necessary, as part of the overall risk assessment. Table 1 summarises some of the main features of the most frequently encountered glove materials. Of note is the high in-use failure rate of vinyl, which is evident in the graph from the *1 Rego & Roley (1999) study. This could indicate that this glove material is not suitable for more rigorous applications in the workplace, where the emphasis may be on personal protection from chemical splashes and biohazards. Also of interest is the emergence of neoprene as a credible synthetic alternative to latex, with some differences to nitrile in terms of chemical barrier performance.

As the physical properties of glove materials are critical for determining barrier effectiveness, details on tensile strength and elongation are also provided in Table 1. Perhaps surprisingly, measurement of physical properties is not a requirement for "Protective gloves against chemicals and micro-organisms" (as defined in EN374-1: 2003 "Terminology & Performance Requirements"). Accordingly details of the nearest appropriate European standard ▸

"this article will review glove barrier properties in the workplace and why gloves really are our first line of defence"

(EN455-2: 2000 covering examination gloves and before accelerated ageing) are provided, as are the ASTM equivalents. The relevance of testing for physical properties is described below:

- *Tensile strength*
  User impact: The stronger the gloves, the more durable they are in use thereby providing optimal personal protection

  Process impact: Stronger gloves can lead to fewer glove changes, thus decreasing the chance of contamination of the process

- *Elasticity*
  ASTM D412 evaluates the amount of force required to stretch the glove. The lower the modulus, the less effort required for movement

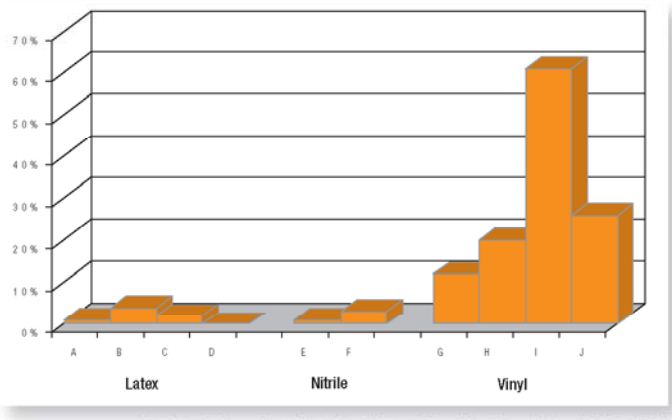
User impact: this measurement gives us an insight as to how much effort glove wearers will have to exert to perform tasks and impacts on hand fatigue. It is particularly relevant to those tasks in the workplace requiring repeated hand movements e.g. manipulating a pipette

Barrier protection of disposable gloves against biohazards

Council Directive 90/679/EEC dated 26th November 1990 is the original version of the regulation covering protection of workers from risks related to exposure to biological agents. It has been substantially revised over the years and Council Directive 2000/54/EEC (*4 OJ L262/21) appears to be the latest version. This Directive classifies biological agents into four groups, which determines the level of risk and the containment level. The biological agent groups are defined as follows:

- *Group 1 biological agent:*
  One that is unlikely to cause human disease. Examples of group 1 biological agents are Lactobacillus spp., Bacillus subtilis, Naegleria gruberi etc

- *Group 2 biological agent:*
  One that can cause human disease and might be a hazard to employees. Whilst it is unlikely to spread to the community, there is usually effective treatment or prophylaxis available. Examples of group 2 biological



Graph to show in-use barrier integrity of latex, nitrile and vinyl gloves*1 Rego & Roley (1999)

Table 1 Summary of main features of glove materials

Material Type	Tensile Strength	Elasticity	Durability	Fit & Comfort	Chemical Resistance (Incidental Exposure)
Latex (Natural Rubber Latex from the rubber tree "Hevea brasiliensis"	Excellent with a minimum tensile strength of 9N per EN455-2 and 14 MPa per ASTM D3578	High level of memory, elasticity, and elongation. Minimum requirement for elongation is 650% per ASTM D3578	Highly resistant to tears and punctures, with in-use failure rates reported to be 0% to 9%*1*2*3	Excellent, conforms to hand	Fair protection especially with water-based chemicals, alkalis & alcohols. Poor resistance to organic chemicals, oils and greases
Nitrile (Acrylonitrile-butadiene, a synthetic co-polymer)	Excellent strength and puncture resistance. Minimum tensile strength of 3.6N per EN455-2 and 14 MPa per ASTM D6319	Medium to high, conforming to the user's hand with use. Minimum requirement for elongation is 500% per ASTM D6319	Highly resistant to punctures and tears. Once punctured tear is visible and quickly spreads. Reported in-use failure rates range from 1% to 3%*1*2	Good to excellent, conforms to hand. Sometimes has high modulus or stiffness	Good protection to a broad range of chemicals including alkalis, fuels, many solvents, greases, animal fats etc. Poor protection against ketones, aromatics and chlorinated solvents
Vinyl (Polyvinyl chloride, a synthetic co-polymer)	Limited strength, with minimum tensile strength of 3.6N per EN455-2 and 11MPa per ASTM D5250 (NB: ASTM differentiates between nitrile & vinyl)	Low to medium, with moderate flexibility. Minimum requirement for elongation is 300% per ASTM D5250	In applications requiring long term or rigorous use, in-use failure rates range from 26% to 61% *1*2*3	Fair, but not usually offering the snug qualities of latex or nitrile	Generally poor, but offering some protection to petroleum-based products and animal fats. Contact with chemicals can release phthalates (often used as a softener in vinyl), which may damage DNA. DEHP is the most commonly used phthalate and is classified as a toxicant in the EU
Neoprene	Excellent strength properties. Minimum tensile strength of 3.6N per EN455-2 and 14MPa per ASTM D6977	Generally higher elasticity than nitrile and closer to latex in elasticity properties. Minimum requirement for elongation is 500% per ASTM D6977	Fair puncture resistance	Good, although sometimes has high modulus or stiffness	Resistant to many chemicals including oils, acids, & large range of solvents. Poor protection to organic solvents

agents are Hepatitis A virus, Polioviruses, Salmonella typhimurium, Ascaris etc

- *Group 3 biological agent: one that can cause severe human disease and presents a serious hazard to employees. It may present a risk of spreading to the community, although an effective treatment or prophylaxis is usually available. Examples of group 3 biological agents are Bacillus anthracis, HIV, Histoplasma capsulatum etc*

- *Group 4 biological agent: one that can cause severe human disease and presents a serious hazard to employees. It may present a high risk of spreading to the community and there is usually no effective treatment or prophylaxis available. Examples of group 4 biological agents are Ebola virus, Marburg virus, Crimean-Congo haemorrhagic fever etc.*

Containment level may be described as the barriers for managing hazardous biological agents in the workplace. Its objective is primarily to reduce the risk to personnel in contact with biological agents, those in the vicinity of the workplace where there is direct contact to biological agents and the wider community from potentially hazardous biological agents. There are four containment levels, which are aligned with the biological agent group. Containment typically covers three elements: facility design, practices in the workplace and safety equipment. The latter addresses the question of what personal protective equipment (PPE) is to be used for each containment level.

Biological agent group	Containment levels	Recommendation on protective clothing	Recommended use of gloves (*5)	Other possible considerations for hand protection
Group 1	1	Yes (in accordance with the principles of good safety and hygiene)	Optional (to be worn if skin on hand is broken or if a rash is present)	Nitrile/neoprene or latex glove that is compliant with EN374-2: 2003 (AQL <1.5 or Level 2)
Group 2	2	Yes, work clothing	Yes (for contact with potentially infectious material and contaminated surfaces or equipment)	As for Group 1. Additionally use long length gloves (<26cm) and seek gloves that have passed the viral penetration test
Group 3	3	Yes	Yes (plus frequent changing of gloves accompanied by hand washing)	As for Group 2, but seek additional protection by using only gloves with an AQL of <0.65 or Level 3 (EN374-2: 2003)
Group 4	4	Yes, full change before entering and exiting	Yes (as part of a one piece positive pressure suit with its own air support system)	Disposable glove may be used as an under glove for extra protection

Table 2 Summary of some of the safety aspects to Council Directive 2000/54/EEC

Water Leak Testing at the Plant

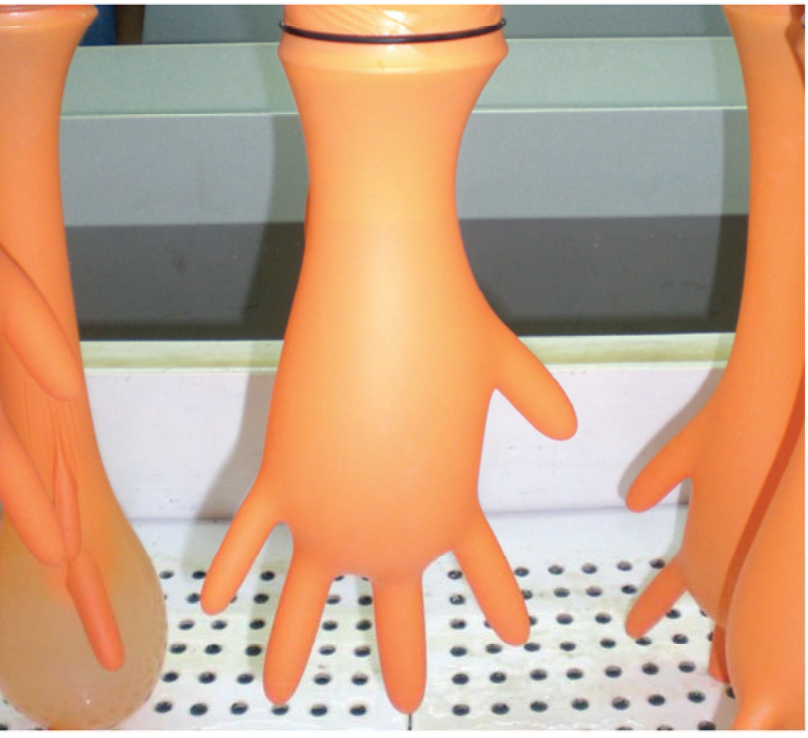


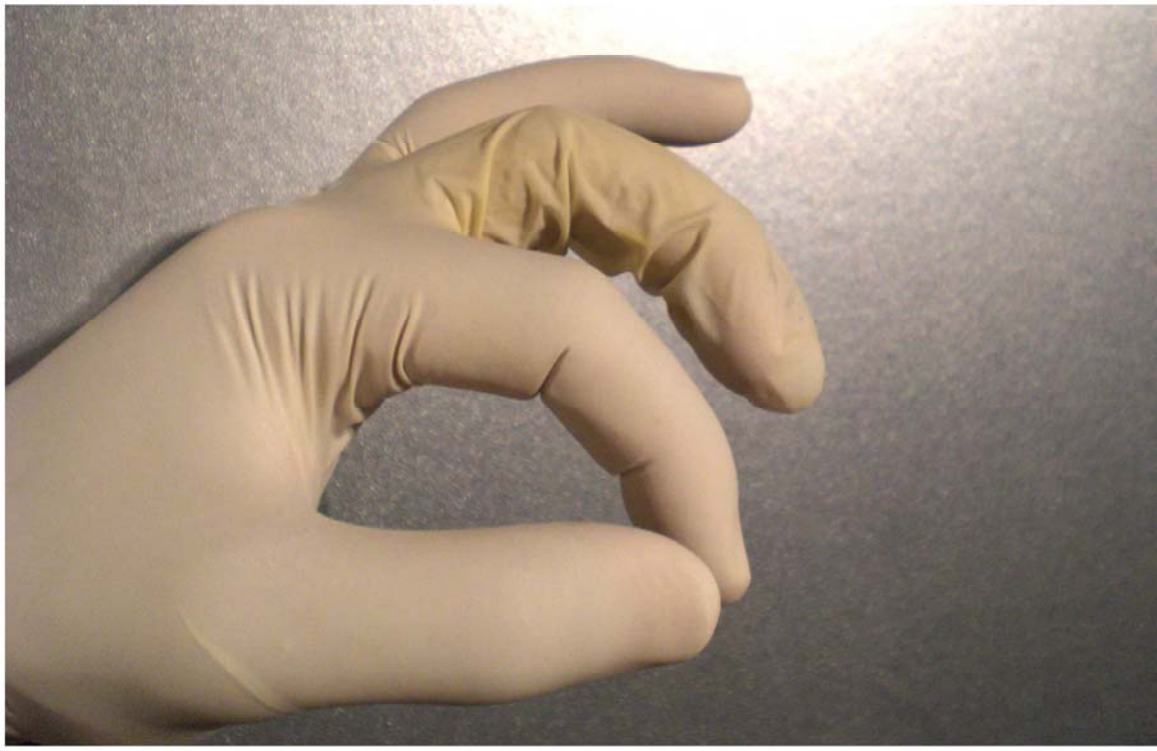
Table 2 is a summary of the details in the Directive from the perspective of some of the safety aspects. As the Directive does not appear to mention specifically gloves, the recommendations from the "Biosafety in Microbiological and Biomedical Laboratories"(*5 CDC/NIH 1999) are given. In addition, there is a heading titled "Other possible considerations for hand protection" which attempts to give some additional options on disposable gloves, as this level of detail is not covered in the regulations. These are not recommendations and the appropriateness of a glove for a specific task must be based on a risk assessment. The possible options given in the above table draw on the standards (as defined in EN374: 2003 "Protective gloves against chemicals and micro-organisms") which relate to the Council Directive 89/686/EEC for Personal Protective Equipment (PPE). Points to note are as follows:

- *EN374-1: 2003 (Terminology & performance requirements) sets the minimum lengths for the liquid proof section of a glove. For a size 10 (XL), this would mean a minimum length of 26cm. In the workplace, this might be to provide adequate protection of the wrist area from chemical splashes and biohazards*

- *EN374-2: 2003 (Determination of resistance to penetration) is the standard relating to the test methodology for evaluating protection against biohazards. Penetration refers to the flow of a chemical agent through seams, porous materials, pinholes and other imperfections in the protective glove (*6 HSE)*

- *Typically for disposable gloves, the penetration test consists of the water leak assay (see picture opposite). Here a test glove is filled with 1000ml of water and inspected for water leakage immediately and if no leakages are noted again after 2 minutes. Given the large volumes of disposable gloves produced, a statistical approach is adopted. An Acceptable Quality*

"containment typically covers three elements: facility design, practices in the workplace and safety equipment"



The effects of chemical degradation

Level (AQL) of 1.5% accepts the probability of 1.5% defects in a batch of gloves. An AQL of 0.65 assumes a tighter quality assurance level, giving the glove wearer a higher level of personal protection. It is for this reason that for group 3 biological agents, only gloves with an AQL of 0.65 are suggested

- *According to EN374-1: 2003 gloves may be considered micro-organism resistant if they achieve at least level 2 (AQL<1.5) in the penetration test outlined in EN374-2: 2003. However it is acknowledged that the term micro-organism resistant applies to fungi and bacteria, but does not apply to viruses. Thus for containment levels 2 and higher, it is suggested that gloves that have passed the viral penetration test (ASTM F1671) are selected. This assumes that for biological agents that may be hazardous to humans, testing specifically for viruses may be beneficial*
- *ASTM F1671 is a standard test method for evaluating the resistance of materials to penetration by blood-borne pathogens using Phi-X174 bacteriophage penetration as a test system. Phi-X174 is non-hazardous and easy to detect. Significantly it is smaller than most viruses including Herpes, HIV, Hepatitis B and Polio virus. Accordingly this test is useful, as it assesses the quality of the glove that cannot be detected using water leak assay*

How do I know if my gloves fulfil the criteria for being micro-organism resistant?

EN374-2: 2003

Level 2

The above pictogram is the standard biohazard sign and is also used on gloves that have fulfilled the criteria for being micro-organism resistant, according to the latest version (2003) of the penetration test (EN374: 2).

Barrier protection of disposable gloves against chemicals

This article focuses on disposables gloves, as this is the most common form of hand protection in the workplace. However, it should be noted that disposable gloves only offer limited protection to chemicals. Typically this does not extend beyond incidental exposure to chemical splashes. The limitations of disposable gloves are now recognized in EN374: 2003 "Protective gloves against chemicals & micro-organisms". As few if any disposable gloves would be able to achieve the required class 2 (a breakthrough time of <30 minutes) from three of the twelve chemicals listed in EN374-1: 2003, most disposable gloves that are certified as protecting against chemicals and micro-organisms will show the following pictogram:

The question mark in the middle of the square-shaped glass beaker reminds those of us engaged in risk assessments in the workplace that we are referring to "low chemical resistant" or "waterproof" gloves. It should also encourage us to seek additional information from the glove manufacturer on the chemical permeation time for specific chemicals that are being used in the workplace. Whilst most reputable glove manufacturers have available extensive chemical permeation data, we need to appreciate the limitations of this data: ▸

- *Chemical permeation is the process by which chemicals flow through the glove material at the molecular level (*6 HSE). A breakthrough takes place when the chemical is detected on the other side of the sample*

- *EN374-3: 2003 (Determination of resistance to permeation by chemicals) is the standard method for evaluating the chemical barrier performance of a glove. Here one layer of the glove is placed between two chambers. The chemical being tested is placed on one side and a receiving fluid on the other. Breakthrough occurs when a permeation rate of 1µg/cm²/min¹ is noted and is reported in minutes*

- *EN374-3: 2003 is a total immersion test and may not be representative of the experience in the workplace, where the emphasis may be on incidental chemical exposure*

- *The tests are done on unused gloves under laboratory conditions. The test methodology does not take into account the stresses and strains to which disposable gloves are subjected whilst being worn for prolonged periods. Similarly a glove in-use is likely to be significantly warmer than an unused glove and the higher level of surface heat may accelerate chemical permeation*

To compensate for the potential shortcomings in EN374-3: 2003, several glove manufacturers now provide data on degradation. The latter relates to the deleterious change in one or more physical properties of a glove material due to contact with a chemical (*6 HSE). In the presence of a chemical, glove materials may become stiff, discoloured or brittle. Likewise they may become softer, weaker and become swollen. Degradation is important as the permeation resistance of a glove material can be substantially reduced. The above picture shows the effects of chemical degradation, sometimes causing the fingers to swell to several times their natural size.

There is currently no internationally recognised test for degradation, thereby making it difficult to validate manufacturers' claims. However as part of EN374, a test for degradation is under development and may address the need for a universal standard to measure chemical degradation.

Table 1 provides some guidance on which glove materials perform best with certain chemical classes. Specific breakthrough data from glove manufacturers will also be helpful as part of the overall risk assessment. It is important to appreciate that under Council Directive 89/656/EEC it is the duty of the employer to audit the risk and provide appropriate PPE. Therefore the suitability of a glove for a specific task must be determined by making a risk assessment.

Finally as has been noted for biohazard protection, EN374-1: 2003 stipulates a minimum length of 26cm for size 10 gloves (XL). As most disposable gloves are of one size, this would mean that all disposable gloves used for protection against chemical splashes and biohazards should have a minimum length of 26 cm. However, few of the gloves routinely used in the workplace would satisfy this requirement. This seems strange given that the rationale for longer cuff gloves is for protection of the wrist from chemical splashes and biohazards.

Conclusion

This article has taken a closer look at the barrier properties of disposable gloves. Particular attention has been given to protection from chemical splashes and biohazards. The value of long cuffed gloves for protection of the wrist has been noted, although it would appear that few manufacturers are to date complying with the minimum length required for conformance with EN374-1: 2003 ("Protective Glove against chemicals and micro-organisms-Terminology & Performance Requirements"). For protection against biohazards, the benefits of using gloves with an AQL of 0.65 was suggested in terms of giving the glove wearer increased protection against biological agents in groups 3 and 4. Similarly the limitations of EN374-2: 2003 (determination of resistance to penetration) was discussed in so far as it does not appear to offer protection against viruses. In this context it was suggested that for protection of biological agents from groups 2 to 4, it may be advisable to use gloves that have proven viral penetration resistance. Whilst ASTM F1671 is not a European standard, it may be a temporary solution. ■

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Other sources of information

a) Health & Safety Executive Advisory Committee on Dangerous Pathogens (2004) "The Approved list of biological agents" March 2004 [online] – accessed via www.hse.gov.uk/pubns/misc208.

b) World Health Organization (2004) "Laboratory Biosafety Manual" Third Edition [online] – accessed via www.who.int/csr/resources/publications/biosafety/biosafety7.

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SHIELD Scientific is a newly founded company that aims to challenge current practices in hand protection, primarily in the laboratory and high technology sectors. Its brands SHIELDskin™ and duoSHIELD™ achieve this through exceeding expectations in compliance, comfort and protection. SHIELDskin™, duoSHIELD™ , ORANGE NITRILE™, ICE NITRILE™ and SKIN NITRILE™ are trade marks of SHIELD Scientific B.V.

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