ANNEX 4: PRINCIPLES OF PROTECTION

1. Introduction

A variety of technologies and strategies can be used to protect individuals physically against contamination by chemical and biological agents. In fact, individual protection is often the measure that comes to mind first in considering methods to counter chemical and biological threats. However, protection is achieved only at a price. The use of protective clothing is always a trade-off between the protection achieved and the problems caused by the protective equipment itself, as discussed in Appendix A4.1 below. It is consequently a mistake to consider protection in isolation. It must always be seen as an integral part of the risk-management process, after consideration of the strategies that may be able to reduce the risk and eliminate the need for protection altogether.

This annex describes the role of physical protection in the risk-management process, and highlights the advantages and disadvantages of different risk-control mechanisms. It concludes with a practical example illustrating the application of the principles that have been introduced.

2. Risk-reduction measures

The level of risk posed by a hazard is a function of the probability of exposure to that hazard and the extent of the harm that would be caused by that exposure. Application of risk-control measures, as part of the risk-management process, seeks to reduce or eliminate the probability and/or the severity of harm. Various risk-reduction mechanisms can be introduced for dealing with chemical or biological agents:

1. Administrative controls
2. Engineering controls
3. Physical protection

These should be understood as integral parts of a system, and a risk-control strategy should never be restricted to one method alone. The strategy should preferably begin to take effect as close to the hazard itself as possible. The best way to prevent casualties from a deliberate release of biological or chemical agents is to make the use of such agents impossible, or at least to reduce the probability of their use. If this fails, the objective of risk control is to minimize human suffering and reduce the loss of assets. Every method has its own advantages and disadvantages.

2.1 Administrative controls

In their application to biological and chemical agents, administrative controls include risk communication (including a warning system), and the evacuation and cordoning off of potentially contaminated areas. This simply reduces the possibility of exposure by avoiding the hazard. The hazard itself is not affected, and no physical protection is introduced. Administrative controls are usually relatively easy to apply and are less costly than other risk-control methods. Since the risk is avoided (reduction of probability), risk reduction through other measures is less important. However, people may choose not to follow administrative instructions (e.g. may leave their homes). The setting up of cordons needs resources that cannot then be used elsewhere. Restricted areas or buildings cannot be used for some time, and certain personnel, such as responders, will still need to enter the area. This means that administrative controls can usually only supplement, but not eliminate, the need for other risk-control mechanisms.

2.2 Engineering controls

Engineering controls involve the use of technologies such as airstream control, filters, and various forms of containment, normally used to contain or limit the spread of a hazard. Unlike administrative controls, engineering controls function independently of human decisions. They can, of course, be bypassed, but usually only by a deliberate action, and for technical reasons are limited to specific locations. Since engineering controls prevent contact with the harmful substance without forcing personnel to use individual protective equipment (thereby shifting the preventive measures towards the hazard and away from personnel), they are a preferred method of risk control. An example of engineering control is the use of a biosafety cabinet for the handling of mail suspected of containing a hazardous substance. This example will be explained in more detail below. Buildings with air-filtration systems also constitute a form of engineering control.

2.3 Physical protection

When physical protection is used, the hazard is not contained, as with engineering controls, nor are personnel kept away from the hazard, as with administrative measures. As explained in Appendix A4.1 below, protection can also cause hazards of its own. For these and other reasons, protection is the least desirable method of risk control. While protection is primarily a supplementary measure, it may sometimes be the only practicable method. When it is necessary to rely on physical protection, the objective should be to limit the number of persons exposed, and to expose them to the lowest possible concentration of contaminant for the shortest possible time. The level of protection selected should also be appropriate for the degree and type of hazard. It is not always necessary to use full protection, e.g. a respirator alone may be adequate to protect against a volatile substance that neither damages the skin nor is absorbed through it. Protection can be achieved via:

1. Individual protection
2. Collective protection

Individual protection covers all types of equipment worn by individuals to reduce the possibility of inhalation of and/or skin exposure to chemical and biological weapons (e.g. respirators and protective suits). Collective protection is in fact a special form of engineering control, reducing the risk of exposure for a group of individuals without containing the hazard, e.g. in filter-ventilated buildings and command centres, shelters or vehicles. Wherever possible, collective protection is preferred to individual protection since it does not cause the problems normally associated with individual protection.

3. Individual protection

As usual, risk-management principles should be used in selecting suitable individual protective equipment. With the introduction of protective barriers between the individual and the hazardous substance, a temporary reduction in the exposure can be achieved. However, it must be remembered that, sooner or later, all chemicals and some biological agents will pass through or permeate the protective barriers. Depending on the type of material used, the protection time can range from seconds to days, but no protective equipment protects the wearer against anything indefinitely. In addition, the protection factor[1] depends largely on the seal or tightness that the overall system can achieve. A respirator that does not fit properly will have a low protection factor. In industrial health and safety, two protection factors are often used, namely the theoretical protection factor, which is purely material-related, and the practical or applied protection factor that is actually achieved in the field (which depends on factors such as the seal and fit of the individual protective equipment). Normally, the protection actually achieved with any protective equipment is much lower than the theory would suggest. The individual protective equipment must be chosen in the light of the type and concentration of the agent, other expected hazards (such as oxygen deficiency in confined spaces), and the activity that the wearer is required to perform. Depending on the nature of the threat agent, there are two main components of individual protection that can be used alone or in combination, namely respiratory protection and skin protection.

3.1 Respiratory protection

Most biological and chemical agents are capable of entering the body through the respiratory system, while some, but not all, can penetrate intact skin. Of the two, the respiratory system is more vulnerable than the skin. From a risk-management perspective, therefore, protection of the respiratory system has priority. There are two major types of respiratory-protection equipment:

1. Air-purifying devices (such as military gas masks).
2. Air-supplying devices (such as self-contained breathing apparatus) (SCBA).

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[1] Concentration of a substance outside the individual protective equipment divided by the inside concentration.

3.1.1 Air-purifying devices

Air-purifying devices (such as filtering masks), remove gases, vapours and/or aerosols from the inhaled air. Clearly, they cannot protect against oxygen deficiency, and their protective ability depends on the filter capacity[2] and selectivity[3] for various contaminants. For biological weapons any aerosol filter will physically retain the contaminants (although not always sufficiently), but filters for chemical agents may require adsorptive materials specifically designed for a certain chemical or group of chemicals.[4] Canisters[5] produced according to military specifications will usually remove known biological and chemical agents from the inhaled air, but industrial canisters may not be suitable for all types of chemical agents. In modern canisters, an aerosol filter is combined with an activated charcoal filter, thereby removing dusts, mists, and vapours or gases. Two major problems may arise with filtering respirators:

1. The filtration capacity may not be adequate for the type and amount of the contaminant.
2. The facial seal may not be tight enough.

The problem of selectivity can be overcome by the use of military-specification canisters, which are suitable for the majority of potential chemical and biological agents. Still, even the best canister can be overwhelmed by very high concentrations of gases and vapours, or even mechanically clogged by otherwise harmless dust, thus increasing the breathing resistance of the canister to unbearable levels. A more serious problem is the effectiveness of the seal of the respirator against the wearer's face. Even the best filter will not protect a person when unfiltered air bypasses the canister via an inadequate facial seal. In industrial health and safety, therefore, the protection factor is often, in practice, orders of magnitude lower than the theoretical (or even tested) protection factor of the canister. Not only the type of respirator (mouthpiece, half-mask, full-face mask or hood), but also the competence of the wearer, facial hair, and other practical factors can significantly reduce the protection level.

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[2] The amount of contamination that a filter can hold back without a break-through.

[3] The ability of a filter to protect against one or more different chemicals.

[4] The problems with adsorption of certain toxic chemicals, such as hydrogen cyanide or perfluoroisobutene (PFIB), are well known.

[5] The filtering cartridge attached to a mask or respirator.

Even when the wearer is well trained and has no facial hair, and the respirator is well fitted, increased breathing will cause an under-pressure inside the mask during inspiration, potentially decreasing the protection. The use of power-assisted respirators, in which an electrically powered fan (blowing unit) is used to produce a slight over-pressure inside the respirator, can partially solve this problem. Power-assisted respirators can also be designed as hoods, covering the head of the wearer completely and not needing a tight face seal, thus ensuring that "one size fits all". However, extremely deep inhalation can still cause an under-pressure, and the air passage through the canister can be increased only to a certain extent without diminishing the filtering effect. In addition, the logistic problems (batteries, maintenance, etc.) and the relatively high cost of power-assisted respirators render them more suitable for specific groups of personnel, such as medical personnel treating potentially contaminated patients. It should also be remembered that the noise from the fan, in some designs, may make communication difficult and put an additional strain on the wearer.

3.1.2 Air-supplying devices

As the name implies, air-supplying devices act independently of the ambient atmosphere and supply the wearer with uncontaminated air. The air supply may be obtained via a stationary system (e.g. a wall-connected air hose), or via transportable systems like the SCBA or the Rebreather.[6] While both types share the advantages of reduced breathing resistance and very high protection factors, they also have certain limitations. The higher protection factors result from the over-pressure inside the respirator facepiece, and the fact that air from a contained and uncontaminated source is being inhaled. In so-called positive-demand devices, the air pressure inside the facepiece is always greater than the outer air pressure. Stationary systems are sometimes equipped with a hood or helmet (constant-flow), and can be used by people who are unable to wear a mask. Stationary systems can provide clean air almost indefinitely, but limit the mobility of the wearer, which will depend on the length of the air hose. In some situations, e.g. in unstable structures or in fire fighting, air hoses cannot be used at all. SCBAs are then more useful, but they provide air for a limited time only. Rebreathers solve this problem to some extent by prolonging the air supply (by a factor of up to four, depending on the model), but not

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[6] A system in which the exhaled air is recirculated, with removal of carbon dioxide and enrichment with oxygen.

completely. Since air-supplying systems are heavy even when made from modern materials such as carbon fibres, they add significantly to the physical burden of the wearer.

Air-supplying systems require a highly skilled wearer if maximal protection is to be achieved. In fact, an untrained person could die from the incorrect use of an otherwise fully functional device. Specialized training and certification of users of air-supplying devices is required by law in a number of countries. Any air-supplying device should undergo regular maintenance and inspection.

It should be clear from the foregoing that correct choice of equipment, proper maintenance, and comprehensive training will all be required if protection is to be adequate. Many organizations have found that a successful approach to respiratory protection requires a formal written Respiratory Protection Programme, which both guides users and draws attention to the many factors that are involved.

3.2 Skin protection

Although the respiratory system is the primary point of vulnerability to chemical and biological agents, the skin may sometimes need protection as well. Depending on the nature of the threat and the required activities, such protection can be provided by coveralls or ponchos, overboots and gloves, or fully encapsulating suits which combine full-body, head, hand and foot protection. Depending on the design and the material used, single or multiple use is possible. The protection factor achieved with body protection depends on:

1. The permeability of the material to chemical and biological agents.
2. The “tightness” of the equipment.

As explained earlier, no material is impermeable to all contaminants for an indefinite period. Both the material’s specific resistance to certain chemicals, and abrasions, micro-holes and cuts can reduce the effectiveness of skin protection. Even an “impermeable” material does not provide unlimited protection. Some widely used materials do not protect against certain chemical agents at all: natural rubber is penetrated by sulfur mustard within minutes. On the other hand, almost all materials will provide sufficient protection against biological agents. Most modern military equipment is designed to provide protection against both chemical

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[7] Respirators are usually designed to fit 95% of the adult population of the country concerned.

and biological agents. Suits can be made from air-permeable materials in order to reduce the heat load for the wearer and to allow them to be used for longer periods. Since these air-permeable materials are essentially a charcoal filter on cloth (acting like an air-purifying respirator), they purify the ambient air to a certain extent, thus providing the wearer with limited ventilation. This should not be confused with the undesired ventilation of the "bellows effect" described below.

Movement of the wearer causes air to be pumped through the hood, sleeves and jacket openings – the so-called "bellows effect". This provides cooling and ventilation to the wearer and may be subjectively very welcome, but it also significantly reduces the protection factor. With relatively tight sealing around the mask facepiece, the sleeves and the leg openings, and a one-piece coverall design, the "bellows effect" can be reduced, but not completely eliminated. For extremely high concentrations of chemical and biological agents it is therefore necessary to use a sealed over-pressurized suit. In addition, in the selection of individual protective equipment, it must be remembered that masks and suits are often designed as an ensemble. Using a different mask or donning the ensemble in a different way can reduce the protection factor significantly. As with all individual protective equipment, the use of protective suits requires trained and physically fit personnel. This is especially important in warm or hot environments, where the physiological strain of wearing protective clothing can be considerable, as is discussed further in Appendix A4.1 below.

3.3 Special cases

Certain groups of people cannot wear standard individual protective equipment at all. Small children (under 7 years) and people with lung dysfunction cannot normally overcome the breathing resistance of an air-purifying respirator. Casualties with head or facial injuries may not be able to wear a mask, and a certain percentage of people cannot be provided with properly fitting masks because of their unusual facial dimensions or structure.[7] Special equipment is then needed, such as casualty bags with a power-assisted respirator, childrens' filtrating jackets, or over-pressurized hoods for prams. The psychological problems associated with the wearing of individual protective equipment can make proper use impossible for some individuals, particularly children.

4. Collective protection

With collective protection, a group of people are provided with uncontaminated air and protected from skin contact with chemical or biological agents without having to cope with the difficulties associated with individual protective equipment. Collective protection is not affected in any way by the physical and mental condition of the users. It also depends less on the level of training than individual protective equipment. Collective protection can therefore be seen as a special form of engineering control and, when the situation allows, is preferable to individual protection. It can be achieved by means of:

1. Shelters and/or vehicles not specifically designed for protection against chemical and biological weapons.
2. Specially designed units.

Generally, any building or vehicle can be used to provide some protection against chemical and biological weapons by making it airtight, thus preventing agents from entering it. This can be achieved by applying chemically resistant sheets and adhesive tape to all openings, such as windows, doors and ventilation openings. Unfortunately, this not only keeps chemical and biological agents outside, but also the oxygen needed to replenish what is being breathed, and traps carbon dioxide inside. However, a makeshift solution can at least provide some level of temporary protection. Two factors limit the protection factor of makeshift adaptations of conventional buildings or shelters to counter the threat of chemical and biological weapons:

1. The tightness and resistance of the seal.
2. The volume of air per person.

As stated previously, it is extremely difficult, if not impossible, to produce an absolutely airtight system. Contaminating agents will penetrate sooner or later. The paradoxical situation may arise that, after a certain time, the concentration of agent outside the shelter will have naturally decreased to a safe level, while those inside the shelter are still exposed to low concentrations. This can lead to a long period of low-level exposure inside the shelter compared with a short high-level exposure outside for the same dosage.[8] It is important for those inside the shelter to know when it is safe to break the shelter seal. In tightly

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[8] The dosage for vapours and aerosols is the amount of a substance per unit volume per unit time, e.g. mg.min./m^3. Depending on the toxicology of a substance, 100 mg/m^3 over 1 min can be the same as 1 mg/m^3 for 100 min.

sealed shelters, monitoring of the dosage both inside **and** outside the shelter will therefore be necessary. With the wrong sealing material (one not resistant to chemical and biological agents) or inadequate seals, the level of exposure inside the shelter might actually be higher than outside.

Another problem with makeshift airtight shelters is the accumulation inside them of carbon dioxide and the using up of the available oxygen. As a minimum, an airtight shelter should have a volume of 10 m^3 per person and per hour (assuming that the occupants will be at rest, or at most, that they undertake only occasional light activities). A somewhat longer period of occupation could be achieved by placing open trays containing quicklime on the floor (to absorb carbon dioxide), but this, of course, does not provide any additional oxygen.

Specifically designed units or shelters are normally fitted with airtight seals and/or over-pressurized with uncontaminated air. The performance of the air-purifying system must be appropriate for the volume of the room and the planned capacity, and a slight over-pressure should preferably be maintained to make airtight seals unnecessary. The system as a whole needs regular inspection and maintenance. Modern buildings are often built with air-conditioning systems. Depending on the capacity of these systems, it may be possible to equip them with high-efficiency particle air (HEPA) and charcoal filters, thus providing an (over-pressurized) shelter. Excellent guidance is available on the protection of building environments.[9]

While a number of factors make the use of collective protection preferable to individual protection, there are also the following disadvantages:

1. Cost
2. Availability in case of need
3. Restriction of mobility

Only a few countries in the world can afford to provide all – or even most – of the population with shelters that will adequately protect against chemical and biological agents. Sweden and Switzerland are two examples of countries that have done so. The costs are determined not only by the building and maintenance costs alone, but also by the loss

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[9] See, for example, *Guidance for protecting building environments from airborne chemical, biological, or radiological attacks*, published by the Centers for Disease Control and Prevention in the United States, available online at *http://www.cdc.gov/niosh/bldvent/2002-139E.html.*

of rooms for other purposes. In Sweden, therefore, shelters must be built in a way that allows them to be used for other purposes in peacetime (e.g. as music rooms in schools or playrooms in nurseries). People must be able to reach the shelter within a reasonable time after a warning has been given. If they are caught in the open, the procedures to allow them to enter the shelter without introducing contamination can be very complicated, requiring both time and resources (e.g. airlocks, decontamination facilities, clothing to change into, etc.). It is also clear that personnel will not be able to move in and out of the shelter freely to carry out tasks in the open unless the shelter has the necessary facilities. Consequently, protected shelters will usually be suitable only for personnel who do not have outside tasks. Another form of collective protection is provided by vehicles protected against chemical and biological weapons. These vehicles have their own filtered ventilation systems. However, those using them will need lengthy training in the procedures for leaving and re-entering such vehicles to prevent the spread of contamination to the inside.

5. An example of the application of risk-management principles: the problem of potentially contaminated mail

After the "anthrax letters" episode in the USA in 2001[10], a number of organizations and companies all over the world have assessed the risk of such an incident on their premises as significant enough to require action. One way of dealing with the situation that might be suitable for a smaller organization is described here. It is presented as an illustration of the role that protection plays in the risk-management approach, and should not be regarded as a method that would be suitable for all organizations or circumstances.

After a thorough risk assessment, a company producing industrial safety equipment (with around 500 employees) concluded that they

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[10] See Appendix 4.3 to Chapter 4.

might become a target for anthrax hoaxes or an actual attack. They were aware that even a hoax or false alarm would shut down production for at least two days (before an all-clear could be given), and would also reduce the productivity of the employees for an extended period for psychological reasons. The company receives approximately 150 letters and small packages every day, plus a number of letters addressed to individual employees. These were normally opened in the mailroom by a clerk, before registration and distribution.

To reduce the risk to personnel and possible loss of company assets to an acceptable level, the company introduced a system of measures, including administrative and engineering controls, and the limited use of individual protective equipment.

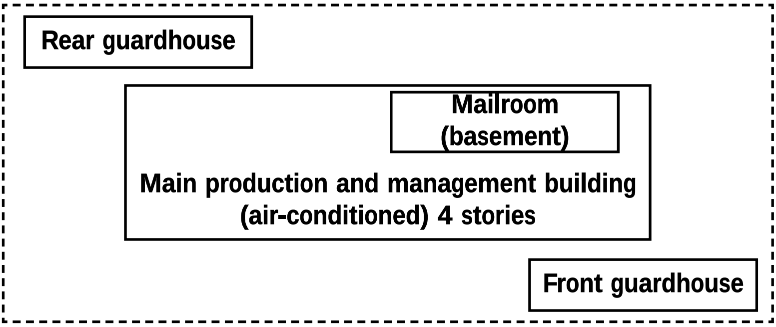

Figure 1. **Schematic facility plan**

Before the “anthrax letters” incident, mail was delivered and visually scanned in the front guardhouse, then received by the mail clerk, opened in the mailroom and distributed to the different parts of the company. Under that system, the opening of an “anthrax letter” would expose the mail clerk to a potentially lethal concentration of anthrax spores, and the air-conditioning system would spread the spores inside the building, thus forcing evacuation and the closing down of production. The company introduced a number of measures to reduce this risk (Figure 1):

1. All employees were requested not to receive any private mail at the company address, thus reducing the amount of mail to be checked by the mail clerk (administrative control).

2. The site for the opening of envelopes was moved from the main building to the rear guardhouse, which has an independent air-conditioning system. In an anthrax scare or hoax, the potentially contaminated area will be restricted to this guardhouse. The production building will not be affected (administrative control).
3. All mail is transported in a tightly sealed plastic bag to the rear guardhouse to prevent any possible cross-contamination (engineering control).
4 All mail is still visually scanned, but now in the rear guardhouse (administrative control).
5. Since the company works with toxic chemicals for testing respirators, several portable chemical fume hoods were available. After assessing the technical specification of these fume hoods, the company safety department recommended that they should be used as biosafety cabinets[11] (engineering control).
6. One fume hood was moved to the rear guardhouse for use as a biosafety cabinet (engineering control).
7. The mail clerk and security personnel were briefed and trained in the opening of the mail inside the biosafety cabinet before carrying out a standard operating procedure requiring that all mail must be opened and screened inside the cabinet (administrative control).
8. Protective gloves and decontamination solution for cleaning the gloves inside the biosafety cabinet were given to the mail clerk (individual protection).
9. As a confidence-building and risk-communication measure, all personnel were informed about the decisions and the process.

The company subsequently experienced two false alarms, both of which were successfully managed without any disruption of daily activity or loss of production.

This is, of course, a simplified example of a logically ordered approach to dealing with a special form of bioterrorism. It illustrates how the use of individual protective equipment can be restricted to the absolutely necessary minimum, preference being given to administrative and engineering controls. The result is not only safer than that achieved by

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[11] A biosafety cabinet is an enclosure with internal under-pressure (ensuring that no air leaks to the outside), equipped with a HEPA filter through which a pumped stream of outgoing air is directed. Such cabinets are commonly used in laboratories where work with potentially harmful organisms is carried out.

the more obvious actions taken by many other organizations (provision of masks and gloves to staff handling mail, i.e. protection alone), but also results in minimal disruption to normal activity, even if a false alarm, hoax, or actual threat materializes.

Further reading

Forsberg K, Mansford SZ. *Quick selection guide to chemical protective clothing*, 3rd ed. New York, Van Nostrand Reinhold, 1997.

The selection, use and maintenance of respiratory protective equipment – a practical guide, 2nd ed. Suffolk, Health and Safety Executive, 1998.

Ridley J. *Safety at work*, 3rd ed. Oxford, Butterworth-Heinemann, 1990.

APPENDIX A4.1: PROBLEMS RELATED TO PROTECTION

Modern biological and chemical protective equipment has made it possible to survive in many types of toxic environment. Such protection, however, may be achieved at the cost of a significantly reduced ability to function. In selecting protective equipment for biological and chemical preparedness, a balance should be struck between the degree of protection necessary for the potential hazard concerned and the resultant increase in difficulty of the functions to be carried out by those wearing such equipment. There may, of course, be considerable differences between the protection requirements of response teams dealing with civil incidents and those of military personnel, who may need to operate for long periods in a toxic biological or chemical environment.

The key to the successful use of protective equipment, whether by civil incident-response teams or the military, is familiarity through repeated training in using the equipment. In extended operations in which protective equipment is required, the following problems need to be carefully considered.

Heat stress

When protective clothing is worn, insulation is increased, evaporation of sweat from body surfaces is reduced, and the body consequently suffers a significant decrease in its natural ability to lose heat. This decrease can be so large, especially if impermeable protective clothing is being worn, that potentially fatal heatstroke is a possibility after less than an hour. Supervisors of responders or emergency services must be aware of the need for careful monitoring of those wearing protective clothing and of the methods of avoiding this problem, e.g. by planned work/rest cycles, or the use of specialized cooling equipment. A further problem associated with the wearing of a respirator is the effort required to breathe against the resistance of the filter canister. This can severely limit the work rate possible, and also significantly increase the psychological stress experienced (see below).

Psychological stress

Apart from the physiological stresses mentioned above, individuals wearing protective clothing can experience great psychological stress. This may even be more important in limiting performance than physiological problems. Stress results from fear of the chemically or biologically contaminated environment, the claustrophobic effects of protective clothing (especially the respirator), the potential impairment of the ability to communicate with colleagues, the general discomfort of wearing the often bulky clothing, perceptions of the increasing physiological stresses (heat and breathing stress), and of the reduced ability to function and perform tasks that may be necessary for survival. As a result, decision-making may be impaired.

Ergonomic difficulties

The nature of chemical protective clothing creates many ergonomic problems that may interfere with the performance even of simple tasks. Thick rubber gloves cause problems with any task requiring fine touch (computer operation, medical examination, etc.), and bulky clothes hamper movement in restricted spaces (e.g. in ambulances). The lenses of the masks may be incompatible with optical equipment, and medical personnel may experience extreme difficulty in carrying out even basic procedures of patient management (cardiopulmonary resuscitation, airway management, etc.).

Side-effects of medication

Certain medications commonly used to counter the effects of biological and chemical agents can create problems of their own. Pyridostigmine is frequently used as a pretreatment drug for nerve-gas poisoning. It is intended to be taken before exposure in order to improve the chances of survival if a nerve-gas attack actually materializes. Pyridostigmine can, however, have side-effects of its own, such as diarrhoea, intestinal cramps and visual problems. The most common item of medical equipment used in chemical defence worldwide is the autoinjector. Although the contents of the different types may vary, the medication generally used is atropine, which is the antidote required after nerve-gas exposure. However, if atropine is injected in the absence of nerve-gas poisoning, it can have significant side-effects, such as increased heart rate, disturbances of the heart rhythm, dry mouth and decreased sweating (causing even more severe heat stress), and blurred vision.

Logistic problems

The logistics associated with the issue of protective equipment to the personnel needing it can also be a problem. Some equipment, once removed from its sealed packaging or contaminated, cannot be readily decontaminated, and consequently is unsuitable for reuse. If large numbers of personnel require protective equipment, this can be extremely costly.

Conclusions

Response teams dealing with civil incidents may be less affected by the problems described above since they are likely to be deployed for shorter periods, and are better able to allow personnel to rest outside the contaminated area without loss of efficiency. If the military are involved, however, some of the problems associated with the use of protective equipment for long periods might arise even when biological or chemical agents have not been released, e.g. when preparations are being made in anticipation of an attack. Such preparations may in themselves be a significant disadvantage for the defending party, and may even be the reason that the threat was introduced by the aggressor. However, a state that elects not to defend or protect itself from biological and chemical weapons might be vulnerable to the full effects of such weapons and to the mass casualties that they produce. It is instructive to note that no major military attack with biological or chemical weapons has yet been made on countries with forces that are well equipped and trained for biological or chemical warfare.

Successful preparedness, including biological and chemical threat assessment, contingency planning and preparation for a biological or chemical incident, calls for a strategy that is both justified by, and relevant to, the potential threat. Overreaction to a threat could be the very effect sought by an aggressor.