



**IAEA**

International Atomic Energy Agency  
*Atoms for Peace and Development*

# Occupational Radiation Protection during High Exposure Operations

Personal Protection and Dose Reduction Measures

# Contents

1. Introduction
2. Protective ware
3. Respiratory protection
4. Decorporation
5. Iodine thyroid blocking
6. Personal shielding
7. Personal hygiene
  1. Food and drinking water monitoring for workers
  2. Sanitary aspects
  3. Prevention of heat stroke
  4. Mental health

# 1. Introduction

Radiation may not be the main dangerous factor required for protection of emergency workers.

Proper attention has to be paid to other conventional risks encountered in the working environment.

## 2. Protective ware

The use of protective ware is especially important for the protection of emergency workers since there is large possibility of contamination that results in external and internal exposure.

Many kinds of product are available, and their quality varies in each aspect such as durability, resistance to chemicals, flames and heat, comfort, and cost.

- ✓ Woven type permeable suits
- ✓ Non-woven type permeable suits
- ✓ Non-woven fabrics or impermeable suits coated with rubber or plastic
- ✓ Fully impermeable, pressurized suits

## 2. Protective ware

Disposability might be considered in some cases. Disposing used suits prevents a build up of contamination which would affect the worker, and prevents transfer or re-suspension of contamination.

Very large number of workers may be involved in emergency operations at the same time, so it is necessary to regularly provide an ample number of various protective wares at appropriate locations.

The securing of transportation and procurement routes of protective wares are important.

# ***Selection of protective ware***

Workplace monitoring data, type of requested work and the performance information of the protective ware are necessary for the best selection of appropriate protective ware.

Performance information of the protective ware, such as materials, permeability, water proof property of the product are usually given in the catalogue.

The manufacturers also supply information relating to the care and usage of the product. A list of performance levels helps to choose the most appropriate suit for the intended work.

# Selection of protective personal equipment

The general guidance for selection of protective suits

X = type of garment is suitable

+R = use together with appropriate RPE depending on specific conditions

\*Type C = Air escapes freely through sleeves and seams

\*\*Type D = Exhaust devices such as valves or filters are fitted; pressurized

Suit type	Expected surface contamination				Expected airborne contamination			
	Solid		Liquid		Aerosol		Gas	
	Low	High	Low	High	Low	High	Low	High
A. Non-ventilated, non-pressurized, permeable fabric or non-woven	X+R				X+R			
B. Non-ventilated, non-pressurized, impermeable	X+R	X+R	X+R	X+R	X+R		X+R	
C*. Ventilated, impermeable	X	X	X	X	X	X		
D**. Ventilated, impermeable	X	X	X	X	X	X	X	X

## ***Selection of protective equipment***

For the selection of appropriate protective equipment it is necessary to consider radiological risks together with other risks that are increased by wearing the protective equipment.

In some case it is effective to wear two types of protective equipment, such as waterproof suit on a permeable suit for the laborious task.

In general heat stress should be avoided by cooling vest or by adequate time management



### 3. Respiratory protection -*Types of equipment-*

Respiratory protective equipment is divided into two categories and several subdivisions in each category.

#### 1. Respirators

They can purify the air by filtering out particulate materials such as dust or low concentrations of gas or vapour. The most common types are:

- a) Filtering face piece respirators
- b) Half face mask respirators
- c) Full face mask respirators
- d) Powered respirators

#### 2. Breathing equipment

They can clean air or oxygen from an independent and uncontaminated source. The most common types are:

- a) Supplied-air respirators
- b) Self-contaminated breathing apparatus

# Types of equipment

Before using a respiratory protective equipment, its performance must be confirmed. Two main protection factors are:

- ✓ Nominal protection factor (NPF)

The expected ratio of the contaminate concentration in the ambient atmosphere to that inside the respiratory protective equipment.

- ✓ Assigned protection factor (APF)

APF is defined by national standards based on national regulations.  
So that APF may vary from country to country.

The efficiency of a respirator to minimize inward leakage depends on two parameters:

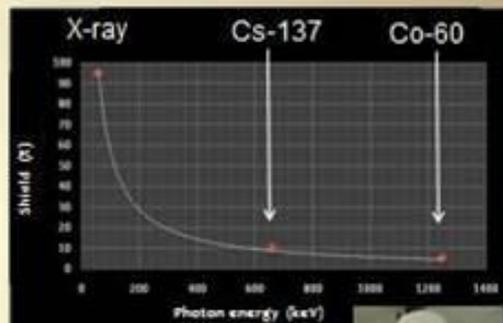
- ✓ The fit to the face

- ✓ The filtering efficiency of the selected filter medium or canister

## Gamma ray protective suit



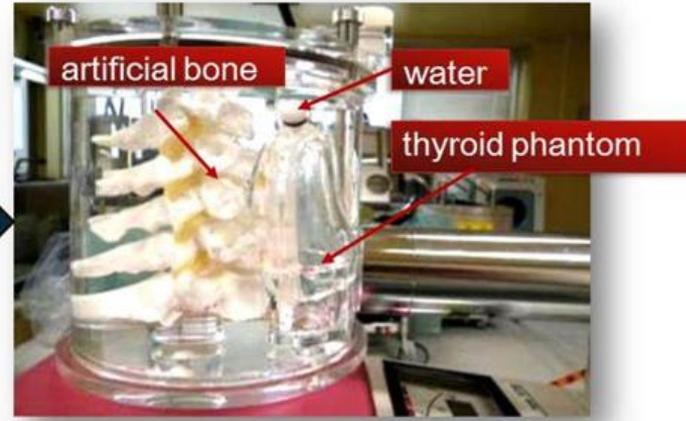
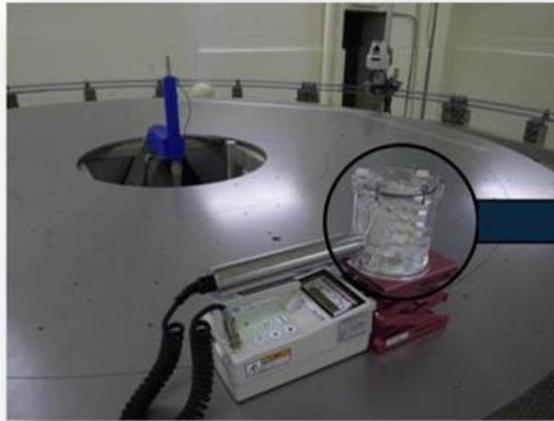
Protective suit  
made of lead sheet



To check the fire fighter's and military equipment, EPD was put on the tissue equivalent phantom, and the dose from  $^{137}\text{Cs}$  was confirmed by the presence of these protective suit. In spite of 20kg in weight, the penetration was 90%.



## *Calibration on dose rate and thyroid conversion coefficient*



The Ba-133 solution with the same mass of a thyroid gland was put in the thyroid phantom. Then the conversion factor between gamma dose rate indicated by the survey meter and Ba-133 activity was decided

## ***Selection of equipment***

Workplace monitoring data, type of requested work the performance information of the respiratory protective equipment are necessary for the best selection of appropriate respiratory protective equipment.

The physical and chemical forms and concentration of contaminants in the workplace will determine the type of respirator or breathing equipment.

The APF/NPF indicates the theoretical best protection that can be achieved.

However, the specified protection factor might not be achieved in practice for various reasons.

The workers' training must emphasize the need of a good fit and correct usage of the mask for the good personal protection.

Training should include the correct way to remove the respiratory protection so that contamination is minimised.

## ***Respirators -Filtering face piece respirators-***

Filtering face piece (FFP) respirators are made of filter material which covers the nose and mouth. The nominal protection factor (NPF) of FFP respirators is relatively low. FFP respirators are mainly used for protection against low to moderately hazardous particles. They are usually disposable and designed to be used once, so that they should not be reused.



N95 respirator

## ***Respirators -Half face mask respirators-***

The half face mask is a face piece made of rubber or plastic to cover the nose and mouth and is held in place by adjustable straps.

The NPFs of the half face mask are usually much higher than that of FFPs.

Two type of filters are available: one is for particles (dust, fumes, mist) and other is for gases and vapours.

Note that the efficiency of the charcoal filter easily decreases when moisture attaches to the charcoal. It is also necessary to note the half face mask more easily slips off the face than the full-face mask respirator.



Charcoal filter



Dust filter

## ***Respirators -Full face mask respirators-***

The NPFs of full face mask respirator are usually higher than that of half face mask respirators.

High NPF of full face mask respirator could be obtained by its proper fitting to the face. Therefore, confirmation of fit is important. One of the easiest method to confirm its fit is a leak check by wearers. The general method of leak check is:

Cover the filter with hands and lightly inhale. If the mask stick to face, it means the mask is correctly worn. If air is leaking it can be recognized that air is passing through the gap between the face and mask.



Charcoal filter



Dust filter

# Respirators -Powered respirators-

The powered air purifying respirators provide flow of air into the mask in order to minimize inward leakage of contaminated air from the gap between the mask and face.

The powered respirators are applicable for particulate contaminants as well as gases and vapours.



Full face mask powered respirator



Powered hoods

## ***Breathing equipment -Supplied-air respirators-***

The supplied-air respirators is the breathing equipment with a compressed air line. A compressed air line is used to supply clean air to a face mask or hood.

In using compressors, the air intake needs to be properly located to prevent intrusion of contaminants into the air supply. It is necessary to supply breathable air of an acceptable quality by using in-line filters and traps.

# Breathing equipment

## **-Self-contained breathing apparatus-**

A self-contained breathing apparatus (SCBA) consists of a full face mask supplied with air or oxygen from compressed gas cylinders carried by the worker.

The air respiratory part attached to the self-contained breathing apparatus has two types;

- (a) demand type
- (b) pressure demand type



Air respiratory



Oxygen respiratory



## 4. Decorporation

Patients with a significant amount of internal contamination should be treated in order to reduce the dose from absorbed radionuclides.

There are several approaches for minimizing internal contamination:

- 1) Focused on reducing the absorption of radionuclides and their deposition in target organs
- 2) Aim to increase the excretion of the radionuclides from the body

Treatment procedures are most effective if they are initiated as soon as possible after contamination has occurred.

Decorporation should be performed under the direction of a physician knowing the medical history and the conditions of the patient.

## 5. Iodine thyroid blocking

Accidents may involve the release of radioactive iodine.

In such cases the thyroid is the organ most at risk and stable iodine tablets can be used to block the uptake of radioactive iodine.

Efficiency of thyroid protection blocking depends on the time interval between taking stable iodine and performing emergency work.

Potassium iodine (KI) is generally used as stable iodine tablets for that purpose. Another compound that national health authorities may decide to use is potassium iodate (KIO<sub>3</sub>).

## ***Iodine thyroid blocking -How KI works-***

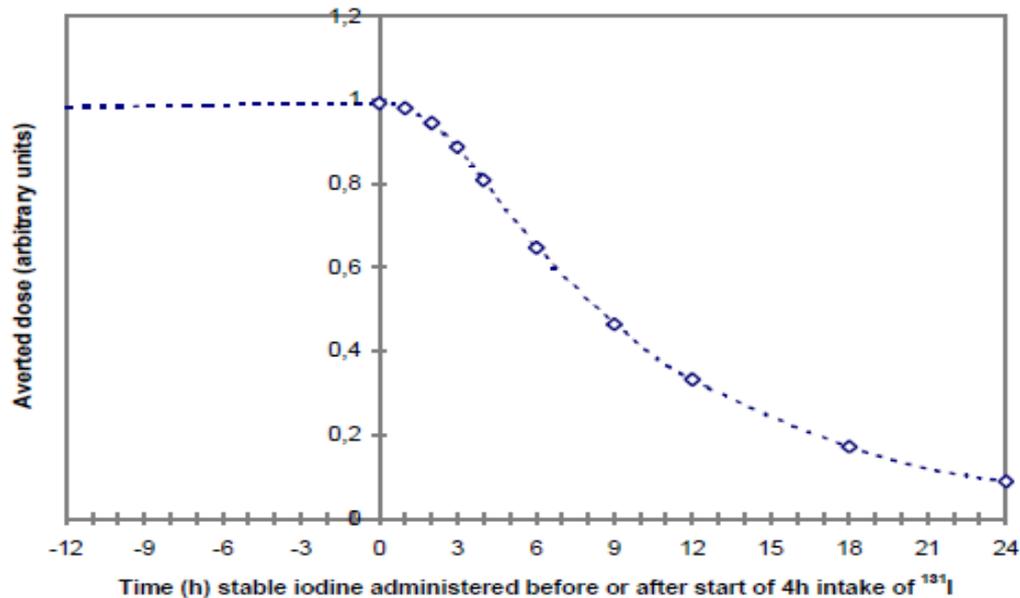
When taken the appropriate dosage of KI within the correct time interval before and after exposure to radioactive iodine, iodine content in the thyroid gland saturates with stable (non-radioactive) iodine.

As a result, radioactive iodine will not be taken up in production of thyroid hormones in thyroid (either non-radioactive or radioactive) and will be excreted through the urine within two days.

# Iodine thyroid blocking

## -Time of implementation-

Averted dose as a function of time stable iodine is administered relative to a 4-h intake of  $^{131}\text{I}$  for different dietary iodine intakes



## ***Iodine thyroid blocking -Instruction of dosage-***

KI tablets should be taken by individuals only when explicitly instructed to do so by supervisor or competent authority.

If stable iodine prophylaxis is performed, it is desirable to make sure that information about persons who took stable iodine is recorded.

The information includes name, daily and total dosage, etc.

# Iodine thyroid blocking -Criteria for dosage-

The generic criteria for iodine thyroid blocking in the international guidance

Generic criteria		Example of protective actions and other response actions
Projected dose that exceeds the following generic criteria: Take urgent protective actions and other response actions		
$H_{\text{Thyroid}}$	50 mSv in the first 7 days	Iodine thyroid blocking

The risk of side effects of KI increases with age, while the risk of radiation-induced thyroid cancer in individuals over 40-years old is low. For this reason, thyroid blocking with KI is not generally indicated in adults over 40 years of age until recently. But recent study shows the risk seems to remain even among the elderly persons. Therefore, it is desirable to administer KI to persons over 40 years old as well.

## ***Iodine thyroid blocking -Side effects-***

There is a possibility of having side effects of stable iodine.

The effects differ widely according to the amount of iodine regularly taken in the diet and the presence of thyroid diseases.

The side effects include for example gastrointestinal disturbances, allergic reactions, minor rashes, iodine-induced thyrotoxicosis, transient hypothyroidism and goitre.

## 6. Personal shielding

A shielding suit of overalls type made of special cloth is also manufactured. This type of shielding suit has relatively good protection for low energy gamma or beta ray radiations, but poor for relatively high energy radiations.



Shielding vest  
*Tungsten*



Shielding vest  
*Special rubber*



Shielding suit

## 7. Personal hygiene

### ***-Food and drinking water monitoring for workers-***

The worker in the emergency should be practically served with food and drinking water stored for emergency or supplied from the outside of an emergency site.

For this purpose, it is important that enough quantity of food and drinking water is stored for emergency and the supply route from outside to the emergency site is established in the preparation stage.

It is because the background radiation levels might be increased and it is not practicable during an emergency to perform proper monitoring of food and drinking water.

In hot summer conditions, air cooling system should be available

## 7. Personal hygiene -*Sanitary aspects-*

In the emergency, the management of the sanitary aspect of the worker is also important. Because a great many workers will enter the accident site for the accident response, the prevention of spread of infectious diseases among the worker are particularly important, especially influenza.

### Influenza

- ✓ Enforcement of hand-washing and a gargle
- ✓ Influenza vaccination
- ✓ Preparation of infection prevention goods
- ✓ Announcement and education for the infection prevention
- ✓ Searching for the fever-stricken

## 7. Personal hygiene -*Sanitary aspects*-

### Food poisoning

- ✓ Enforcement of hand-washing and the worker's physical condition management
- ✓ Sanitary management during food preparation
- ✓ Clarification of the response when the occurrence of the food poisoning
- ✓ Announcement and education for the infection prevention

Provision of the medical care service near the site is advisable for the sanitary management.



Influenza vaccination



Searching for the fever-stricken  
via thermography

## 7. Personal hygiene -*Prevention of heat stroke-*

Especially during an emergency, maintaining the health condition of workers is important to smoothly conduct required response tasks as scheduled.

The following are essential aspects that should be paid more attention as precautionary measures.

- ✓Lack of sleep
- ✓Hangover
- ✓Diabetes
- ✓Hypertension
- ✓Heart trouble
- ✓Kidney trouble
- ✓Fever
- ✓Diarrhea
- ✓Working environment of very cold or hot

## 7. Personal hygiene -*Prevention of heat stroke-*

Heat stroke is the most common problem encountered especially during hot seasons. For prevention of the heat stroke, following measures are generally effective.

- ✓Using WBGT\*, working hours, frequency and duration of breaks, and work load should be adjusted
- ✓Work under the blazing sun is prohibited in principle
- ✓Appropriate rest and frequent intake of water and salt are encouraged
- ✓Physical management using check sheets
- ✓Wearing cool vests
- ✓Establishment of a work environment that workers are allowed to claim poor condition
- ✓Establishment of an environmental that early diagnosis at the medical room is encouraged
- ✓Implementation of measures to enhance adaptability to the working environments
- ✓Education and instruction of the way to prevent heat stroke measures

\*WBGT = Wet Bulb Global Temperature

## 7. Personal hygiene -*Prevention of heat stroke-*

It is very important to take each measure for the prevention of heat stroke before the hotter season starts. Some protective equipment may increase work load and cause heat stroke. Therefore, in addition to the measure mentioned above, it is necessary to improve the work environment for the prevention of heat stroke. The following methods are exemplified.

- ✓ Use of protective suits with good breathability
- ✓ Limiting the area where full-face mask is required
- ✓ Provision of a rest area near workplace

## 8. Mental health

The emergency workers may have to carry out their job under multiple stressors such as radiation exposure and other occupational risks.

One of the most serious influences in a nuclear accident is the psychological effect.

It is important, therefore, to take care the mental health of the workers as well as their physical health. The mental health support by an specialized physicians is provided, if necessary.

Following is the example for that approach:

- ✓ To pay attention to mental health status of workers
- ✓ To provide personal counselling with those who have risk of mental health
- ✓ To inform the workers of the availability of the counselling services
- ✓ Information on posttraumatic stress disorders (PTSD)