



# Personal Protection Equipment and Monitoring Devices for Maritime Chemical Emergencies



**MEDITERRANEAN ACTION PLAN (MAP)  
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR  
THE MEDITERRANEAN SEA (REMPEC)**







INTERNATIONAL  
MARITIME  
ORGANIZATION



UNEP-PNUE



MAP



REMPEC

REGIONAL MARINE POLLUTION EMERGENCY  
RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)  
MEDITERRANEAN ACTION PLAN

# Guide for Personal Protective Equipment and Monitoring Devices for Maritime Chemical Emergencies

Regional Information System

[www.rempec.org](http://www.rempec.org)

December 2012



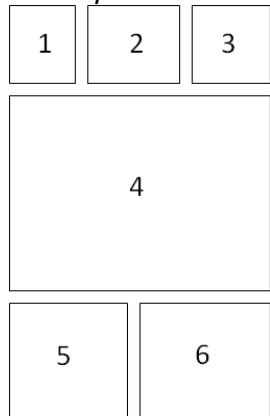
## Note

This document is aimed at facilitating the implementation of the "Protocol concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency" of the Barcelona Convention (Emergency Protocol, 1976) and the "Protocol concerning Co-operation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea" (Prevention and Emergency Protocol, 2002) by the Contracting Parties of the Barcelona Convention.

These "Guidelines", which are advisory, do not affect in any way already existing or planned national laws and regulations related to matters covered by it. REMPEC assumes no liability whatsoever for any potentially damaging consequences which could result from the interpretation and use of information presented in this document.

The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of IMO, UNEP, MAP and REMPEC concerning the legal status of any State, Territory, city or area, or of its authorities, or concerning the delimitation of their frontiers or boundaries.

Cover photos:



1. © Observatoire Tunisien de l'Environnement et du Développement Durable – Agence Nationale de Protection de l'Environnement – ANPE
2. © International Tanker Owners Pollution Federation - ITOPF
3. © ITOPF
4. © Centre de documentation, de recherche et d'expérimentations sur les pollutions accidentielles des eaux
5. © Maritime New Zealand
6. © ITOPF

The Guidelines are downloadable from REMPEC's website ([www.rempec.org](http://www.rempec.org)) in the Section "RIS/Operational Guides and Technical Documents"

For bibliographic purposes this document should be cited as follows:

IMO/UNEP: Regional Information System - Operational Guides and Technical Documents - Guide for the Personal Protective Equipment and Monitoring Devices for Maritime Chemical Emergencies, REMPEC, December 2012.



## **TABLE OF CONTENTS**

### ***PERSONAL PROTECTIVE EQUIPMENT AND MONITORING DEVICES FOR MARITIME CHEMICAL EMERGENCIES***

1. INTRODUCTION
2. ROUTES OF EXPOSURE
3. DESCRIPTION OF PERSONAL PROTECTIVE EQUIPMENT (NON-RESPIRATORY EQUIPMENT)
  - 3.1 Head and facial protection
  - 3.2 Hand protection
  - 3.3 Foot protection
  - 3.4 Body protection
  - 3.5 Protective garment fabrics and performance parameters
  - 3.6 Ancillary personal protective equipment
4. DESCRIPTION OF PERSONAL PROTECTIVE EQUIPMENT (RESPIRATORY EQUIPMENT)
  - 4.1 Facepieces
  - 4.2 Air pressure in facepieces
  - 4.3 Respirators
    - 4.3.1 Air-purifying respirators
    - 4.3.2 Atmosphere-supplying respirators
  - 4.4 Protection factors of respiratory equipment
  - 4.5 Common problems encountered when wearing respiratory equipment
  - 4.6 Maintenance and storage
5. PORTABLE MONITORING DEVICES FOR CHEMICAL SPILL RESPONSE
  - 5.1 General notions
  - 5.2 Air monitoring portable devices
  - 5.3 Water monitoring portable devices
6. SPILL PROTECTIVE LEVELS AND ASSOCIATED PROTECTIVE EQUIPMENT (THE SELECTION OF PROTECTIVE EQUIPMENT)
7. ENTRY INTO ENCLOSED SPACES
8. DECONTAMINATION
  - 8.1 Decontamination methods
  - 8.2 Criteria for site selection and site management
  - 8.3 Materials, equipment and layout for establishing an on-site decon station
  - 8.4 On-site decontamination operating procedures
9. CONCLUSION

ANNEX1 MAINTENANCE CHART FOR A SELF-CONTAINED BREATHING APPARATUS (SCBA)  
ANNEX 2: LEVELS OF PROTECTION FOR PRE-DETERMINED LEVELS OF HAZARDS  
ANNEX 3: DECONTAMINATION SOLUTIONS



# **PERSONAL PROTECTIVE EQUIPMENT AND MONITORING DEVICES FOR MARITIME CHEMICAL EMERGENCIES**

## **1. INTRODUCTION**

A hazardous material spill is an unplanned event where the magnitude of the event may be small or large, where the time to react to the event is critical and where the level of exposure may range from insignificant to fatal, with exposure of the individual occurring in either open space with good ventilation (e.g. on the deck of a ship) or the exposure occurring in a confined space with poor ventilation (e.g. in a cargo hold).

A chemical spill emergency is not routine and this factor together with the multiple hazards encountered such as the multi-substance effect if the spill involves more than one chemical, the unfamiliar conditions, the disorderly physical environment, and the lack of complete information at the initial stages distinguishes a hazardous material spill emergency from the occupational setting, the latter usually involving the routine handling of a known substance. It is therefore essential that those responding to a chemical spill emergency are equipped with adequate personal protection to ensure their safety.

It must be emphasized that personnel protection, of some form, is required during all phases of the response operation [i.e. the control phase-clean up-recovery-disposal phase], whilst the degree of protection will depend on the circumstances of the incident as it evolves.

In a chemical spill situation, the following are some of the hazards that response personnel can be exposed to:

- combustion;
- corrosion;
- explosion;
- flammability;
- radioactivity;
- poison;
- heat stress;
- cold stress;
- oxygen deficiency;
- failure of protective equipment;
- falling debris;
- high concentration(s) of spilled material.

The essential function of protective equipment is to reduce or eliminate, as far as is possible, the risks of exposure against the physical, chemical and thermal hazards listed above. **Personal protective equipment does not reduce the hazard, it only sets up a protective barrier which can be broken if there is a wrong choice of equipment or if the equipment is used incorrectly or if defective.**

## **2. ROUTES OF EXPOSURE**

The way a hazardous substance expresses its effects on the body is, in part, determined by the route of exposure. A brief description of the potential routes of exposure of personnel during response operations is thus warranted.

There are **four ways a hazardous substance can enter the body**:

- **inhalation:** this is the route of entry for gases (e.g. hydrogen sulphide, chlorine) vapours (e.g. acetone and trichloromethane vapours) and particulate matter (e.g. coal dust, asbestos, silica). Exposure via this route can lead to an irritation of the respiratory tract lining, causing lesions in the lung tissues. It can also lead to the absorption of the substance into the systemic system via the alveoli, causing damage to other parts of the body which are at a distance from

the point of entry.

- **dermal contact:** this is the slowest route of entry into the body but is a common problem encountered during response to hazardous chemical spills. Some substances can pass through the skin into the bloodstream causing internal damage (e.g. aniline, phenol) Others can cause surface damage on contact due to their corrosively (e.g. caustic soda, hydrofluoric acid). In this regard the eyes deserve special mention due to their particular vulnerability to damage from corrosive and toxic vapours or gases.
- **ingestion:** this is the route of entry for substances which are present in food and liquids. Once a toxic substance is absorbed through the digestive system, it is usually stored in the liver where it may be detoxified. Damage to the liver cells can however take place, if the concentration of the substance reaches a certain threshold limit. Provided that proper protective clothing is worn and good decontamination practices are followed to prevent secondary contamination, this route of exposure should not be a major concern for response personnel.
- **injection:** the last route of entry is when the skin is punctured or broken (e.g. cuts, lesions, wounds) by objects contaminated with the toxic material. Once this has taken place, the systemic system will deliver the substance to other parts of the body.

The concentration (or dilution) of the substances together with the length of exposure are two other factors which determine the extent of damage which an individual experiences on exposure to a particular hazardous substance. To this end, all response personnel who use protective equipment should be familiar with both its use and its limitations.

### 3. DESCRIPTION OF PERSONAL PROTECTIVE EQUIPMENT (NON – RESPIRATORY EQUIPEMNT

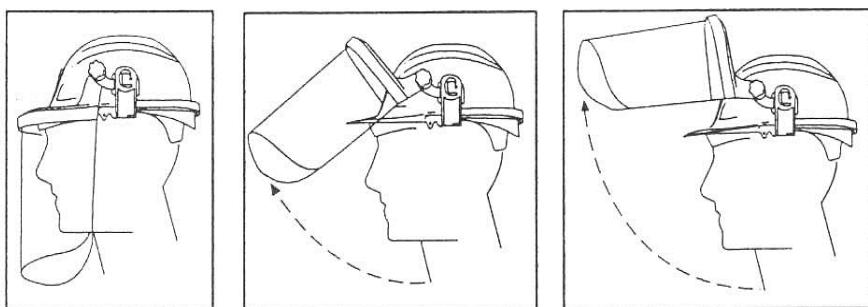
**Personal protective equipment** comprises **protective clothing** and **respiratory equipment**. Briefly, it can be described as the **equipment which shields or isolates response personnel from the physical, chemical and/or thermal hazards at the incident scene**. Personal protective equipment is worn in various combinations to protect the respiratory and auditory system, the skin, the eyes, the face, the hands and the rest of the body. Additional equipment is sometimes worn or carried by response personnel to detect and monitor their exposure to the spilled material as well as to measure the level of contamination in the immediate surroundings.

#### 3.1 Head and facial protection

Protection of the head, ears, eyes and face is achieved by utilizing a combination of equipment such as hard hats (also known as safety helmets), ear plugs or muffs, safety spectacles or goggles and/or face shields. Head and facial protective gear includes:

- **hard hats** (see **Figure 1**) which are intended to reduce head injuries and to provide protection from falling objects and projectiles. Certain design features are worth noting:
  - the presence of a head harness with a fitted sweatband to ensure that the helmet can be securely fitted, yet comfortably supported on the head;
  - the presence of sloped "rain" channels on the rim of the hat to divert overhead liquid spills from reaching the wearer's shoulders and neck;

- the ability to allow the use of helmet accessories such as a winter liner and a chin strap. The former is worn during cold weather whilst the latter helps to secure the hat to the head and is worn during bending/ducking movements. Most hard hats are today designed to give their wearers the opportunity to attach ear, eye and face protection.
- **face shields** which are intended to provide eye and face protection from the physical hazards and from the splashes of liquids, although they provide no protection against dust and vapour hazards. They come in various designs such as those with an adjustable ratchet headgear with a flip-up facility. It is advisable to use a face shield in combination with a hard hat (see **Figure 1**).



Connect screen flip-up facility

**Figure 1: Hard hat with visor**

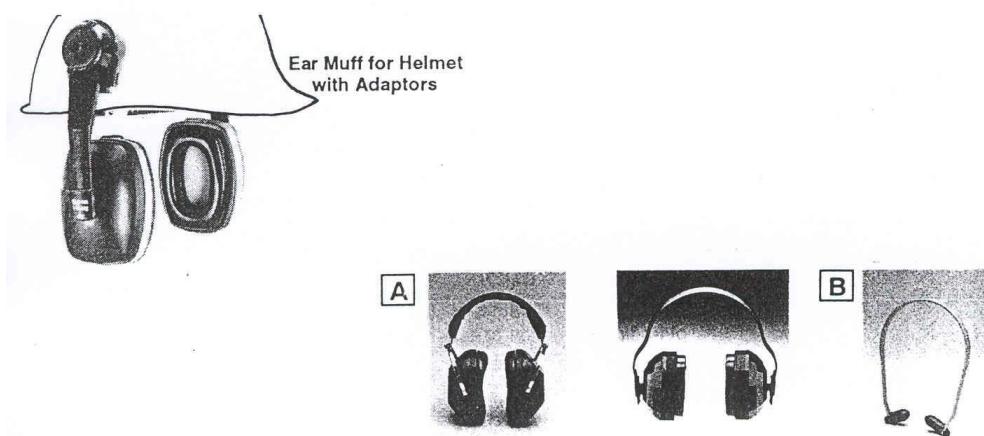
In this configuration, there should not be a gap in the attachment between the face shield and the brim of the hat. This will ensure that there is no leakage into the face shield from overhead spills. Other design features worth noting are:

- the anti-fog (non-mist) nature of the visor;
- the chemical resistance of the face shield;
- bottom moulded cap for lower face protection in the chin area;
- the anti-scratch and anti-static nature of the visor.
- **Safety spectacles and goggles** which are intended to provide eye protection ( see **Figure 2, (a), (b)** ). This type of eye protection is usually worn with a half face respiratory mask or when no face shield is used. Safety spectacles can be utilized together with a face shield as long as the wearer's vision is not impaired. Certain design features worth noting are:
  - the anti-fog (non-mist) nature of the lens;
  - the chemical resistance of the material of construction;
  - the wide vision design for goggles and the presence of side shields for spectacles (for lateral protection);
  - the anti-scratch and anti-static nature of the lens;
  - the good fit of the safety spectacles when worn over prescription spectacles. (In this case the term is known as "over specs").



**Figure 2: Examples of safety spectacles (a) and goggles (b)**

- **Ear muffs and plugs** (see **Figure 3**) which are intended to protect the auditory system from excessive noise and high pitched sounds resulting from the use of heavy machinery and impact tools.



**Figure 3: Hearing protection: [A] ear muffs, [B] ear plugs**

- **Ear muffs** consist of a padded strap of absorbent material with a cushioned ear cup attached to either end. The ear cushions can be either liquid or foam filled. Some features worth noting for ear muffs are:
- the non-interference with safety helmets or face masks for ear muffs which are of the strap type;
  - the possibility for direct helmet fixing;
  - the light weight construction to ensure comfort when worn for long periods;
  - the good seal of the ear cushion to ensure a consistent level of protection and proper sound attenuation.
- **Ear plugs** come in reusable or disposable types. Design features worth noting for ear plugs are:
- the non-allergenic nature of the material of the caps/pods to avoid skin irritation of the ear canal;
  - the effective sealing of the ear opening without causing discomfort to the user when worn for long periods or due to frequent donning and doffing (removal);
  - for the reusable types of ear plugs, the detachability of the caps/pods from the connecting cord or plastic neck band for routine cleaning.

In some cases, protective equipment can make communication difficult. Manufacturers have responded to this problem by developing a range of combined hearing protection and communication systems so that each person wearing the headset can communicate with his counterpart through a standard or throat mouthpiece via a light weight radio system which can be belted or pocket mounted.

### 3.2 Hand protection

**Hand protection is achieved by wearing gloves.** There exists a wide choice of suitable glove types. Certain features worth looking for when selecting a particular type of glove are:

- the resistance of the glove material to the chemical of concern including extreme environments such as spillages involving high and low temperature cargoes;
- the resistance to abrasion, punctures and tears;
- a good fit to maintain maximum digit dexterity and overall flexibility;
- a good grip (this is achieved by having a roughened surface on the palm side and fingers of the glove);
- glove thickness and length of cuff (the thicker the material and longer the cuff, the greater the protection);
- the presence of inner lining or the possibility of wearing a hand cotton stockinette under the glove for added protection.

In some cases due to the heavy nature of the work or the abrasion nature of the hazard, hide work gloves might need to be worn over chemical gloves. Hide gloves, particularly those used in fire-fighting, are able to withstand heat, cracking, water stiffness and remain supple after repeated moisture exposure. However, once a hide glove becomes contaminated, it should be discarded as the hide will act as a sponge, holding the contaminant against the inner side of the glove bringing the contaminant into direct contact with the hand.

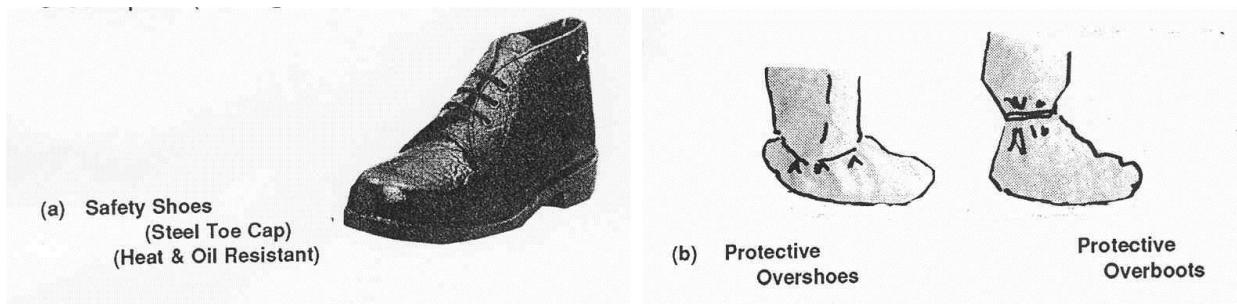
Irrespective of the glove type, good practice dictates the following:

- checking the integrity of the gloves before wearing them by looking for tears or pinholes and other weak spots (signs of cracks or peeling are usually good indicators);
- discarding any gloves that are contaminated or soiled with hard-to-remove substances;
- sealing of the gloves (with tape) to coveralls/splashsuits to prevent liquids from dripping inside the gloves and running onto the wrist and hand.

### 3.3 Foot protection

The feet are as susceptible to contamination as the hands, especially when considering the possible contact when walking on areas which have been contaminated by the spilled material. The number of hazards for which foot protection may be required can range from falling objects to corrosive or toxic spilled products. The choice of foot protection will also depend on the type of response activity to be carried out. For example, the footwear needed by response personnel entering the spill site will be quite different to that required by personnel manning the command post at the incident site.

The type of footwear generally worn by response personnel is either the **shoe boot type** (made of leather or some natural or synthetic polymer) or the **disposable type** which is worn over other work shoes space (see **Figure 4**).



**Figure 4: Shoe boot (a) and disposable type (b) of foot protection**

Although the selection of a particular boot type will depend on the task at hand, certain features worth looking for when selecting a particular type of footwear, particularly the shoe boot type, are:

- the light weight construction of the boot;
- the anti-static property of the sole to reduce the risk of sparks;
- the presence of a steel toe cap;
- the good grip of the sole (cleated sole) for anti-slip purposes;
- the density of the sole for protection against treading on sharp objects;
- the chemical and heat resistance of the sole unit;
- the water repellency of the leather uppers for shoe boots made of leather;
- the reinforced shank if the shoe boots are made of rubber.

For protection against hazards resulting from liquid spills, boots coated with materials having elastomeric properties should be worn (i.e. natural and synthetic rubbers such as polybutadienes, polychloroprene, polyisoprene). It is also important to note that trousers should be worn over and outside the boots to prevent the spillage of corrosive or toxic liquids into the boot.

### 3.4 Body Protection

Protective clothing used for spill emergencies can be divided into the following two broad categories: **full bodied** and **partial bodied garments**.

Full bodied garments include:

- **full-encapsulating suits** which are one-piece gas/vapour tight suits designed to protect the wearer against gases and vapours. These suits provide a total body seal for entry and are therefore used with portable or remote air supplies. In this way, a self-contained breathing environment for entry into hazardous zones containing toxic atmospheres is provided;
- **non-encapsulating suits** which are not gas tight and therefore provide no real protection against gases and vapours but are effective in protecting against splash penetration (in this case they are known as splash suits);
- **proximity suits** which are 2- or 3-piece ensembles made of heat-reflective material with layers of insulating lining. This type of suit protects the wearer, who is present in close proximity to a strong thermal source for a short time, against radiant heat of

substantial high temperatures. Heat-reflective gloves and boots also need to be worn. These suits are not designed for fire entry and although not primarily designed for protection against hazardous material spills, they may have limited use against the hazards associated with liquid contact;

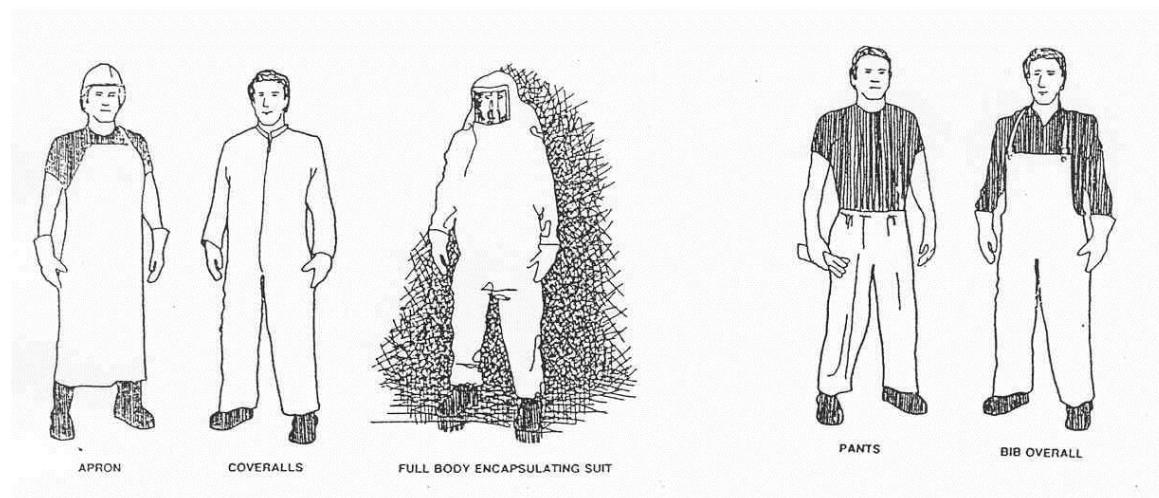
- **fire entry suits** which are ensembles made up of a coat, boots, gloves and a hood, each made up of flame-resistant materials whose outer layer is usually aluminized. These suits provide heat and flame protection for a short duration. Respiratory protection must be used with a fire entry suit.

Partial bodied garments include:

- **overalls;**
- **aprons;**
- **bibs;**
- **overalls;**
- **coats;**
- **jackets.**

An important point is that fire-fighting, chemical protective and high temperature clothing all fall under the heading of protective clothing. However, although a hazardous material spill may require the use of chemical protective clothing, one which involves a fire may require both fire-fighting and chemical protective clothing. In this regard, it should also be emphasized that the standard fire-fighting clothing is not designed to provide chemical protection although it does provide limited protection in some cases. Some fire protective suits are however, now being manufactured for use in areas contaminated by gas.

Some of the protective clothing arrangements described above are shown in **Figure 5**.



**Figure 5: Examples of protective clothing arrangements**

### 3.5 Protective garment fabrics and performance parameters

The overall performance of a garment fabric will vary according to the length of exposure, the concentration of chemical(s) spilled and the external temperature.

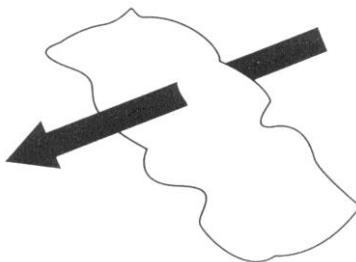
The major selection factors for a garment fabric are:

- its weight;

- its strength to resist damage due to abrasion, punctures and tears;
- its resistance to chemical degradation, permeation and penetration;
- its resistance to heat, flames, sparks and other potentially flammable situations;
- its resistance to high temperatures;
- its flexibility to facilitate the dexterity and the ease of movement of the wearer;
- its cleanability to facilitate decontamination and cleaning after use;
- its ageing resistance to ensure a long service life and to avoid replacement after a short time.

It should be mentioned that if a fabric is not chemical resistant, apart from exposing the wearer to the toxic effects of the chemical, the fabric will lose mechanical strength and thus age faster. The chemical resistance and the compatibility of a fabric are therefore important criteria when selecting a particular fabric or material of construction. Certain performance parameters are usually measured to indicate the suitability of a material. These are:

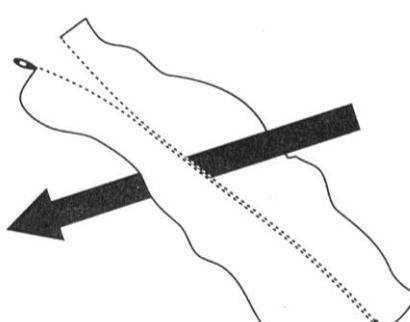
- **permeation** which is the movement of a chemical at the molecular level through the intact fabric or material (see **Figure 6**). This involves the following sequence:
  - sorption of the molecules of the substance onto the external surface of the material;
  - diffusion of the sorted molecules through the material;
  - desorption of the molecules from the external surface of the material.



**Figure 6: Permeation**

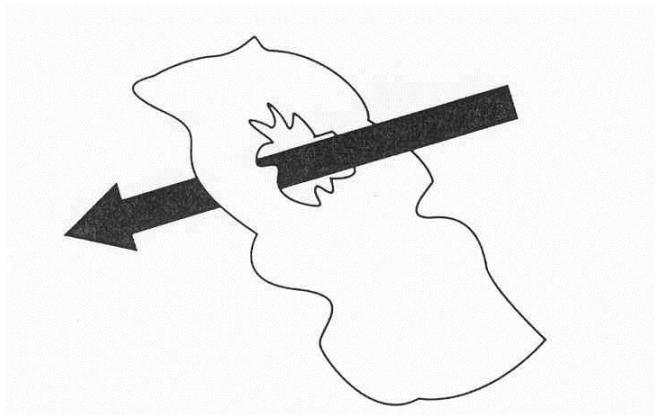
Measurable parameters associated with permeation are:

- the breakthrough time which is the elapsed time between the initial contact of the hazardous chemical with the outside surface of a protective clothing fabric and the moment the chemical can be detected on the inside surface of the material (usually measured in minutes);
- the permeation rate which is the average rate of permeation of a hazardous substance following breakthrough once a steady state flux is reached (usually measured in mg/m<sup>2</sup>/sec). Permeation rates generally decrease with increasing molecular weight of the substance and are also dependent on the thickness of the material;
- **penetration** which is the flow of a substance through zippers, button holes and other similar clothing closures (see **Figure 7**). It must be noted that seams and similar closures have shorter breakthrough times than the constituent material itself;



### **Figure 7: Penetration**

- **degradation** which is the molecular breakdown of a protective clothing or equipment material due to contact with a chemical (see **Figure 8**).



### **Figure 8:**

Other performance related measurements which are sometimes carried out include:

- **flame impingement** which provides information on whether the material ignites easily and whether it will continue to burn once ignited;
- **material burst strength** which provides information on how the material resists rupture by protruding objects;
- **material durability** which provides information on the chemical resistance following abrasion and flexing of the material;
- **puncture propagation** which provides information on how well the material resists snagging;
- **tear strength** which provides information on how well the material resists tearing once initially torn.

Both unsupported and coated fabrics are used today as garment fabrics or materials of construction, some of which are marketed under specific trade names. The list of materials includes:

- Butyl rubber;
- Neoprene;
- Polyvinyl chloride;
- Polyurethane;
- Nitrile;
- Chlorinated polyethylene;
- Nomex;
- Viton;
- Tyvek;
- Hypalon.

Owing to the extensive array of protective clothing fabrics and materials, each with its own specific chemical and mechanical properties, a response organization will no doubt face a quandary when trying to select the most suitable garment fabric or material of construction of the protective equipment which will best satisfy its needs.

The following points can, however, simplify the decision of a response organization when selecting a particular fabric and/or material of construction for protective clothing.

- i) The time period a person responding to a hazardous material spill will spend in the contaminated area is linked to the availability of the air-supply. In the case of a self-contained breathing apparatus (SCBA), which is usually the respiratory apparatus chosen in hazardous material spills, the fabric and/or material of construction must have a minimum breakthrough time which exceeds the period of air-supply provided by the respiratory apparatus used (usually 30 to 60 minutes in the case of SCBA).
- ii) The choice of one garment fabric over another should take into account the fact that the material chosen should provide protection for the most commonly spilled chemicals. It will probably be found that one material will handle most situations. A response organization will still need to decide whether to invest in additional protective clothing to cover the rare events involving certain substances (the most costlier option) or to accept the fact that a delay will exist in its ability to respond to these "non-recurring" events if the additional protective clothing is not acquired.
- iii) Resistance tables for a particular fabric should be accompanied by chemical permeation and breakthrough data.
- iv) A response organization should request information from the supplier/vendor on test procedures and testing protocols that have been used for producing chemical resistance information and other data. Some independent organizations such as the American Society for Testing and Materials and the U.S. National Fire Protection Association have devised standard testing methods for measuring the chemical resistance of protective clothing fabrics. In Europe, an E.C. directive exists entitled "Manufacturing of Personal Protective Equipment (89/686/EEC) which outlines how these products must be marked and certified. The marking (the "CE" mark) is required by European legislation and is a marking of conformity and it verifies that a producer has complied with certain criteria during the manufacturing of the garment. Irrespective of the source from where a certified suit is acquired, it should have a label which shows its compliance with a set standard and should provide information and warnings to the user, as well as, a mark of the organization that has certified it. Since chemical resistance is usually measured against a chemical which is taken to represent a chemical class (e.g. acetone for ketones, acetonitrile for nitriles), the chemical resistance of the fabric would still need to be verified for its intended use with those priority chemicals of concern to a particular response organization. Manufacturers may assist with such specific requests.
- v) A protective garment may need to be used with other devices such as visors, gloves and boots. Information should therefore be sought on all the major materials of construction and the selection of an ensemble of protective equipment should be based on the premises that the weakest material is the limiting factor.
- vi) It is important to keep the number of different types materials of construction to a minimum in the ensemble of protective equipment chosen.

### 3.6 Ancillary personal protection equipment

Other supporting pieces of protective equipment carried by response personnel for personal protection in spill emergencies include items such as:

- flashlights or lanterns to enhance visibility in enclosed spaces and wherever visibility is poor;
- fall-arrest devices such as safety harnesses or belts and life lines to enable response personnel to work at elevated heights, to prevent falls and to permit the removal of response personnel in confined spaces if they are overcome by the toxic atmosphere;
- reflective strips and other high visibility clothing which allow the wearer to be seen at night or in poor visibility conditions.

It must be emphasized that any hardware carried must be spark-free or explosion-proof for use in combustible atmospheres.

## 4. DESCRIPTION OF PERSONAL PROTECTIVE EQUIPMENT RESPIRATORY EQUIPMENT

Protection of the respiratory system is required when:

- the surrounding atmosphere is contaminated with potentially respiratory materials such as particulates, vapours and gases;
- the surrounding atmosphere is deficient in oxygen (oxygen content of clean dry air is 20.93 vol percent; the oxygen content of air containing 1 vol percent water vapour is 20.7 vol percent);
- a combination of the above two factors is present at the spill site.

Protection of the respiratory system is achieved by wearing a respirator. **A respirator is a device which is worn over the mouth and nose, or the entire face or head and which is intended to protect against any airborne physical and chemical hazards, either by removing the contaminant from the air or by supplying an independent source of clean air for breathing.** An essential part of any respirator is the facepiece.

### 4.1 Face pieces

The **facepiece** (i.e. the device which encloses the mouth and nose, whole face or head) can be of two types, tight fitting and loose fitting.

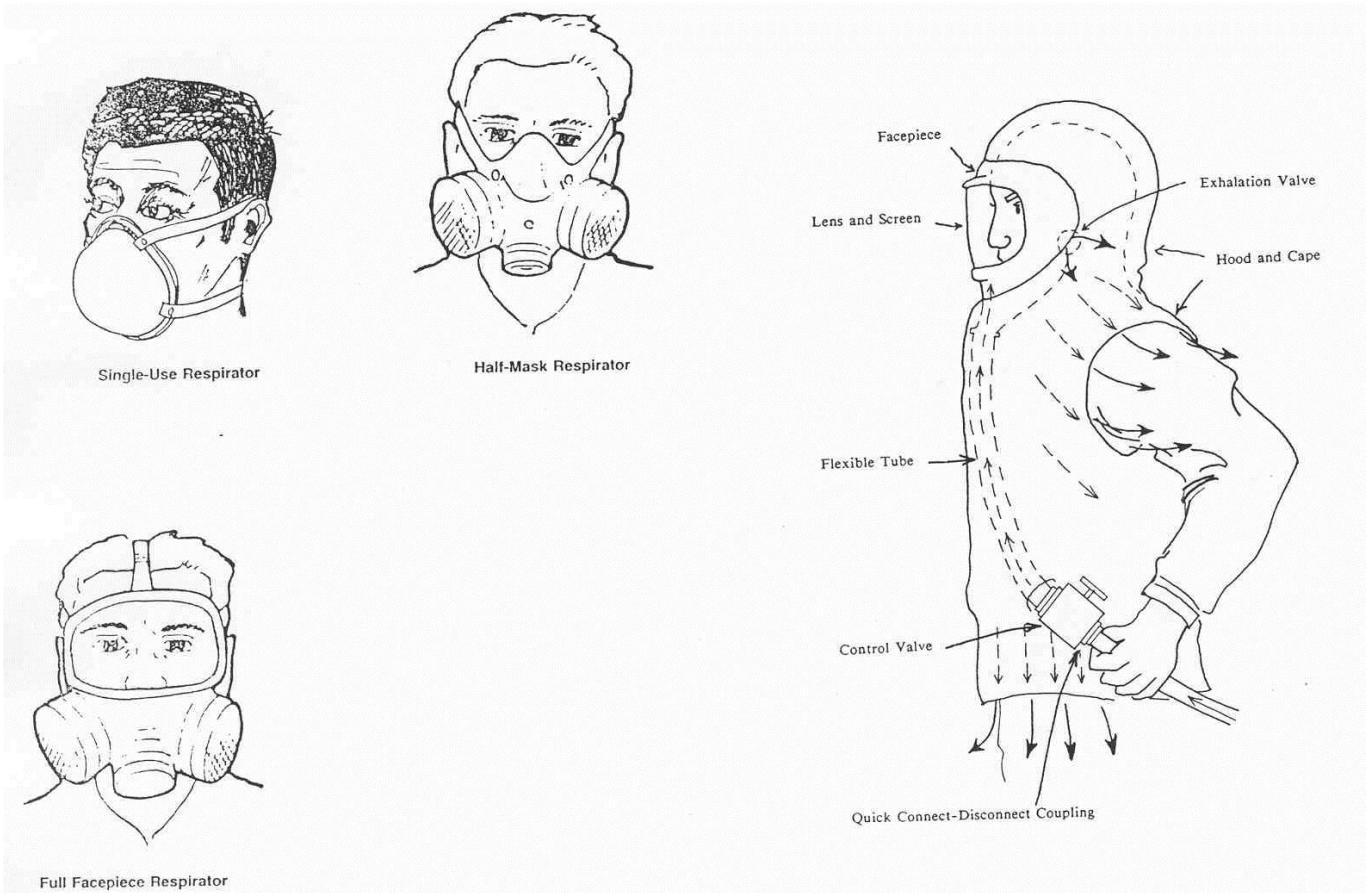
Tight fitting facepieces are often referred to as masks and form a tight seal between the facepiece and the skin. They are made of flexible impermeable mouldable materials such as rubber or neoprene. All designs incorporate some kind of adjustable elasticated head straps which buckle together or wrap at the back of the head.

Depending on the amount of facial cover, tight fitting facepieces can have one of three configurations:

- **quarter mask:** covering the mouth and the nose with the lower sealing surface resting between the chin and the mouth. This type of mask is easily dislodged and is therefore not often used;
- **half mask:** covering the mouth and nose with the lower sealing surface passing under the chin. The type of mask provides a better seal than the quarter mask;
- **full-facepiece:** covering the face from the forehead, approximately below the hairline, to under the chin. By also covering the eyes, this type of mask provides the greatest

protection to the wearer. The incorporation of a visor or eye pieces permits vision.

Loose fitting facepieces include hoods, helmets, suits and blouses. Since they enclose the head, loose fitting facepieces usually require an independent source of clean air. There are various designs which make categorizing difficult. They can, however, be divided into three main groups, according to the extent of area covering they provide. Thus:



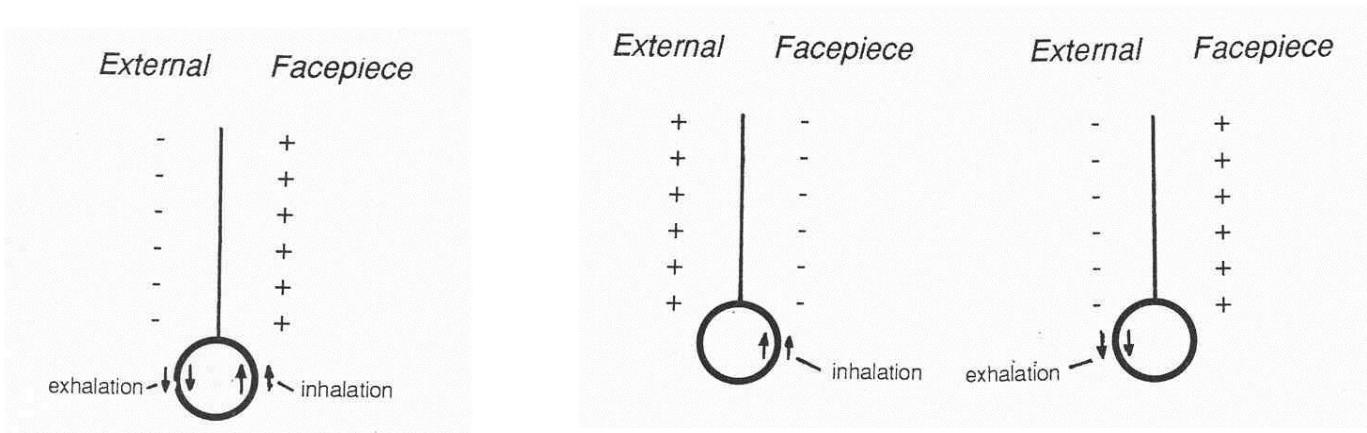
**Figure 9: Examples of different facepiece configurations**

#### 4.2 Air pressure in facepieces

The air pressure inside the breathing zone of a facepiece can be either negative or positive relative to the ambient external air pressure. For this reason respirators can be classified as either positive or negative pressure devices. A positive pressure respirator maintains a positive air pressure inside the breathing zone of the facepiece with respect to the external pressure during both the inhalation and exhalation phase. On the other hand, a negative pressure respirator has a negative air pressure inside the breathing zone of the facepiece relative to the ambient external air pressure on inhalation which on exhalation becomes positive (see **Figure 10** for pressure differences created during inhalation/exhalation phases in the two types of facepieces). An important advantage of the positive pressure respirator is the continual build-up of positive air pressure created in the breathing zone so that any leaks are directed outwards, thereby preventing the penetration of contaminated air from the exterior.

Positive Pressure Respirator

Negative Pressure Respirator



**Figure 10: Air pressure inside a facepiece during the different phases of respiration**

The two factors which determine whether a device is a positive or negative pressure respirator type are the configuration or design of the mask and the associated method of air supply. Negative pressure respirators require the use of tight fitting facepieces since an air-tight seal is required at the interface between the facepiece and the skin to prevent the leakage of contaminated air into the breathing zone of this facepiece during inhalation. In contrast, loose fitting facepieces require a forced air supply at all times and thus, this type of facepiece can only be used with positive pressure respirators. It is, however, important to point out that tight fitting facepieces are used with positive pressure respirators.

#### 4.3 Respirators

**Respirators** can be divided into the following two main categories depending on how they provide clean air to the user:

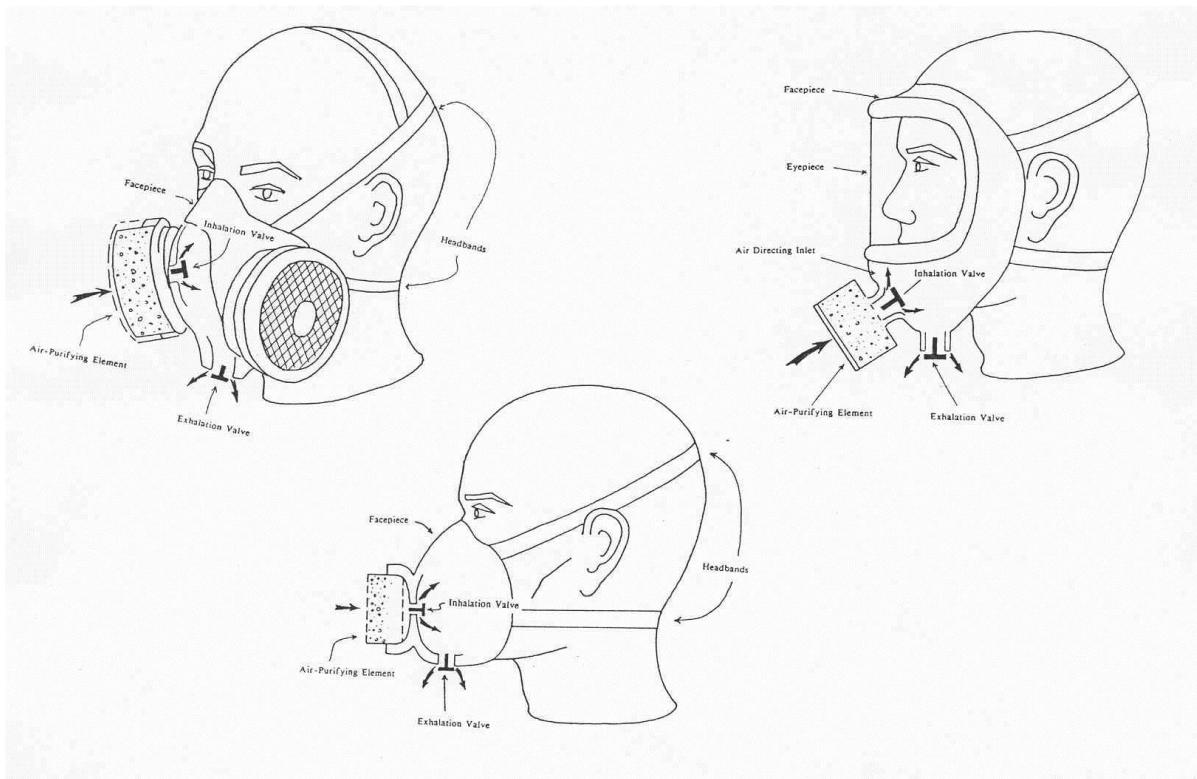
- **air-purifying respirators which remove the contaminant from the surrounding air by means of a filtering mechanism before the air is inhaled.** This category of respirators can be further sub-divided into:
  - powered respirators in which an air blower is used to pass contaminated air through the filtering element and subsequently clean air is drawn into the air space of the respirator;
  - non-powered respirators where the current of air is drawn through the filtering element
  - as air is inhaled by the user.
- **atmosphere-supplying respirators** (also known as air-supplying respirators) **which provide clean air from an external independent source other than the surrounding air.** This category of respirator can be further sub-divided into:
  - self-contained breathing apparatus (SCBA) commonly known as breathing apparatus, where the air supply originates from a portable cylinder carried by the user;
  - air-line respirators (also known as supplied air respirators) where the air is supplied through a hose from a fixed source of fresh or compressed air.

A "third" category of respirator is the **combination respirator which is assembled from**

**parts of two or more types of respirators.** Manufacturer's advice is to be sought when considering this option since parts of a specific respirator may not be interchangeable with others.

#### 4.3.1 Air-purifying respirators

**Air-purifying respirators** (see **Figure 11**) usually comprise a tight fitting facepiece (the mask) with a filter, canister or cartridge which purifies the air as it is drawn through a non-return valve(s) into the breathing zone of the facepiece. The air-purifying device may be either directly attached to the facepiece or fastened to the user's body (back or front mounted) and connected to the facepiece by means of a flexible hose. The exhaled air flows directly to the exterior through the exhalation valve(s). The purifying element may be designed to remove particulates, gases, vapours, mists or a combination of these, as required. The service life of the filtering device depends on the chemical concentration present, the type of filter material used and the breathing volume of the user.



An air-purifying respirator **should not** be used:

- in oxygen deficient atmospheres;
- in enclosed or confined spaces;
- in atmospheres where the concentrations and/or identity of the chemical hazard are unknown;
- in atmospheres where the concentration of the chemical hazard is at or near to the "immediately dangerous to life or health (IDLH)" threshold;
- for protection against chemical hazards with poor warning properties e.g. odour, taste, or irritation;
- in atmospheres where the concentration of the chemical hazard is greater than that for which the respirator is marked for use; (NOTE: The filtering mechanism of an air-purifying respirator is easily penetrated and overwhelmed in high concentrations; if a

wearer detects an odour or a taste of gas in the inspired air, or feels eye or throat irritation, the spill area should be left immediately for an area that contains clean respirable air. The filtering element should also be replaced as soon as possible and before re-use of the respirator);

- after its end-of-service-life.

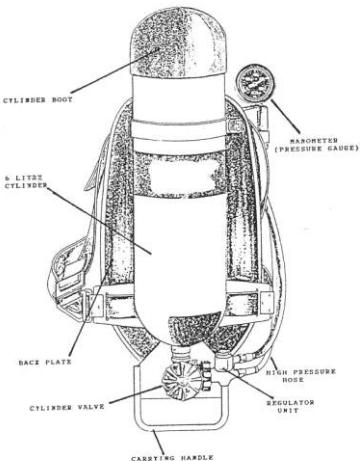
#### 4.3.2 Atmosphere –supplying respirators

**Atmosphere-supplying respirators** could be one of two types:

- self-contained breathing apparatus (SCBA);
- air-line respirators.

In a **self-contained breathing apparatus** (SCBA) the air supply comes from a source carried by the user. SCBA's are classified as either **closed** or **open circuit systems**:

- closed circuit systems are "re-breather units", indicative of the mode of operation whereby the air is rebreathed after the exhaled carbon dioxide is "scrubbed" by a chemical sorbent and the oxygen consumed replenished from an oxygen supply. (NOTE: When air is exhaled, its original constituents are present with the exception of oxygen which has been replaced by the catabolic product, carbon dioxide.). Advantages of closed circuit systems are the long working durations (1-4 hours) and the comparatively free movement over an unlimited area. Disadvantages of these systems are their bulk and for those which operate with negative facepieces, the possible inward leakage of contaminated air. Closed circuit units are not commonly used in emergency response.
- Open circuit systems consist of a portable supply of compressed air contained in a cylinder(s) attached to a carrying back plate or frame with a harness or straps for buckling purposes (see **Figure 12**). Air is supplied from the cylinder containing compressed air through a regulator. The regulator is either attached directly to the facepiece (usually a full facepiece) or is mounted to the cylinder and is connected to the respiratory inlet of the facepiece by means of a flexible hose. The purpose of the regulator is to supply air from the high pressure storage (the cylinder) to the facepiece at approximately atmospheric pressure and at the required flow volume consistent with the user's ventilation rate. Upon exhaling, the used air is exhausted to the outside via an exhalation valve. Most designs have a pressure gauge to indicate the pressure and hence the quantity of air in the cylinder as well as an audible alarm which is activated when the air supply reaches a certain critical level (usually 20-25 percent of the total). Advantages of open circuit systems are their low cost to purchase and maintain, their ease of use, their compatibility for use with fully encapsulating suits and the comparatively free movement of the user over an unlimited space. A disadvantage is their shorter working durations (30-60 minutes).



**Figure 12:** Open circuit self-contained breathing apparatus

➤ Two types of regulators are used with SCBAs:

- demand units which supply air as it is inhaled. A disadvantage of these units is that the supply is only activated on inhalation, leading to a negative pressure within the facepiece. Contaminated air from the exterior could thus leak in. **Demand units are appropriate where oxygen deficient environments are the only expected hazard;**
- pressure demand units which work on the same principal as the demand type but maintain a small continuous flow of air into the facepiece even without inhalation. This system ensures that any leakage is always to the exterior. **Pressure demand units should be used in the presence or suspected presence of highly toxic atmospheres.**

An additional factor that needs consideration is whether the SCBA is worn inside or outside of the protective garment. The configuration will depend on the type of protective garment worn, since there are those where the SCBA must be worn inside the suit and those where the equipment must be worn outside. **Table 1** summarizes the arguments for choosing either of the two configurations.

**TABLE 1**

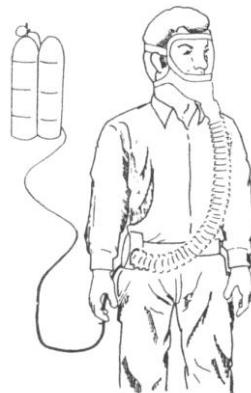
FACTOR	INSIDE ADVOCATES	OUTSIDE ADVOCATES
Protection of SCBA itself	Main advantage of wearing SCBA inside.	SCBA does not require protection, it has thick materials and can be decontaminated.
Operation of SCBA	SCBA does not require any operation or can be done on the inside anyway.	SCBA must be worn on the outside to allow access to gauge and by-pass.
Replacement of SCBA bottles	This does not have to be done as user usually does only one shift inside suit anyway.	Can be done easily on outside.
Vision	---	Is clear as one lens is present.
Decontamination	It is very simple since there is a simple exterior surface.	SCBA can be decontaminated without difficulty.
Communication	---	Is much better as normal speaking diaphragm is external.
Ease of movement and work	---	Suit is lighter and less bulky.
Assistance in case of "man down"	---	Can be done readily and in an emergency, wearer's "buddy" has access to all controls in the event that wearer has difficulty in operation.

When using a SCBA, the following precautions are necessary:

- the face mask must be checked and adjusted to ensure air tightness;
- the pressure gauge must be checked before use and the cylinders charged;
- the audible low pressure alarm should be fully functional;
- the pressure gauge should be read frequently during use;
- a facepiece whose exhalation valve is designed for demand operation should not be used with a pressure demand regulator;
- compressed oxygen should not and must not be used in a device designed for compressed air.

In an **air-line respirator**, the air supply originates from stationary source of compressed air (the compressor) and is delivered through a small diameter hose and regulator to a facepiece (see **Figure 13**). Air-line respirators are available in demand, pressure-demand and continuous-flow configurations. Air from the compressor is filtered and its pressure reduced to that required to supply air to a half or full face mask, helmet, hood or complete suit. Because

of the small diameter of the hose, it is imperative that the air supply is adjusted to maintain a constant pressure. If the pressure drops, an auxiliary air supply of compressed air bottles should be available for switching over and the user should immediately be signalled to leave the area.



**Figure 13: Air-line respirator arrangement**

Advantages of air-line respirators are their use for long continuous periods, minimal breathing resistance, light weight, low maintenance costs and moderate initial purchase price. Disadvantages of these respirators are the restriction of the user's mobility due to the trailing of the air supply hose and the possible interruption of air supply caused by damage to the air supply hose or due to failure of the air compressor.

When using an air-line respirator, the following precautions are necessary:

- the face mask must be checked and adjusted to ensure air tightness;
- a separate supply of clean air should be available for rapid change-over in the event that the
- compressor fails to maintain a constant air pressure or the efficiency of air supply becomes
- suspect;
- the working air pressure should be checked before use;
- the audible low pressure alarm should be tested before use;
- any action such as kinking, crushing or cutting which may restrict the movement of air through
- the hose should be prevented;
- the equipment should be used at the correct operating air pressure and hose length as
- specified by the manufacturer.

#### 4.4 Protection factors of respiratory equipment

A **protection factor of a respirator** is an expression of performance based on the ratio of the contaminant concentration outside the facepiece of the respirator to the contaminant concentration inside the facepiece. **Table 2** presents the protection factors for the different types of respiratory protection equipment.

**TABLE 2**  
**RESPIRATORY PROTECTION EQUIPMENT AND**  
**ASSOCIATED PROTECTION FACTORS**

<b>RESPIRATOR</b>	<b>PROTECTION FACTOR</b>
<u>AIR-PURIFYING PARTICULATE</u>	
Single-use dust mask	5
Quarter mask	5
Half mask	10
Full facepiece mask	50
Powered dust mask	1000
<u>AIR-PURIFYING GAS-ABSORBING</u>	
Half mask	10
Full facepiece	50
<u>SUPPLIED AIR RESPIRATORS</u>	
Demand half mask	10
Demand full facepiece	50
Pressure-demand half mask	1000
Pressure-demand full facepiece	2000
Continuous flow helmet or suit	2000
<u>SCBA's (SELF-CONTAINED BREATHING APPARATUS)</u>	
Open-circuit demand	50
Open-circuit pressure demand	10000
Closed-circuit, oxygen tank-type	50
<i>(ALL ARE FULL FACEPIECE)</i>	

The protection factors in the above table represent average values for a large number of individuals. However, since assessments of protection factors depend on user/respirator systems, anything that can give rise to inward penetration such as poor fit of the facepiece will reduce the value of the protection factor.

In view of the data presented in the above table and when considering the uncertainties involved **in a hazardous material spill**, particularly in the initial stages and, recognizing the high respiratory protection required in a spill environment, **the open-circuit type of SCBA with full facepiece operated in the pressure-demand mode should be the respirator of choice.**

#### 4.5 Common problems encountered when wearing respiratory equipment

Some **problems encountered when wearing respiratory protection equipment** are:

- the lack of a proper seal due to facial irregularities or deformities (e.g. scars, severe acne, facial skin creases) or the presence of facial hair (beards, sideburns, stubble);
- interference with communication, solved by using special communication equipment designed for use with respirators;
- the physiological stress and fatigue of the wearer, solved by selecting light weight equipment (NOT AT THE COST OF PROTECTION);
- a certain amount of discomfort;
- interference with vision either when contact lenses cannot be used (especially true for air-supplied respirators) or when ordinary eye glasses cannot be used (especially true for full facepiece respirators). This can be partially solved by having special corrective lenses installed inside the full facepiece respirator by the manufacturer of the equipment;
- resistance to breathing due to a restriction of air flow as a result of the plugging of the filter element. This is solved by replacing the filter element;
- lack of confidence in the use of a respirator. This is solved by well-designed training programmes and regular exercises.

#### 4.6 Maintenance and storage

Breathing apparatus needs to be maintained and, thus, the equipment needs to be inspected and tested regularly. (**Annex 1** shows a Maintenance Chart for a SCBA). Facepieces should be cleaned and disinfected after use. Air cylinders should be refilled as soon as possible after use. If a fault or defect is observed on inspection, it should be made good promptly and a record kept of any repairs undertaken. Breathing apparatus should be stored in a suitable, clearly marked place which is readily accessible. It must be pointed out that, as for all other equipment, if the breathing apparatus is properly maintained and stored, it will have a longer service life.

### 5. PORTABLE MONITORING DEVICES FOR CHEMICAL SPILL RESPONSE

Most hazardous products, other than oil, are not visible to the naked eye once spilled and therefore can only be located with the help of monitoring devices. **A monitoring device can be defined as that equipment or instrument which can measure or detect contaminants in the surrounding environment.**

The use of monitoring devices at a spill site helps:

- to determine the level and extent of hazard/contamination (and hence indirectly the level of decontamination);
- to detect and identify unknowns;
- to determine the level of personal protective equipment;
- to implement effective mitigating measures.

Monitoring devices for use at a spill site can be divided into three major categories:

- pocket-portable;
- person-portable;
- carrier-portable.

This Section of the Regional Information System is intended to focus on personal protection. It is, therefore, beyond the scope of this document to focus on all three categories even though carrier mounted systems such as analytical instruments used in fixed laboratories but

assembled in a mobile laboratory or other measuring equipment which is ship or aircraft mounted have found use in chemical spills. The following will, thus, summarize the salient features of field portable monitoring devices usually carried by response personnel.

## 5.1 General notions

There is a limit to the number of monitoring devices which can be carried to and handled at a spill site. Apart from the type of hazard encountered, the following criteria will determine the suitability of a portable monitoring device for chemical spill use:

- portability so that it can easily be transported and handled at the spill site;
- availability of the specific carrier if the device is to be carrier mounted;
- ability to provide qualitative and quantitative results for a wide range of contaminants (this reduces the number of different devices that will need to be carried to a spill-site);
- ease of use, operation and maintenance in the field (e.g. alarm for pre-set concentration limits, ease of physical manipulation of knobs, buttons or switches of the console);
- rapidity to give direct results without having to make complex calculations;
- accuracy so that the actions taken are based on reliable results;
- sensitivity to detect concentrations of hazardous substances below their IDLHs or Maximum Allowable Concentrations (MACs);
- field worthiness for use under a wide range of conditions (e.g. humidity, range of temperatures, absence of interference from other substances);
- long-lasting self-contained power source to allow a longer field service period (a power source which is wearing out gives fluctuations in its readings);
- requirement of accessories (e.g. reagents);
- cost which to a certain extent increases with detection capability.

A wide variety of monitoring devices exist which operate on different principles and measure different parameters associated with a chemical release. Each device has its own mode of operation and its limitations, however, irrespective of any instrument or device used, response personnel need to be proficient in its:

- operation;
- calibration;
- limitation;
- maintenance.

The choice of a particular monitoring device will depend on:

- whether the chemical spilled is known or unknown (for unknown chemicals, samples need to be taken for identification by chemical analysis in which case a sampling system is required); (NOTE: NOT TO LOOK FOR A CHEMICAL DOES NOT MEAN THAT IT IS NOT PRESENT);
- the physico-chemical and toxic properties of the chemical spilled, since the device chosen may be specifically designed to monitor the chemical or alternatively, it may be designed to measure some hazard associated with the release of the chemical (e.g. oxygen deficient atmosphere);
- whether the chemical spilled is to be detected or measured in the air or the water.

## 5.2 Air monitoring portable devices

Suitable **hand-held or pocket portable monitoring devices for an accidental release of a substance which will disperse completely or partially in air are:**

- **for toxic substances:**
  - photoionization detector (PID)
  - flame ionization detector (FID)
  - diffusion tubes
  - personal passive dosimeter
  - gas detector for specific gases
  
- **for combustible substances:**
  - combustible (explosion) gas meter
- **for radioactive substances:**
  - radiation detector
  
- **for particulates:**
  - aerosol monitor
  
- **miscellaneous use:**
  - oxygen meter
  - carbon monoxide meter
  - personal sampling pump with collection media (sorbent tubes)
  - wind speed and direction meter

### 5.3 Water monitoring importable devices

**Detection and analysis using hand-held monitoring devices for an accidental release of a substance which will disperse completely or partially in the water column is generally done through the use of analysis sticks, colorimetric test systems and titration systems.** Person portable, ready-to-use water monitoring systems are available in kit form. However, these commercially available kits are compound(s) specific and would need to be upgraded or modified to include the analysis of other substances not covered by the analytical protocols of the kit. Alternatively, an emergency water analysis response kit for field use could be put together on the basis of standard chemical methods for chemicals specifically chosen from a chemical spill priority list. The analytical instruments chosen should fit in a utility box which could be carried by one or two persons to the spill site. The emergency water analysis response kit could contain the following qualitative and quantitative measuring devices:

- pH meter;
- conductivity meter;
- analysis sticks;
- spectrophotometer;
- digital titrator;
- basic glassware;
- pre-packed reagents;
- manual of methods;
- radiation detector.

## 6. SPILL PROTECTIVE LEVELS AND ASSOCIATED PROTECTIVE EQUIPMENT (THE SELECTION OF PROTECTIVE EQUIPMENT)

When responding to a hazardous material spill, all those directly involved with the incident should be issued with adequate protective equipment. A selection of the correct items of equipment is of critical importance and should be based on information including:

- the identity of the substance(s);
- the quantity spilled;
- the physical state of the substance (liquid, gas, solid, vapour, mist, dust, fumes,

- cryogenic);
- fire and explosive hazards;
- toxicology and health data;
- estimated concentration of the substance where the exposure of response personnel is likely;
- whether the estimated concentration approaches the flammable limits (for flammable substances) or the "IDLH" threshold (for toxic substances);
- any oxygen deficiency of the surrounding atmosphere due to air displacement;
- permeability to the substance of the materials of construction of the protective equipment available;
- the type and stage of response operation (mitigation - clean-up - recovery - disposal).

If the above information is available, then the incident is well-defined. If the above information is not available or if some of it is not clear, then it is best to assume and cater for the worst possible scenario.

Although personal protective equipment is essential to prevent exposure of a responder to a hazardous material spill, it may also inconvenience or disable the wearer in the following ways:

- by inducing claustrophobia
- by inducing heat stress;
- by inducing rapid fatigue;
- by impairing communication;
- by limiting vision;
- by giving a false sense of protection;
- by overprotecting, causing needless hardship.

Thus, the selection of the most appropriate protective equipment apposite to the circumstances of the incident is essential. Equally important is for response personnel who use personal protective equipment to be monitored closely for physiological and psychological changes such as:

- pulse rate;
- body temperature;
- skin colour;
- mental alertness;
- blood pressure;
- body weight / fluid balance.

Selecting the appropriate protection equipment for a hazardous material spill might seem a confusing and daunting task when all factors involved are considered, such as the resistance of the materials or fabric to the chemical(s) spilled, respiratory support requirements, heat stress, reaction by-products when other chemicals are present, the gamut of protective equipment configurations to choose from and the phase of response.

**The task is manageable if the approach taken is that of selecting a level of protection in relation to a predetermined degree of hazard.**

In a hazardous material spill (excluding fire and explosion possibilities) certain response organizations define **four basic levels of protection**:

- **Level A protection** which is worn in unknown situations or when the situation requires the highest level of eye, skin and respiratory protection. The SCBA and the totally encapsulated suit are the protective equipment of choice for these conditions.

- **Level B protection** which is worn when the situation requires the highest level of respiratory protection but a lesser degree of skin protection is needed. The SCBA and chemical resistant suits are the protective equipment of choice for these conditions.
- **Level C protection** which is worn in situations where the hazards are known and the atmospheric concentration of the contaminant does not present a cutaneous hazard. Assuming also that the atmosphere is not oxygen deficient which means that a SCBA is not needed, adequate respiratory protection can be obtained by using air-purifying respirators. Air-purifying respirators and standard clean-up clothing consisting of liquid-repellant coveralls are the protective equipment of choice for these conditions.
- **Level D protection** which is worn in situations where there are no airborne contaminants of concern and where the likelihood of harm by contact with the spilled material is minimal. Coveralls are the protective equipment of choice for these conditions.

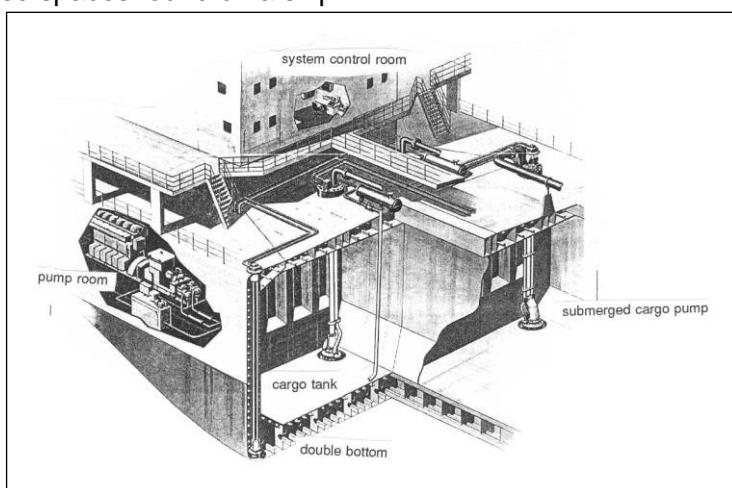
**Annex 2** elaborates further on the above approach and provides more information on the recommended equipment for the different levels of protection, giving details of the circumstances when the equipment should be used and the criteria of limitation. It must, however, be emphasized that the information on design specification in **Annex 2** has to be accompanied by performance expectation data to ensure that there are no shortcomings when selecting the protective equipment.

## 7. ENTRY INTO ENCLOSED SPACES

Various enclosed and confined spaces are found on a ship such as:

- electric motor rooms;
- cargo compressor and pump-rooms;
- hold spaces;
- inter-barrier spaces;
- void spaces;
- cofferdams;
- cargo pipe tunnels;
- double bottoms;
- duct keels.

Whereas some of these enclosed or confined spaces are entered during normal handling operations, others are not. **Figure 14** is a simplified diagram illustrating some of the enclosed or confined spaces found on a ship.



**Figure 14: Section of a parcel tanker**

Enclosed or confined spaces on ships may be dangerous because:

- they may contain flammable or explosive mixtures;
- they may contain toxic gases or vapours;
- they may be adjacent to other spaces containing dangerous cargoes, which may have leaked
- into them in either liquid or gaseous form;
- they may have been inserted and therefore contain insufficient oxygen to support life.

It is advisable that response personnel do not enter an enclosed or confined space unless there is a compelling reason to do so. If entry of response personnel into a confined or enclosed space cannot be avoided, the following precautions should be taken:

- atmospheric checks should be carried out, where possible, to determine the presence and concentration of any flammable or toxic vapour, gas or air borne particulates and to determine the oxygen level;
- atmospheric tests should be carried out at all levels (top, middle and bottom);
- no one should enter if the concentration of a flammable substance exceeds the lower explosive level;
- when an accident involves a flammable or toxic substance, the space should be force-ventilated to keep the air concentration down to a safe level;
- when ventilation is carried out, the ventilating hose should run as far down the space as possible whilst the air intake should be placed in an area to draw in fresh air;
- care should be taken not to compound the problem, by ensuring that force-ventilation does not re-distribute the contaminant to other parts of the ship which have not as yet been contaminated;
- response personnel entering the space should be equipped with the proper protective equipment (i.e. clothing, respiratory devices, safety harnesses or life lines);
- response personnel entering the space should be instructed on the conditions that will require their immediate evacuation;
- portable lights or other equipment used by response personnel should be of the approved type;
- standby persons with proper rescue equipment should be available at all times at the entrance of the space;
- standby persons should have no other duties other than to serve as standby and to know who to notify in case of an emergency and should only enter a confined space when assistance arrives;
- a system of communication should be agreed upon before entry and closely adhered to on entry, between those inside and those on standby (communication could be by way of visual signals, voice, signal line, radio or any suitable type). Irrespective of the means of communication, each message should be acknowledged by the recipient to show that the message is understood and is being acted upon, if necessary.

## 8. DECONTAMINATION

Within the context of response personnel safety, **decontamination (abbreviated to "decon" by most response organizations) is defined as the process for neutralizing or eliminating contaminants by physical or chemical methods to render response personnel, their equipment and their supplies safe and to prevent dispersion of the spilled product through secondary contamination.**

During an incident involving hazardous materials, it is best to assume that contamination will occur, thus requiring a technically sound decontamination process. This latter process should be seen as an integral part of the overall response effort.

Decontamination guidelines should be devised at the preparedness stage, well before an accident occurs and should address issues such as:

- applicable decontamination methods;
- criteria for deacon site selection and site management;
- materials, equipment and layout for establishing an on-site decontamination station;
- decontamination operating procedures.

## 8.1 Decontamination methods

A number of methods exist for decontamination, all of which fall within the following two basic methods:

- **physical methods** where the chemical is removed from the contaminated matrix with no resultant change in the chemical structure of the contaminant;
- **chemical methods** where the chemical is removed from the contaminated material through a process which changes the chemical to be removed into another and due to this process facilitates its separation from the contaminated matrix. One should be aware that through this process another chemical is introduced.

Below is a **general description of the methods available for decontamination purposes**:

- **sorption** (absorption and/or adsorption) which is a dry technique consisting of either the removal of the contaminant with some inert natural product e.g. soil, sand or some other commercially available product or of the wiping down with cloth, paper, towels, etc. The main advantage of such a technique is that there is no problem of possible reaction with water. Furthermore, it is useful when water is not available (although this is not the case with maritime-related emergencies). A disadvantage of this technique is that the contaminant sorbed onto the inert material usually remains unchanged and will still retain its toxic properties. The contaminated inert material must be disposed of accordingly. Since the interaction of the contaminant with a sorbent surface may cause the generation of heat, information needs to be sought from the supplier on a commercially available product to be used, to ensure compatibility. Although this technique has been used in the "pick-up" of liquids from water and flat ground surfaces, it has a limited application for the decontamination of response personnel equipment, in particular since further cleaning is required after decontamination by this method;
- **evaporation** which is a simple method involving the conversion of a liquid into vapour. It requires minimal personnel involvement since it relies mainly on the inherent properties of the spilled chemical. It is important that the vapours produced do not present a hazard. Furthermore, evaporation is not as effective on porous surfaces as it is on non-porous ones due to the "soaking effect" of the liquid;
- **vacuuming** which is a method for the collection of materials, usually solids, into a receptacle by means of suction. The equipment used should be suited for the material being vacuumed. When selecting the equipment the following should be borne in mind:
  - does the equipment have its own power supply and/or does it require a generator?
  - will it operate safely in a humid environment?
  - how effective is its filtering system?
  - are replacement parts easily available?

- how easy is it to clean?
  - is the equipment safe to use in a flammable or explosive atmosphere?
- **chemical alteration** which is a method consisting of changing the chemical structure of the contaminant to render it less harmful. Two processes which fall under this heading are chemical degradation which is the natural breakdown (usually through a natural process) of the contaminant and neutralization which is the addition of a chemical agent of opposite pH. The latter has been used for specific contaminants. Using other chemicals, whether in solution or not, to reduce the hazardous nature of a contaminant should be done in consultation with experts experienced and familiar with both products, i.e. the altering/neutralizing agent and the contaminant. With this method, further rinsing is still required (see "dilution and washing");
- **dilution and washing** which is a wet method using primarily water to flush away the contaminant from the surface. It is one of the most widely practiced methods for decontamination. The advantages of this technique is that it reduces the concentration of the contaminant and it is relatively cheap decontamination technique since water is usually available in sufficient quantities. Water, as the diluent, is used when the contaminant is water-soluble. Materials that are not soluble in water can be washed with detergent solutions. However, using water or detergent solutions is, sometimes, not enough and in this case a hybrid method of using decontamination solutions (i.e. solution containing specific chemicals) followed by a rinse solution and water wash-down might have to be used (see **Section 8.4** below for further details). Disadvantages of the method are the possible reactivity of the contaminant with the water and the problem of containment and disposal of contaminated wash and rinse water.

It must be recognized that the small amount of contaminant washed off personal protective equipment will probably result in minimal damage to the environment when compared to the spill itself. However, this does not preclude those responsible in the response from informing the relevant authorities of any potential pollution arising from the decontamination procedure. In cases of contaminants which may have a severe effect on the environment, minimal amounts of water should be used. This should not, however, be at the cost of personnel safety. It might still also be necessary to collect the washings or wash water following decontamination;

- **isolation and disposal** which is a method for the disposal of severely contaminated personal protective equipment which cannot be cleaned. The contaminated object should be treated as hazardous waste and the appropriate competent authorities consulted. In this case, an area on the site should be designated for the deposition of contaminated equipment and the equipment should later be disposed of accordingly.

In the case of an unknown contaminant, it might be necessary to verify the effectiveness of any of the methods described above, unless it is decided to dispose of the contaminated equipment as hazardous wastes.

## 8.2 Criteria for sites selection and site management

Ideally, on-site decontamination should be carried out as close as possible to the incident in order to limit the spread of the contaminant. Positioning the decon site at a distance from the incident location will require transportation of response personnel between the incident and decon site. Any form of transport would then also need to be decontaminated. However, in a marine incident decontamination close to the incident may not always be possible. Considerable judgement is needed to site-select an area. Nevertheless, the dimensions of the area itself should not be large. The selection of the site will depend on the extent of

contamination, on how much will be completed at the incident site and on the proximity of the marine casualty to the shore:

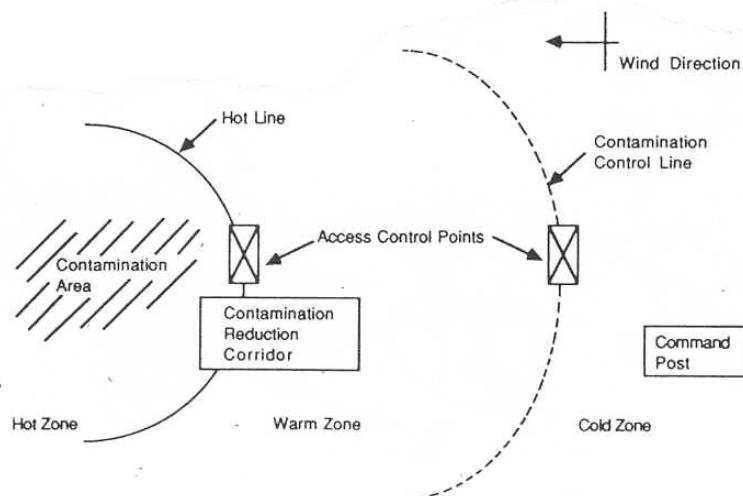
- for a **ship which is berthed alongside a quay**, a land-based decon site might be most suitable;
- for a **ship which is at an outside berth in a port**, either a land-based decon site or a barge or work vessel of suitable size positioned at the appropriate distance might be considered;
- for a **ship in open waters**, a decontamination site on board or one ashore may be set up or a combination of on and off-site decon stations might be considered.

When **selecting a site as a decon area**, the following criteria need to be considered:

- weather conditions such as prevailing wind conditions. An upwind location should ideally be chosen, although the possibility of shifting winds should be taken into consideration to avoid having to move decontamination operations elsewhere once they are functioning;
- proximity of the incident;
- availability of power and lighting which is of particular relevance during long-term operations;
- factors such as the slope of the terrain, the ground surface porosity and the location of drains and sewers for land-based decon sites.

Once a suitable site has been selected, the next step is to position the decon station in relation to the accident. If the typical three-zone system of area designation is used for setting up emergency response work zones, then the decon station should be positioned in the "warm" zone (see **Figure 15** for delimitations of work zones).

**Hot zone also known as Exclusion or Restricted Area**  
**Warm zone also known as Contamination Reduction or Limited Access Area**  
**Cold zone also known as the Support Area**



**Figure 15:** **Diagram of control zones**  
**(All decontamination activities occur in the Warm Zone)**

**Once the decon station has been set up, a person should be placed in charge** whose responsibilities would include:

- seeking advice from specialists on how much decontamination is required;
- supervising and monitoring the operations, including upgrading or downgrading of the decontamination process as the circumstances dictate;
- monitoring the movement of personnel through the decontamination process (decontamination of personnel is usually organised in a flow-through system so that personnel move from a dirty end (control point) to the clean end (exit point));
- maintaining communication and co-ordination with other groups e.g. with a medical team in the event of injured personnel (for the actual communication a direct link should be established);
- ensuring that any personnel assisting in the decontamination process are appropriately attired;
- handling and preparing for the transfer of clean protective equipment as well as the handling of partially contaminated or contaminated materials (clothing and equipment) which might either need further cleaning or need to be disposed of as hazardous wastes;
- record keeping;
- post-incident clean-up activities at the decon site.

### 8.3 Materials. Equipment and layout for establishing on site decon station

The materials, equipment and actual layout of personnel decon station for on-site decontamination will depend on factors such as:

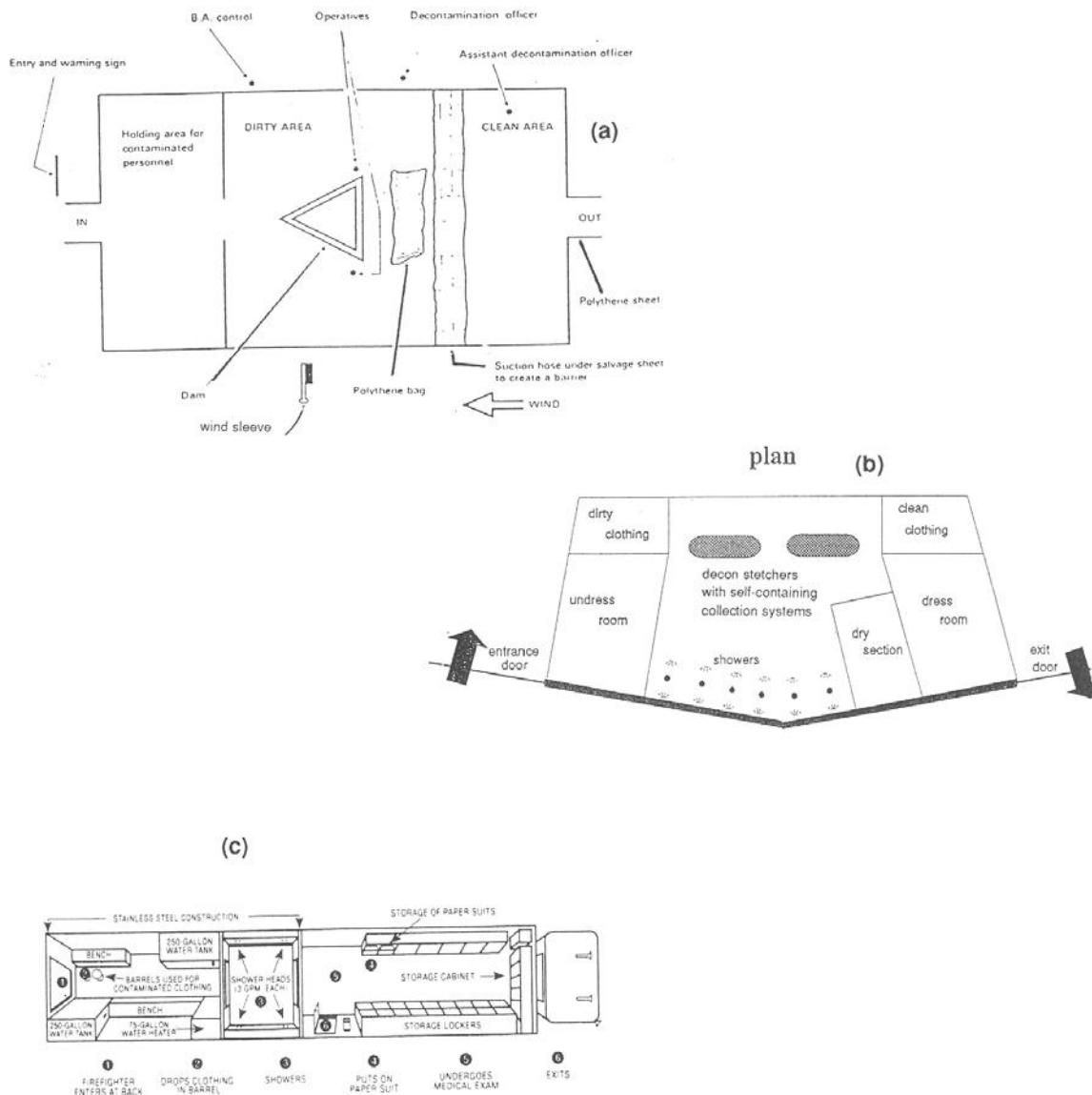
- the extent and type of hazards encountered at the spill site;
- the level of decon required;
- the availability of equipment and supplies;
- the weather conditions.

**The following is a list of equipment and materials used for on-site decontamination purposes:**

- **for cleaning:**
  - source of warm and/or cold water for washing and/or rinsing;
  - water spraying devices and portable pumps;
  - field shower assembly;
  - eye wash fountains;
  - brushes (long and short handled) and sponges;
  - detergent and/or decontamination solutions;
  - absorbents to clean off gross contamination;
  - vacuum equipment with independent power pack;
  - rags, cloth and independent paper towels.
- **for containment:**
  - tape (e.g. traffic tape), flags and poles for marking boundaries;
  - tubs and/or inflatable wading pools for wash solutions;
  - plastic sheets and/or diking material for major containment;
  - plastic sheets to create an uncontaminated space for changing;
  - portable pump to recover contaminated washings.
- **for storage and transportation of contaminated equipment:**

- tags and plastic bag ties;
  - heavy plastic (industrial) bags which should be large enough to be used as liner bags. The transparent type are preferable since they permit easy identification of the contents without opening;
  - impervious containers for contaminated equipment (e.g. plastic or lined drums or boxes);
  - drums and holding tanks for contaminated wash and rinse solutions (e.g. tank truck).
- **for protection of the decon assistant(s):**
- encapsulating suits, coveralls, hoods, gloves;
  - breathing apparatus.
- **for replacement of protective equipment:**
- availability of appropriate protective clothing and other protective equipment that can be used
  - while original items are being decontaminated.
- **for personal cleaning after decontamination:**
- wash basin, soap, water, nail brushes and towels.
- **for sheltering of personnel during decontamination:**
- inflatable tent;
  - decon trailer.
- **miscellaneous items:**
- benches or stools for personnel to sit on during removal of protective equipment;
  - tables to raise decontamination items to waist level for easy access.
- **The general features of the layout** of a decon station are:
- clearly marked boundaries and warning signs;
  - clearly marked entry and exit points;
  - a location at the entry point where contaminated personnel can await their turn to be decontaminated;
  - a containment system for flush/wash down solutions and water;
  - a disrobing area;
  - a personal wash point or area;
  - a storage point or area for the deposition of contaminated equipment;
  - access to medical treatment and/or check-up upon exit.

**Figures 16a, b and c** illustrate schematically some examples of the physical layout of on-site decon stations of different complexity. **Figure 16a** shows the layout of a minimally developed personnel decontamination station consisting of a zone demarcated by traffic tape where the decon process takes place on plastic sheets arranged so as to hold water if that is used. **Figure 16b** shows a more elaborate personnel decontamination station where the decon process takes place inside an inflatable tent and contains equipment for decontaminating injured personnel. **Figure 16c** shows what can be considered to be a maximally developed personnel decontamination station. This is a self-contained unit which is housed in a trailer and which therefore requires no mounting or assembly.



**Figure 16: Examples of layouts for on-site decontamination stations**

#### 8.4 Onsite decontamination operation procedures

In view of the different properties of hazardous materials, decon operating procedures need to be flexible to allow for upgrading or downgrading as the situation of the accident change. Flexibility also allows the revision of a particular procedure if it is judged not to be working effectively. In addition, owing to the nature of the situation, it might be the case not to go through the entire procedure. To this end, a certain professional judgement needs to be exercised, based on the technical knowledge and practical experience of the person in charge of decontamination.

Unless the spilled material is a water reactive substance, the most common method for the decontamination of personnel and their equipment is by dilution and washing especially when water is used to flush away the hazardous material. As elaborated in **Section 8.1**, the method consists of using either water alone or a combination of decon solutions and copious amounts of water for washing and rinsing respectively. It is important that the rinsing process removes all excess decon solution adhering to the surface of the protective equipment. **Annex 3**

presents decon solutions for specific groups of hazardous materials which can be made up from easily available "off-the-shelf" products.

Although emergency response organizations should develop their own decon operating procedures, the following are some useful practical hints which can assist in ensuring a successful decon operation and which are applicable to all situations:

- written instructions should be prepared in advance;
- personnel should avoid sitting down or leaning against drums containing any form of contaminated materials including contaminated debris;
- cuts, wounds, lesions or abrasions suffered by personnel should be attended to as fast as is feasibly possible;
- personnel removing personal protective equipment should not smoke, eat, drink or touch their face or body until the hands and face have been scrubbed;
- if dehydration of response personnel has occurred and replacement of fluids is permitted before full decontamination, a washdown around the head and upper body should be carried out and any liquid should be consumed from bottles containing straws or drinking tubes which have been handled only by someone with uncontaminated hands;
- washing of the body should occur after the decontamination procedure;
- decontamination tasks should be accomplished with as few assistants as possible so as to limit the number of personnel at risk being exposed;
- protective clothing, in particular a chemical suit, which is removed should be kept right-side-out to minimize contamination of its inner surfaces. The suit should be rolled on itself to reduce its external surface, thereby minimizing contact of the person handling the contaminated clothing;
- breathing apparatus should be kept on for as long as it is required during the decon process;
- in order to minimize contamination problems, monitoring devices and other types of sampling equipment should be placed in plastic bags with only the detecting element exposed to the exterior when being used at the accident scene;
- contaminated equipment which is either not completely clean or which is not required for reuse should be segregated and placed in containers which should be labelled with warnings and details;
- to minimize the risk of secondary contamination from the donning and doffing of contaminated personal protective equipment, response personnel re-entering the contaminated area of the accident should utilize unused or uncontaminated equipment. In this regard, using equipment (in particular clothing) which is disposable is a viable option.

## **9. CONCLUSION**

Response personnel called upon to deal with a maritime chemical emergency must be properly equipped to ensure their safety against the physical, chemical and thermal hazards they may encounter. It is important that the equipment chosen is appropriate for the task at hand and the choice should be based on the hazardous materials and/or conditions present. It is also important to recognize that although no one material of construction or garment fabric can satisfy the protective requirements against all chemicals, the selection of a garment fabric is facilitated if the material chosen is based on the premiss that it will provide protection against the most common materials spilled or likely to be spilled. Such an approach will ensure that most emergency situations can be dealt with.

Finally, it must be mentioned that a maritime chemical emergency poses a risk of exposure not only to response personnel working in the immediate vicinity of the spill site, but also to those who come in contact with these personnel or their equipment. Thus, decontamination should be seen as an integral part of the overall response plan. To this end, the selection, acquisition and maintenance of equipment, the preparation of decontamination procedures as well as the familiarization and training of response personnel in the use of personal protective equipment require planning and preparation at the emergency preparedness stage.



## ANNEX I

### MAINTENANCE CHART FOR A SELF-CONTAINING BREATHING APPARATUS (SCBA)

MAINTENANCE	Before Use	After Use	Monthly	Half Yearly	Yearly	Every 2 years	Every 3 years	Every 6 years
Clean and Disinfect Mask		X		X				
High Pressure Leak Test	X	X	X	X	X	X	X	X
Trigger Pressure of the Demand Valve	X	X		X	X	X	X	X
Leak Test of the Demand Valve	X	X		X	X	X	X	X
Test of Warning Device	X	X	X	X	X	X	X	X
Testing of Cylinder Pressure	X	X	X	X	X	X	X	X
Checking of Membrane of the Demand Valve		X		X	X	X	X	X
Changing Membrane of the Demand Valve							X	
Major Overhaul of Apparatus								X
Testing of Spare Cylinders						X		
Testing of Cylinder Valve					X	X	X	X
Mask Leakage Test	X	X	X	X	X	X	X	X
Positive Pressure Test (+ Auto)	X	X	X	X	X	X	X	X
Low Pressure Test	X	X	X	X	X	X	X	X
Changing of Speech Diaphragm						X		



## ANNEX II

### LEVELS OF PROTECTION FOR PRE-DETERMINED LEVELS OF HAZARDS

LEVEL OF PROTECTION	EQUIPMENT	PROTECTION PROVIDED	SHOULD BE USED WHEN	LIMITED CRITERIA
A	<p><b>RECOMMENDED</b></p> <ul style="list-style-type: none"> <li>▪ Pressure-demand, full facepiece SCBA or pressure-demand supplied air respirator with escape SCBA</li> <li>▪ Fully-encapsulating chemical resistant suit</li> <li>▪ Inner chemical-resistant gloves</li> <li>▪ Chemical-resistant safety boots/shoes</li> <li>▪ Two-way radio communications.</li> </ul> <p><b>OPTIONAL</b></p> <ul style="list-style-type: none"> <li>▪ Cooling unit</li> <li>▪ Coveralls</li> <li>▪ Long cotton underwear</li> <li>▪ Hard hat</li> <li>▪ Disposable gloves and boot covers</li> </ul>	The highest available level of respiratory, skin and eye protection.	<ul style="list-style-type: none"> <li>▪ The chemical substances has been identified and requires the highest level of protection for skin, eyes and the respiratory system based on either:           <ul style="list-style-type: none"> <li>- Measured (or potential for high concentration of almost phrenic vapours, gases or particulates               <ul style="list-style-type: none"> <li>or</li> </ul> </li> <li>- Site operations and work functions involving a high potential for splash immersion or exposure to unexpected vapours, gases or particulates of materials that are harmful to skin or capable of being absorbed through the intact skin.</li> </ul> </li> <li>▪ Substances with a high degree of hazard to the skin are known or suspected to be present and skin contact is possible.</li> <li>▪ Operations must be conducted in confined, poorly ventilated areas until the absence of conditions requiring Level A protection is determined.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Fully-encapsulating suit material must be compatible with the substances involved.</li> </ul>
B	<p><b>RECOMMENDED</b></p> <ul style="list-style-type: none"> <li>▪ Pressure-demand, full facepiece SCBA or pressure-demand supplied air respirator with escape SCBA</li> <li>▪ Chemical-resistant clothing (overalls and long-sleeved jacket: hooded, one or two piece chemical splash suit: disposable chemical – resistant one piece suit)</li> <li>▪ Inner and outer chemical-resistant gloves</li> <li>▪ Chemical-resistant safety boots/shoes</li> <li>▪ Hard hat</li> <li>▪ Two-way radio communications</li> </ul>	The same level of respiratory protection but less skin protection than Level A. It is the minimum level recommended for initial site entries until the hazards have been further identified	<ul style="list-style-type: none"> <li>▪ The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection but less skin protection. This involves atmospheres:           <ul style="list-style-type: none"> <li>- With IDLH concentrations of specific substances that do not represent a severe skin hazard;               <ul style="list-style-type: none"> <li>or</li> </ul> </li> <li>- That they do not meet the criteria for use of air-purifying respirators.</li> </ul> </li> <li>▪ Atmospheric contains less than 19.5 percent oxygen</li> <li>▪ Presence of incompletely identified vapours of gases is</li> </ul>	<ul style="list-style-type: none"> <li>▪ Use of only vapour or gases present are not suspected of containing high concentration of chemicals that are harmful to skin or capable of being absorbed through the intact of skin.</li> <li>▪ Use only when it is highly unlikely that the work being done will generate eight high concentration of vapours, gases of particulates or splashed of material that will affect exposed skin.</li> </ul>

			indicated by direct-reading organic vapour detection instrument, but vapours and gases are not suspected of containing high levels of chemicals harmful to skin or capable of being absorbed through the intact of skin	
C	<p><b>RECOMMENDED</b></p> <ul style="list-style-type: none"> <li>▪ Full facepiece, air purifying canister equipped respirator.</li> <li>▪ Chemical-resistant clothing (overalls and long-sleeved jacket: hooded, one or two piece chemical splash suit: disposable chemical-resistant one piece suit)</li> <li>▪ Inner and outer chemical-resistant gloves</li> <li>▪ Chemical-resistant safety boots/shoes</li> <li>▪ Hard hat</li> <li>▪ Two-way radio communications</li> </ul> <p><b>OPTIONAL</b></p> <ul style="list-style-type: none"> <li>▪ Cooling unit</li> <li>▪ Coveralls</li> <li>▪ Disposable gloves and boot covers</li> <li>▪ Face shield</li> <li>▪ Escape mask</li> <li>▪ Long cotton underwear</li> </ul>	<p>The same level of skin protection as Level B but a lower level of respiratory protection.</p>	<ul style="list-style-type: none"> <li>▪ Atmospheric contaminants liquid splashes, or other direct contact will not adversary affect any exposed skin.</li> <li>▪ The types of air contaminants have been identified, concentrations measured , and a canister is available that can remove the containment</li> <li>▪ All criteria for the use of air-purifying respirators are met.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Atmospheric contaminants liquid splashes, or other direct contact will not adversary affect any exposed skin.</li> </ul>
D	<p><b>RECOMMENDED</b></p> <ul style="list-style-type: none"> <li>▪ Coveralls</li> <li>▪ Safety boots/shoes</li> <li>▪ Safety glasses or chemical splash goggles</li> <li>▪ Hard hat</li> </ul> <p><b>OPTIONAL</b></p> <ul style="list-style-type: none"> <li>▪ Gloves</li> <li>▪ Escape mask</li> <li>▪ Face shield</li> </ul>	<p>No respiratory protection. Minimal skin protection.</p>	<ul style="list-style-type: none"> <li>▪ The atmospheric contains no known hazard.</li> <li>▪ Work functions preclude splashes, immersion, or the potential for unexpected inhalation or contact with hazardous levels of any chemicals.</li> </ul>	<ul style="list-style-type: none"> <li>▪ This level should not be worn in the Exclusion Zone.</li> <li>▪ The atmospheric must contain at least 19.5 percent oxygen.</li> </ul>

## ANNEX III

### DECONTAMINATION SOLUTIONS

<u>Decon Solutions</u>	<u>Concentrations</u> <sup>(1,2)</sup>	<u>Remarks</u>
1. Aqueous soln. of a low foaming detergent	As per label of the commercial product	Widely used. Suitable at site where contaminant is not known or where a variety of contaminants exists. Good for radioactive hazards.
2. Aqueous soln. of trisodium phosphate	1-2 % Na <sub>3</sub> PO <sub>4</sub> 5 % Na <sub>3</sub> PO <sub>4</sub>	Good general purpose decon soln., including organic solvents.
3. Aqueous soln. of sodium carbonate (washing soda)	5 % Na <sub>2</sub> CO <sub>3</sub>	Good at sites where contaminant is an organophosphate pesticide. Effective in neutralizing inorganic acids although the reaction is exothermic (HEAT GIVEN OFF).
4. Aqueous soln. of sodium bicarbonate (baking powder)	5 % Na HCO <sub>3</sub>	Good at sites where contaminant base labile compounds. Effective in neutralizing acids and is a better choice than Na <sub>2</sub> CO <sub>3</sub>
5. Aqueous soln. of calcium hypochlorite (bleaching powder)	10 % Ca Cl (OCl) 5-6 % Ca Cl (OCl)	Good for cyanide salts and ethologic hazards. For ethologic hazards administer via spray.
6. Aqueous soln. of ethylene-diamine tetra-acetic acid	EDTA is a commercially available product. Follow product label	Good for heavy metal salts due to its multidentate chelating properties.

- (1) The original percentage of the concentrate should be taken into account when calculating the final strength of a solution. It is important to follow the manufacturer's instructions.
- (2) Owing to the fact that the information has been extracted from more than one information source, more than one final strength is sometimes given for a particular decon soln.



INTERNATIONAL  
MARITIME  
ORGANIZATION



REMPPEC  
MARITIME HOUSE, LASCARIS WHARF, VALLETTA VLT 1921, MALTArempec@rempec.org -  
[www.rempec.org](http://www.rempec.org)