



**IAEA**

International Atomic Energy Agency  
*Atoms for Peace and Development*

# Occupational Radiation Protection during High Exposure Operations

Preparedness and Action in Emergency

1. Introduction
2. Emergency planning and responsibilities
  1. Emergency preparedness categories
  2. Emergency classes and action in emergency
  3. Emergency planning zone or distances
  4. Summary on expected levels of health risks for emergency workers

# 1. Introduction

The requirements and guidance for protection of workers in emergency exposure situations are set out in DS 453, in GSR Part 3 and GSR Part 7.

# 1. Introduction

DS453  
23 June 2016

IAEA SAFETY STANDARDS SERIES No. GSG  
(DS453)

## OCCUPATIONAL RADIATION PROTECTION

Jointly sponsored by IAEA, ILO

## Preparedness and Response for a Nuclear or Radiological Emergency

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OECD/NEA, PAHO, CTBTO, UNEP, OCHA, WHO, WMO



**General Safety Requirements**  
**No. GSR Part 7**

## Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards

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**General Safety Requirements Part 3**  
**No. GSR Part 3**

## Arrangements for the Termination of a Nuclear or Radiological Emergency

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**XXX**

General Safety Guide  
No. GSG-**X**

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**Action:** /

# 1. Introduction

## Exposure groups of workers in emergency exposure situation

Group	Definition
A	Emergency workers who have specified duties in response to a nuclear or radiological emergency*
B	Workers performing their duties at working places and being not involved in response to a nuclear or radiological emergency
C	Workers who are asked to stop performing their duties at working places and to leave the site
D	Workers who are accidentally exposed as a result of an accident or incident at a facility or in an activity and whose exposure is not related to the emergency response

Nuclear emergency (nuclear fuel cycle) : see TMI, Chernoby, Fukushima

Radiological emergency (non nuclear fuel cycle) : see Goiana

# 1. Introduction

Considering the wide range of scenarios in a nuclear or radiological emergency and HEO to the workers groups, appropriate protection strategies should be applied.

Protection of emergency workers specified:

- Group A:** should be provided in line with the **requirements** set out in the **GSR Part 3** for emergency exposure situation and **GSR Part 7**
- Group B:** should be provided in the same way as for workers in planned exposure situation in line with the **requirements** set out in **GSR Part 3**
- Group C:** should be provided in the same way as for members of the public in emergency exposure situation in line with the requirement set out in GSR Part 7
- Group D:** in relation to medical follow-up, treatment and dose assessment should be in line with GSR Part 3 and in GSR Part 7.

## 2. Emergency planning and responsibilities

The requirement 4 of the GSR Part 7 states that “*the identified hazards and potential consequences of an emergency shall provide a basis for establishing arrangements for preparedness and response for a nuclear or radiological emergency*”.

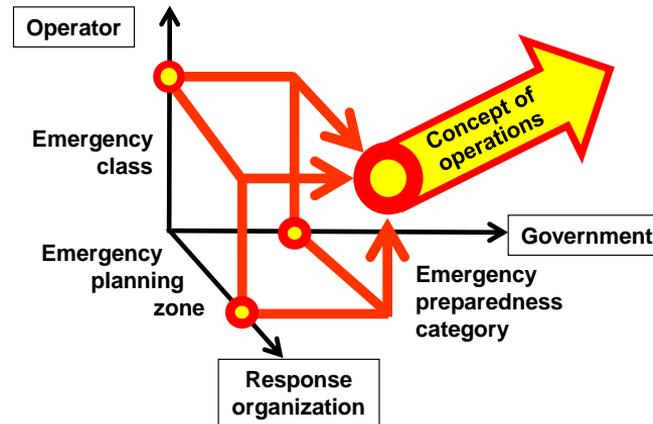
Concept of operation of emergency workers at scene of emergency is an important element of the emergency plan.

***concept of operations.** A brief description of an ideal response to a postulated nuclear or radiological emergency, used to ensure that all those personnel and organizations involved in the development of a capability for emergency response share a common understanding.*

## 2. Emergency planning and responsibilities

Each scenario of exposure of emergency worker could be envisaged as a point in the three-dimension system of emergency coordinates of;

1. Emergency preparedness category (EPC)
2. Emergency class (EC)
3. Emergency planning zone or distance (EPZ)



## 2. Emergency planning and responsibilities

Concept of operation of emergency workers in event of radiation emergency should be developed at preparedness stage because of joint work of the government, operator of facility or practice, local authority, and response organization.

The emergency plan should include:

- a) The persons or organizations responsible for ensuring compliance with requirements for protection and safety of workers in a nuclear or radiological emergency including those for controlling the exposure of emergency workers
- b) Defined roles and responsibilities of all workers involved in the response to a nuclear or radiological emergency
- c) Details on adequate self-protective actions to be taken, protective equipment and monitoring equipment to be used, and dosimetry arrangements in accordance with expected level of exposure and risk
- d) Consideration of access control for workers in a nuclear or radiological emergency on the site

## ***Emergency preparedness categories***

Arrangements for the protection of workers in a nuclear or radiological emergency should be a part of the emergency plan based on the assessment of Emergency Preparedness Category (EPC) of the facility or area in accordance with international requirements in GSR Part 7.

The degree of planning should be commensurate with the nature and magnitude of the risk and the feasibility of mitigating the consequence should an emergency occur.

# Emergency preparedness categories

EPC	Description
I	Facilities, for which on-site events are postulated that could give rise to severe deterministic effects off the site that warrant precautionary urgent protective actions
II	Facilities, for which on-site events are postulated that could give rise to doses to people off the site that warrant urgent or early protective actions
III	Facilities, for which on-site events are postulated that could warrant protective action and other response actions
IV	Activities and acts that could give rise to a nuclear or radiological emergency that could warrant protective actions and other response actions. Category IV represents a level of hazard that applies for all States and jurisdictions
V	Areas within emergency planning zones and distance in a State for a facility in Category I or II located in another State.

# Emergency classes

Requirements and guidance for emergency response are specified in the international requirements in GSR Part 7 for 5 classes of emergency:

- i. **General emergencies** at facilities in EPC I or II for an emergency that warrants taking precautionary urgent protective actions, urgent protective actions and other response actions on the site and off the site.
- ii. **Site area emergency** at facilities in EPC I or II for an emergency that warrants taking protective actions and other response actions on the site and in the vicinity of the site.
- iii. **Facility emergencies** at facilities in EPC I, II or III for an emergency that warrants taking protective actions and other response actions at the facility and on site but does not warrant taking protective actions off the site. Emergencies in this class do not present an off-site hazard.
- iv. **Alerts** at facilities in EPC I, II or III for an event that warrants taking actions to assess and mitigate the consequence at the facility.
- v. **Other** nuclear or radiological emergencies for emergencies in EPC IV or V that warrant taking protective actions and other response actions at any location.

# Emergency classes

It is required that the operator of EPC I, II or III facility is responsible for declaration of the emergency and its classification.

The requirements in GSR Part 7 provide:

1. Alert:
  - a) To assess and to mitigate the consequence of the event
  - b) To increase the readiness of the on-site response organizations
  
2. Facility emergency:
  - a) To mitigate the consequence of the emergency
  - b) To protect workers in Group B, C and D and visitors on the site

# Emergency classes

3. Site emergency:
  - a) To mitigate the consequence of the emergency on the site and to protect workers in Group B, C and D and visitors on the site
  - b) To increase the readiness to take protective actions and other response actions off the site if this becomes necessary on the basis of observable conditions, reliable assessments and/or monitoring results
  - c) To conduct monitoring and sampling off the site
  
4. General emergency:
  - a) To mitigate the consequence of the emergency on the site
  - b) To protect workers in Group B, C and D and visitors on the site and people off the site

Other nuclear or radiological emergencies:

- a) To mitigate the consequence of the emergency on the site, to protect those in the vicinity
- b) To determine where and for whom protective actions and other response actions are warranted

# Emergency planning

Facilities in EPC I, II or III requires special attention for planning emergency response on the site:

- To regain control of the situation using group A workers in such a way that their doses are both justified and optimised, and also do not exceed the dose criteria
- To protect workers in Group B and D, and visitors on the site
- To prevent development of the catastrophic conditions on the site
- To prevent the severe release off the site
- To provide the migratory and recovery actions on the site to regain the control over the source

The **guidance values** for restricting exposure of emergency exposure on the site of the facilities in EPC given in GSR Part 7.

TABLE IV.2. GUIDANCE VALUES FOR RESTRICTING EXPOSURE OF EMERGENCY WORKERS

Tasks	Guidance value <sup>a</sup>
Life saving actions	$H_p(10)^b < 500 \text{ mSv}$ This value may be exceeded under circumstances in which the expected benefits to others clearly outweigh the emergency worker's own health risks, and the emergency worker volunteers to take the action and understands and accepts these health risks
Actions to prevent severe deterministic effects and actions to prevent the development of catastrophic conditions that could significantly affect people and the environment	$H_p(10) < 500 \text{ mSv}$
Actions to avert a large collective dose	$H_p(10) < 100 \text{ mSv}$

<sup>a</sup> These values apply only for the dose from external exposure to strongly penetrating radiation. Doses from external exposure to weakly penetrating radiation and from intake or skin contamination need to be prevented by all possible means. If this is not feasible, the effective dose and the equivalent dose to a tissue or organ that are received have to be limited to minimize the health risk to the individual in line with the risk associated with the guidance values given here.

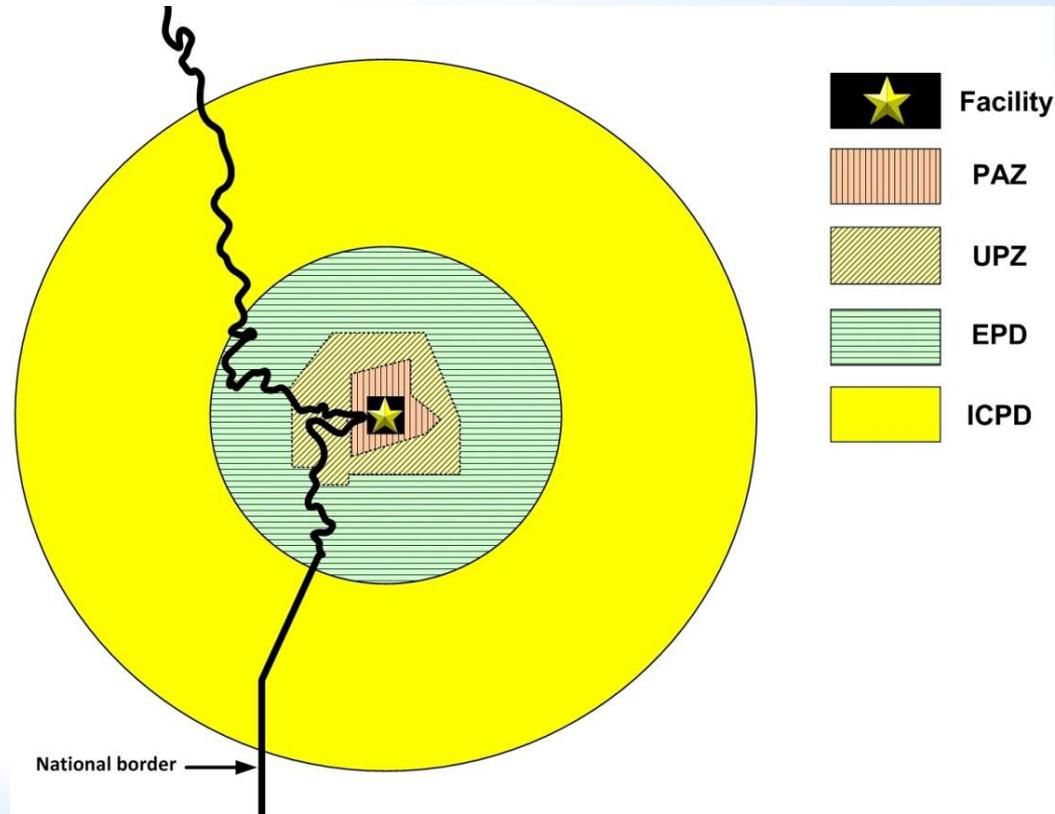
<sup>b</sup>  $H_p(10)$  is the personal dose equivalent  $H_p(d)$  where  $d = 10 \text{ mm}$ .

## ***Emergency planning zones or distances***

The international requirements in GSR Part 7 are that, off-site of facilities in Category I or II, arrangements are required to be made for effectively making and implementing decisions on urgent protective actions within following emergency planning zones or distances.

- i. A precautionary action zone (PAZ)
- ii. An urgent protective action planning zone (UPZ)
- iii. An extended planning distance (EPD)
- iv. An ingestion and commodities planning distance (ICPD)

# Emergency Zones and Distances



## ***Emergency planning zones or distances***

i. A precautionary action zone (PAZ);

for facilities in Category I, for which arrangements shall be made to take urgent protective actions and other response actions, before any significant release of radioactive material occurs, in order to avoid or to minimize severe deterministic effects.

ii. An urgent protective action planning zone (UPZ);

for facilities in Category I or II, for which arrangements shall be made to initiate urgent protective actions and other response actions, if possible before a significant release of radioactive material occurs or after release occurs in order to reduce risk of stochastic effects.

## ***Emergency planning zones or distances***

### iii. An extended planning distance (EPD);

from the facility, for facilities in Category I or II, is the area beyond the UPZ for which arrangements shall be made to conduct monitoring and assessment of the radiological situation off the site in order to identify areas within a period of time that would allow reducing the risk of stochastic effects effectively by taking:

- a) urgent protective actions and other response actions within a day following a significant release
- b) early protective actions and other response actions within a week to a month following a significant release

## ***Emergency planning zones or distances***

### iv. An ingestion and commodities planning distance (ICPD)

from the facility, for facilities in Category I or II, is the area beyond the EPD for which arrangements shall be made to take response actions:

- a) to protect the food chain and water supply systems as well as commodities other than food from contamination following a significant release
- b) to protect the public from ingestion of food, milk and drinking water and from use of commodities other than food that may be contaminated following a significant release

## Suggested emergency zones and area sizes for nuclear installations and facilities with dispersible radioactive material

Facilities	PAZ	UPZ	EPD	ICPD
Reactor facility				
Power higher than 1000 MW (th)	3 – 5	15 – 30	100	300
Power from 100 to 1000 MW (th)	3 – 5	15 – 30	50	100
Power from 10 to 100 MW (th)	None	0.5 – 5	2 – 25	5 – 50
Power from 2 to 10 MW (th)	None	0.5	1 – 2	2 – 5
Power less than 2 MW (th)	None	None	None	None
Facility with dispersible radioactive material				
$10^5 \leq \text{IDM}$	3 – 5	15 – 30	100	300
$10^4 \leq \text{IDM} < 10^5$	3 – 5	15 – 30	50	100
$10^3 \leq \text{IDM} < 10^4$	None	0.5 – 5	2 – 25	5 – 50
$10^2 \leq \text{IDM} < 10^3$	None	0.5	1 – 2	2 – 5
$\text{IDM} < 100$	None	None	None	None

IDM = Index of Dangerous Material

Unit: km

# Comments on the evaluation of emergency zones and projected exposures

- The suggested zone sizes are based on very conservative assumptions (\*) such as ground release, non filtered huge catastrophic release of radionuclides from the reactor after the accident.
- Assumption of a ground release is very unlikely and not comparable to the expected high pressure or energetic release, and more scientific based release studies take into account actual meteorological and dispersion conditions obtained through data from meteorological stations over at least a one year period. Diffusion particle-in-cell modeling should be used instead of simplified Gaussian models.

# Comments on the evaluation of emergency zones and projected exposures

- After the Fukushima accident safety upgrades of NPPs all over the world were made including passive containment filter systems, passive H<sub>2</sub> recombiners, additional mobile safety equipment and power supplies, additional heat sink options from the environment or local water sources. These upgrades ensure higher levels of radionuclide containment in case of general emergency scenarios. In the PAZ and UPZ there will be threat of deterministic effects, it is more likely to produce doses to the public comparable to doses found in normal planned exposure situations.

## ***Emergency planning zones or distances***

In response to nuclear emergencies in EPC I and II the arrangements for protection of the emergency workers should take into account that:

- The doses of emergency workers performing tasks in PAZ could exceed the threshold levels for development of severe deterministic effects if proper precautions are not taken
- The doses of emergency workers performing tasks in UPZ but beyond the PAZ will be unlikely to exceed the threshold levels. Nevertheless, the daily effective dose of emergency workers performing tasks in UPZ could exceed 10 mSv/d
- The daily effective dose of emergency workers performing tasks in EPD are unlikely to exceed 10 mSv/d
- The daily effective dose of emergency workers performing tasks in ICPD is unlikely to exceed 1 mSv/d

## ***Emergency planning zones or distances***

In response to radiological emergencies in EPC III and IV the arrangements have to be in place for establishing a safety perimeter of an inner cordoned area around scene of event.

That inner cordoned area should cover the territory with ambient dose rate above 100  $\mu\text{Sv/h}$  at 1 m above the ground surface.

The access of emergency workers (first responders) to that inner cordoned area should be controlled and subject to radiation protection procedures.

# Suggested radius of inner cordoned area (safety perimeter) for a radiological emergency

Situation	Radius of inner cordoned area
<b>Initial determination - outside</b>	
Unshielded or damaged potentially dangerous source	30 m around
Major spill from a potentially dangerous source	100 m around
Fire, explosion or frames involving a potentially dangerous source	300 m radius
Suspected bomb (potential RDD*) exploded or unexploded	400 m radius or more to protect against the second explosion
<b>Initial determination – inside a building</b>	
Damage, loss of shielding or spill involving a potentially dangerous source	Affected and adjacent areas (including floors above and below)
Fires, suspected RDD* or other event involving a potentially dangerous source that can spread materials in the building	Entire building and appropriate outside distance indicated

\*RDD: Radiological Dispersal Device (dirty bomb)

## ***Emergency planning zones or distances***

The scene of emergency in EPC IV could have heterogeneous contamination with “hot spots” inside the safety perimeter. It has to be taken into account that doses of emergency workers performing the tasks in “hot spots” could exceed the threshold levels of the development the severe deterministic effects if proper precautions are not taken.

## ***Emergency planning zones or distances***

The area in EPC V are similar to these in EPC I or II. It is unlikely that this area will include the extension of PAZ of a NPP in a neighbouring State.

Therefore;

- The doses of emergency workers performing tasks in extension of UPZ but beyond the PAZ are unlikely to exceed the threshold levels for the development of severe deterministic effects. Nevertheless, the daily effective dose of emergency workers performing tasks in UPZ could exceed 10 mSv/d
- The daily effective dose of emergency workers performing tasks in extension of EPD are unlikely to exceed 10 mSv/d
- The daily effective dose of emergency workers performing tasks in extension of ICPD are unlikely to exceed 1 mSv/d

# Summary of expected levels of health risk emergency workers

Expected health effects for EPC (PWoP : Possible Without Protection)

EPC	Category of exposed persons	Health risk	
		Deterministic	Stochastic
I	On-site emergency workers and staff of the facility	PWoP	PWoP
	Off-site emergency workers	PWoP	PWoP
II	On-site emergency workers and staff of the facility	PWoP	PWoP
	Off-site emergency workers	Unlikely	PWoP
III	On-site emergency workers and staff of the facility	PWoP	PWoP
	Off-site emergency workers	Unlikely	Unlikely
IV	First responders and emergency workers	PWoP	PWoP
V	Emergency workers	Unlikely	PWoP