RC III.

New challenges in radiation protection

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Initiated by the comprehensive ICRP Publication #103 ("The 2007 Recommendations of the International Commission on Radiological Protection") significant progress is experienced both in scientific and regulatory-legislative areas of radiation protection, often termed also as "health physics". Some "selected chapters" of this large discipline will be presented and discussed in detail, somewhat reflecting the subjective choice of the presenter as well. The two topics selected for this short course are the radiation protection issues of a serious nuclear or radiological emergency and the interpretation of the concepts of exemption and clearance, with special emphasis on the tasks and challenges of decommissioning. Lessons learned from major nuclear emergencies, especially from the Fukushima accident, induced extensive work in – inter alia – dose projection modelling, rapid and still efficient procedures of personal and environmental monitoring in order to improve effectiveness of emergency response planning.

In addition to the decommissioning of obsolete nuclear facilities, major accidents with significant environmental impact also resulted in the generation of large masses of potential radioactive wastes, the processing of which shall be preceded by an accurate, precise and cost-effective classification procedure based on internationally accepted terms of exemption and clearance which are in turn directly related to the estimated dose consequences of the selected fate of these materials.

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New Challenges in Radiation Protection

Peter Zagyvai, C.E.R.

Contents:

- General aspects of radiation protection: brief summary of „key points” as stipulated in IAEA GSR Part 3 and Council Directive 2013/59/EURATOM (EU BSS)
- New challenges in radiation protection concerning Emergency Preparedness and Response (EPR)
- New challenges in radiation protection concerning decommissioning of major nuclear facilities (D&D)

Compiled from several lectures presented at graduate university courses (BME University) and training courses for experts (IAEA)

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1) Brief summary of „key points”

- Dose definitions
- Health hazards related to dose
- Exposure modes: incurrence, situations, scenarios, etc.

COUNCIL DIRECTIVE 2013/59/EURATOM

of 5 December 2013

laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom

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

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General Safety Requirements Part 3

No. GSR Part 3

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Health effects from ionizing radiations: possibly unfavourable physical, chemical and biological changes in human tissue

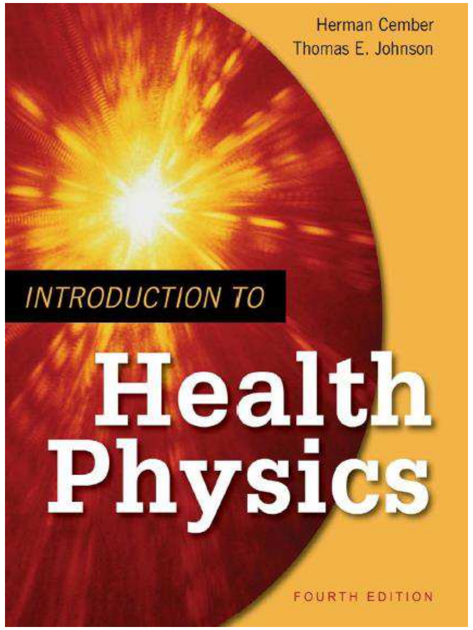
Interactions: energy transfer leading to multitude of ions per absorbed particle
» **physical changes** ($<10^{-15}$ s) : excited atoms, ionization
» **chemical changes.** (10^{-15}-10^{-11} s): free radicals, ions, reactions

in living organisms:
» **biochemical changes** (10^{-11}-10^{-3} s): changes in cellular functions, changes in metabolic behaviour
» **biological changes** (10^{-3} s/hours/days/weeks/years)

Characterization of energy absorbed from ionizing radiation by matter

ABSORBED (physical) DOSE

$$D = \frac{dE}{dm} \approx \frac{\Delta E}{m}\left[\frac{J}{kg}, Gray, Gy\right]$$



$$D = \frac{dE}{dm} \approx \frac{\Delta E}{m} \left[\frac{J}{kg}, Gray, Gy \right]$$

Physical dose: total radiation energy absorbed in unit mass of any material, comprises only physical interactions.
Applicable to any type of direct or indirect ionizing radiation **(α, β, γ, n, p, X-ray** etc.).
Applicable only to ionizing radiations, but includes every type of energy transfer, not only energy leading to ionization.
Does not include secondary scattered radiations that are not absorbed in the same target.
„Unites” energy amounts from each origin = pertains directly to the target, not to the individual radiation components (sources).

Biological effects of ionizing radiations

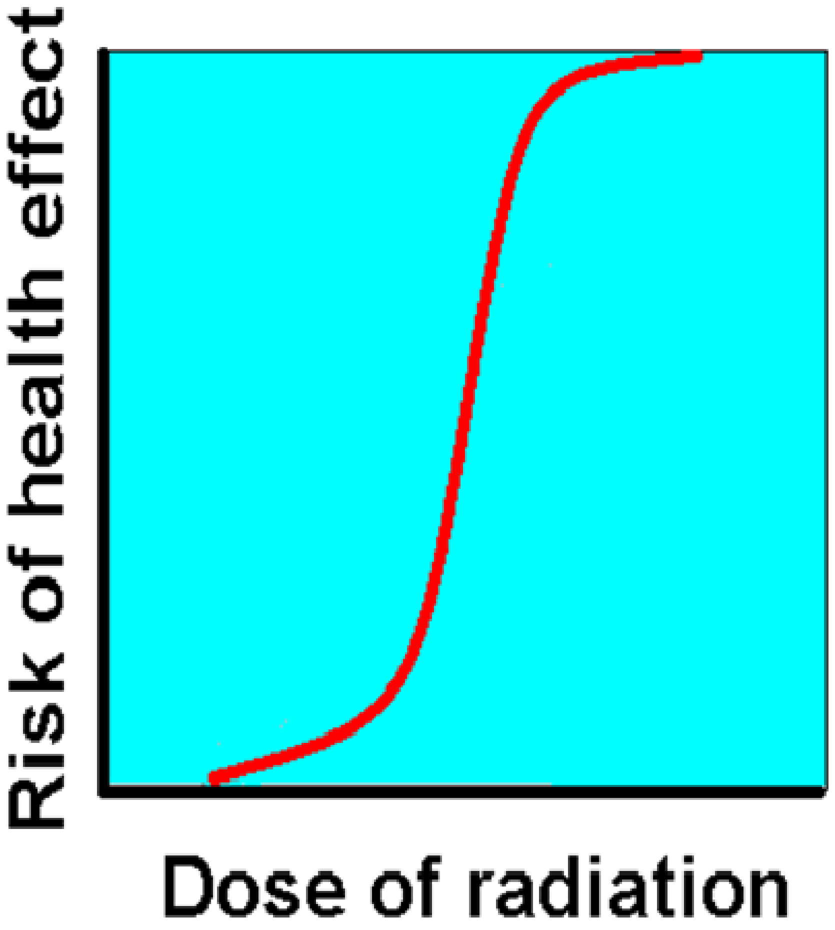
- Deterministic effect: the cell does not survive the collision – it is „deadly damaged” by the energy transferred from collision with radiation particles.

- Stochastic effect: the cell survives the collision but its DNA structure is changed so the descendant cell of the next generation (following mitosis = cell replication) will be different from the parent.

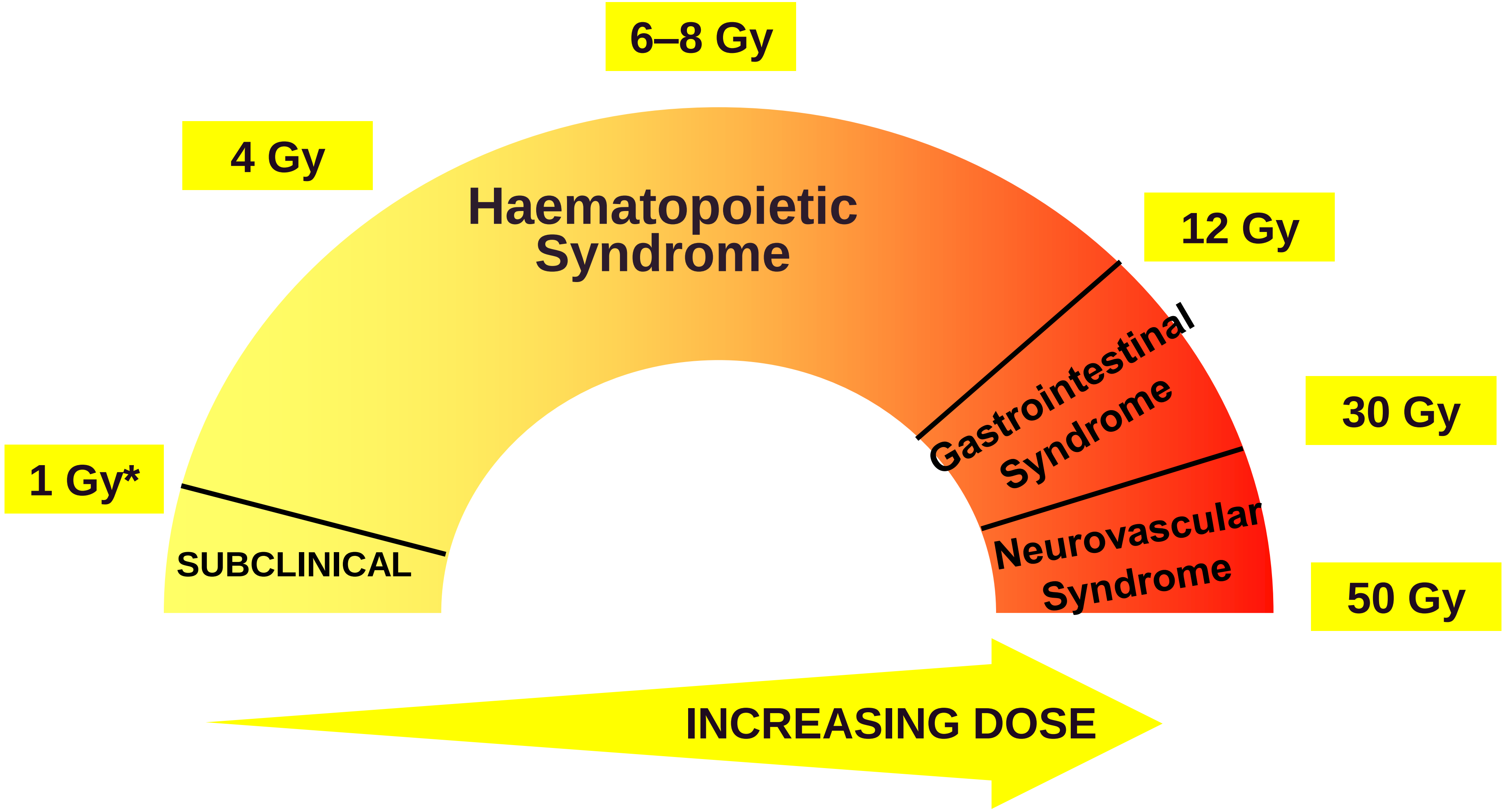
Deterministic effects

Deterministic effects

- occur only if a threshold is exceeded (threshold for most sensitive tissues: 0.3 – 0.4 Gy, foetus: 0.1 Gy)
- so many cells are damaged that devastation (necrosis, „burning”) of tissue takes place
- acute/immediate effect
- life-threatening effects on these tissues: central nerve system, gastrointestinal system, haematopoietic system



Severity of deterministic effects



Acute Radiation Syndrome (ARS) in Chernobyl NPP staff and first responders

Degree of ARS	Range of RBE weighted whole body dose [Gy]	Number of patients	Number of deaths
Mild (I)	0.8-2.1	41	-
Moderate (II)	2.2-4.1	50	1
Severe (III)	4.2-6.4	22	7
Very severe (IV)	6.5-16	21	20
Total	0.8-16	134	28*

* 28 died in 1986 from a combination of high external doses of γ-exposure and skin burns due to β-emitters

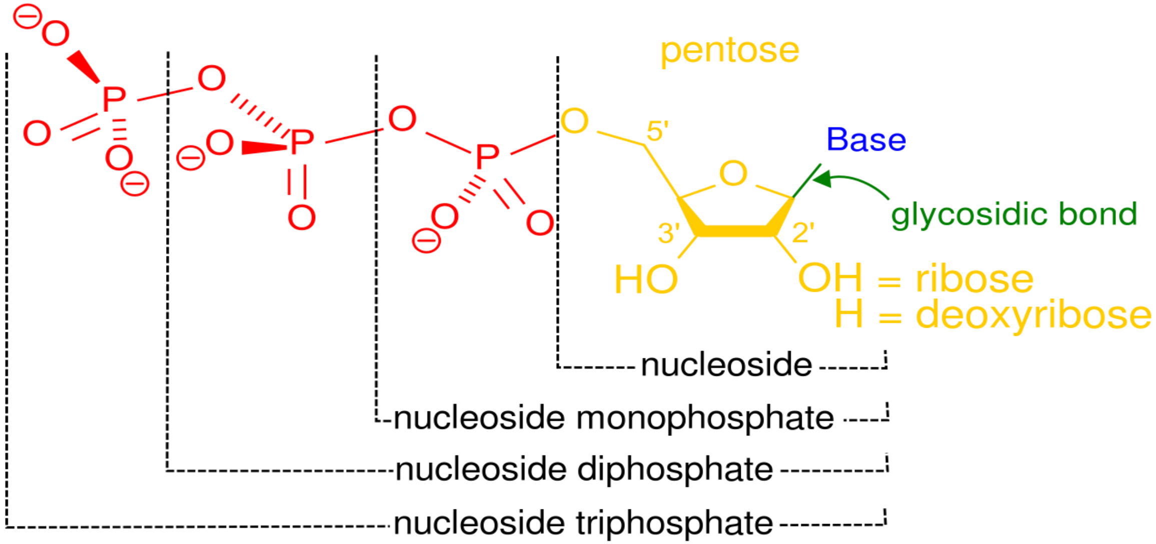
Stochastic effects of ionizing radiations

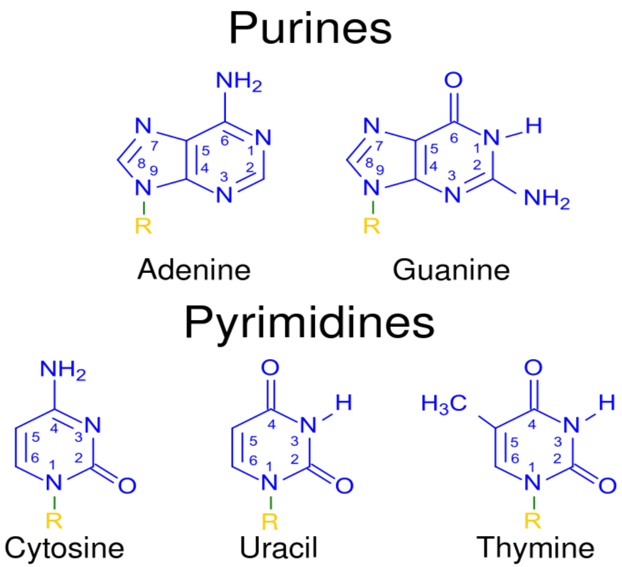
„Primary target”: DNA-content of cell nucleus

DNA: macromolecule with a double spiral shape constructed from sugar- and phosphate groups accompanied by organic bases (A,D,C,T,U). Chain link: nucleotide. The spirals are connected by hydrogen bonds between the bases.

Genetic information (composition of proteins of a cell) is coded by DNA structure in the chromosomes.

Gene: piece of DNA chain coding a protein or a cellular feature; group of genes = genom.



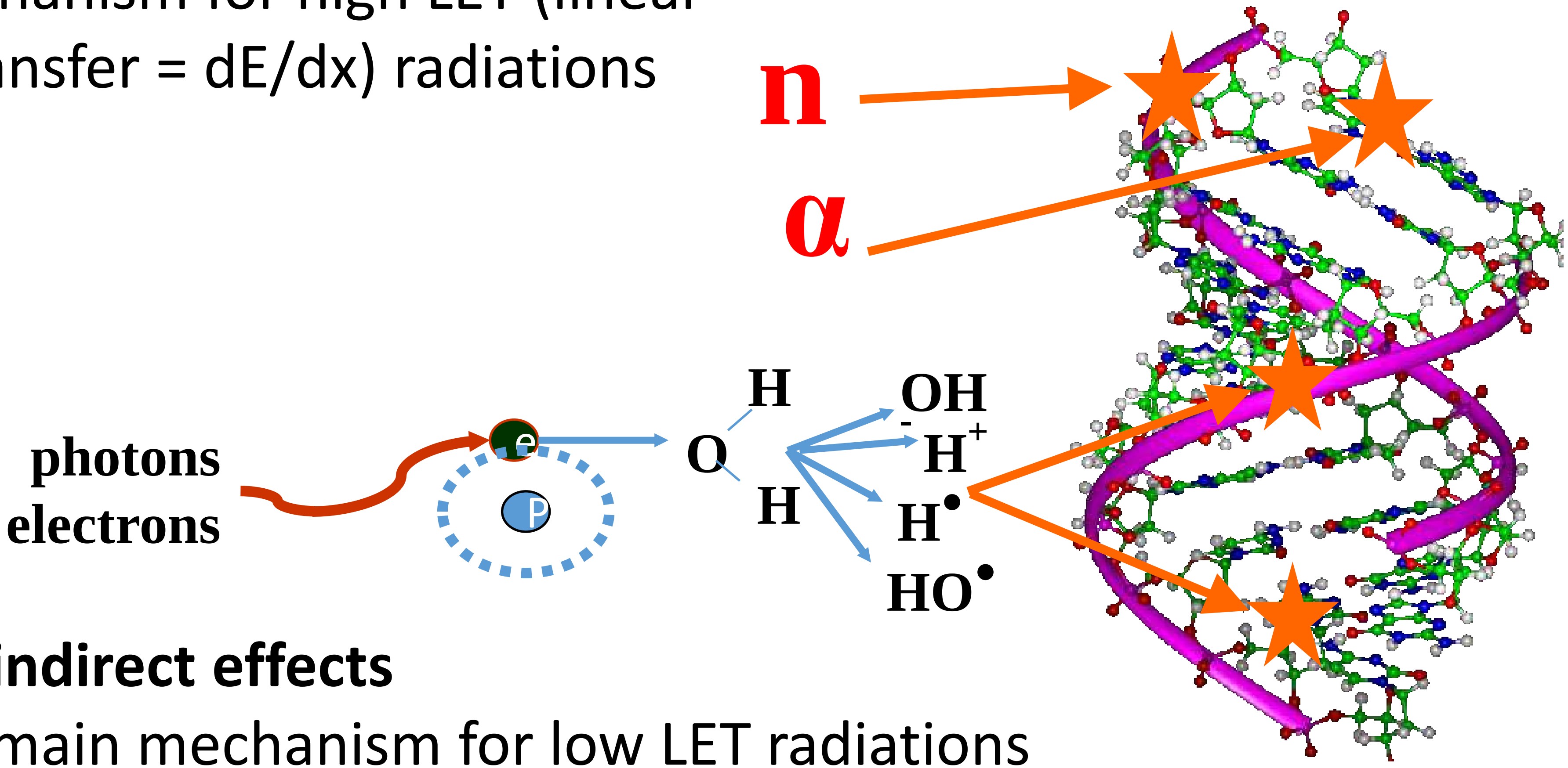


Radiation effects on DNA

High LET radiations are able to cause more strand breaks on the **SAME** DNA than low LET radiations

direct interaction

main mechanism for high LET (linear energy transfer = dE/dx) radiations



indirect effects

main mechanism for low LET radiations

Equivalent dose – measure of stochastic biological effect of ionizing radiations

$$H = D \cdot w_R \ [\text{Sievert}, \text{Sv}]$$

D: absorbed (physical) dose [Gy]

w_R radiation weight factor – function of LET (conversion factor of Gy to Sv)
$w_{R,\alpha} = 20$
$w_{R,\gamma} = 1$
$w_{R,\beta} = 1$
$w_{R,n} = 2{,}5 \div 20$ depending on neutron energy

Detriment of absorbed dose depends on energy transferred to a cell-size volume of living human material (microdose).

„Anthropomorphous" dose quantity and unit: radiation weight factors are (probably) different for other living organisms (animals, plants).

Equivalent dose characterizes ONLY the stochastic effect!!!

Internal dose: radioactivity is incorporated (inhaled, ingested)
External dose: ionizing radiation penetrates the human body

$$E = H_E = \sum_T H_T w_T [Sv]$$

<u>Effective dose</u>
w_T tissue weight factor

$$\sum_T w_T = 1$$

New tissue weight factors (recommended in 2007 in ICRP#103):

gonads

w_T=0.08 (genetic effects – not confirmed)

Somatic effects

most vulnerable – from <u>general</u> cancer statistics

w_T=0.12 lungs, stomach, colon, red bone marrow, breast, rest

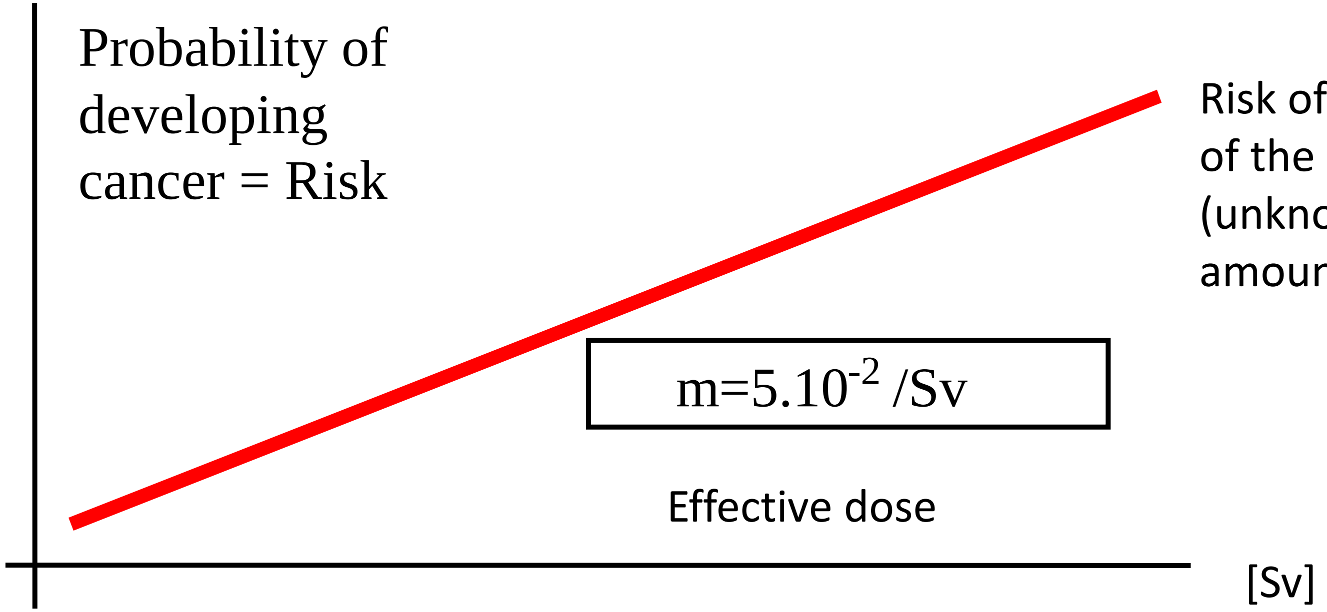
vulnerable

w_T=0.04 liver, kidney, thyroid, bladder, oesophagus

less vulnerable

w_T=0.01 skin, bone surface, salivary gland, brain

Detriment of ionizing radiations – stochastic effect:
- no dose threshold (effect of low doses is not confirmed)
- cellular mutation (chance for repair until mitosis/meiosis)
- dose/risk function is linear (?)



Risk of an individual is the sum of the risks of the tissues (unknown owing to small amount of certified data)

Dependence was calculated from the epidemiological statistics of the survivors of Hiroshima and Nagasaki bombings.

Deduction of dose/risk line - The nuclear bombing survivors

1. About **200 000** people died in Hiroshima and Nagasaki in 2-4 month after bombing. Almost 50% of them died in the first day.
2. A survey on A-bomb exposure as part of Japan’s 1950 national census revealed that about **284 000** people had been exposed to the bombs and survived.
3. Life Span Study (**LSS**) cohort with the total number of about **120 000** was organized in 1958:
   - all of the heavily exposed A-bomb survivors;
   - a selected population of the less exposed and non-exposed residents of both cities matched by age and sex with the first group

Life Span Study mortality (1950-2002)

Diseases	Deaths			Attributable fraction
	observed	expected	excess	
Solid cancer	6 718	6 205	**513**	**8.3%**
Leukemia	317	219	**98**	**44.7%**

86 611 people with evaluated "Colon dose"

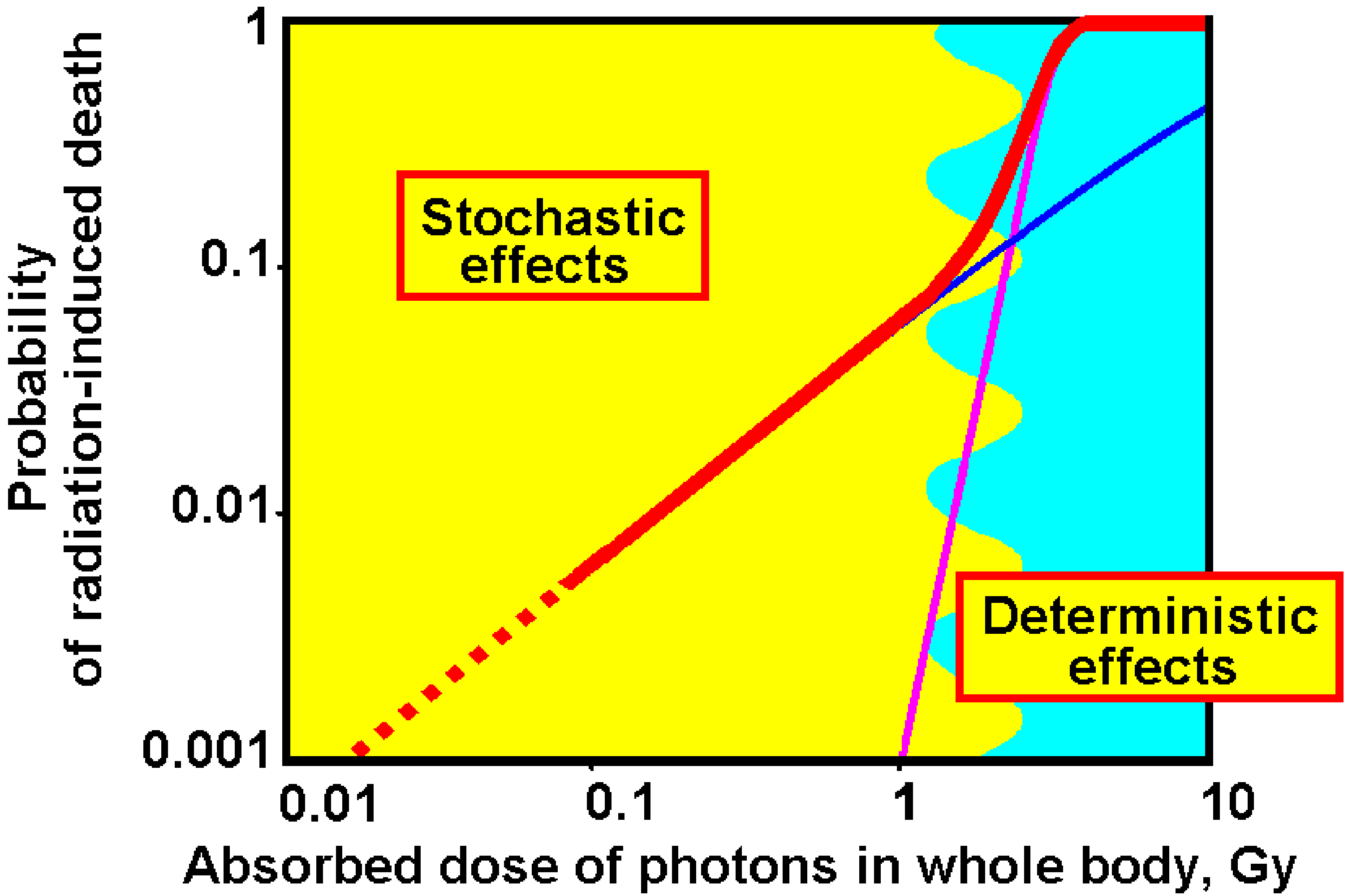
38 509 with dose **< 5 mSv**

6 000 with dose **> 100 mSv**

700 with dose **> 1000 mSv**

Dose reconstruction was accomplished between 1980 and 1990

Radiation health effects - summary



Standard measurable dose quantitites

- Dose and dose rate meters are capable of measuring absorbed dose only incurred as external exposure
- Real biological dose is different at every part of the body even in a homogeneous radiation field
- Personal dose equivalent $H_P(d)$ – absorbed dose measured at depth *d* (mm) in human body
- Ambient dose equivalent H*(d) – absorbed dose measured at depth *d* (mm) in ICRU sphere of standard composition (76% O, 11% C, 10% H, 3% N)
- Strongly penetrating radiation d = 10 mm
- Weakly penetrating radiation d = 0.07 mm
- Internal exposure is impossible to be measured directly – only calculations are feasible

From international recommendations to national regulations

Annals of the ICRP

PUBLICATION 103

The 2007 Recommendations of the International Commission on Radiological Protection

Verordnung über den Schutz vor Schäden durch ionisierende Strahlen (Strahlenschutzverordnung - StrlSchV)

StrlSchV

Ausfertigungsdatum: 20.07.2001

Vollzitat:

"Strahlenschutzverordnung vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), die zuletzt durch Artikel 5 Absatz 7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212) geändert worden ist"

COUNCIL DIRECTIVE 2013/59/EURATOM

of 5 December 2013

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General Safety Requirements Part 3
No. GSR Part 3

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Radiation protection regulations – basic safety principles

Basic principles – first stated in 1976, extended in 1991 and 2007 → appeared in GSR Part 3 and EU BSS

- Justification: application of a radiation source must have a positive benefit = cause more good than harm
- Optimization: application of a radiation source must have a maximum benefit = planning basis - ALARA (As Low As Reasonably Achievable) for magnitude of incurred dose and number of exposed persons
- Limitation –limits for each individual for immission and emission are set that shall not be exceeded – dose limits (DL) for immission of individuals; dose constraints (DC) for emission of installations defined as the maximum allowable dose consequence for the most affected individual.

Other general viewpoints of radiation protection guidance:

- ❑ Exposures of high doses causing severe deterministic effects shall be *averted.*
- ❑ Only doses from „applications" can be limited, purely natural phenomena leading to elevated doses are *excluded* from regulatory aspects. (*Yes, but what is PURELY natural?)*

Radiation protection requirements – implementation of safety principles

Exposure situations:

- planned,
- emergency and
- existing

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Radiation protection requirements – implementation of safety principles

Dose limits for planned exposure situations:

- **Radiation workers** – 20 mSv/year effective dose, with special permit: max. 50 mSv/year but max. 100 mSv in 5 consecutive years, further values (equivalent dose) for lens of eye, extremities and skin – implementation: national dosimetry service, operational dose meters, control of internal exposure with certified equipment
- Lower values (6 mSv/year effective dose etc.) for students and apprentices
- **Public** – 1 mSv/year effective dose, further values for lens of eye , extremities and skin

Radiation protection requirements – implementation of safety principles

Reference levels for the public involved in existing and emergency exposures

- Existing: 1 – 10 mSv/year effective dose *(Radon in homes?)*
- Emergency/accident: ≤ 100 mSv/year effective dose
- Termination of emergency situation; transition to existing situation: below 1 – 10 mSv/year effective dose

Reference levels for emergency responders: life saving, crucial and relevant protective operations: 250 mSv (IAEA GSR Part 7:<500 mSv), 100 mSv and 50 mSv per event, resp. → see further

Radiation protection requirements – implementation of safety principles

Dose constraints for planned exposure situations:

- ❑ Radiation workers: dose constraints can be set in local RP ordinance for particular work processes associated with radiation exposure risks higher than the average. *Confirmation: by personal dosimetry*
- ❑ Population: primary nuclear and radiological facilities (with high radioactive inventory and/or high radiation risks) are obliged to set specific dose constraints (10 – 100 μSv/year effective dose) for the representative (=most affected) person considering all possible exposure pathways originating exclusively from that dedicated facility. They are determined by the licensee and approved by the regulatory body. *Confirmation: release limits derived by certified dispersion models*

Radiation protection requirements – implementation of safety principles

Release limits (RL) in association with dose constraints

$$RLC = \sum_i \frac{A_{i,out}}{RL_i} < 1$$

Release limits (airborne and liquid) defined for each radionuclide present in the inventory of the facility are related to the dose constraint of the facility by means of dispersion models comprising emission, migration and exposure processes. They should be validated by comparing their results to actual emission events.

Release limits (RL) [Bq/year] of facilities are approved by the regulatory body. They are combined in a joint Release Limit Criterion (RLC)

Activity reaching the most affected person (A_{max}) = maximum intake is much less than the released (A_{out}) value. Maximum permissible A_{out} = release limit.

Release limits derived from dose constraints

- „Negligible dose” ≤ 10 - 30 µSv/year → basis of EXEMPTION and CLEARANCE from regulatory control – minimum (reasonable) value of dose constraints
- Maximum permissible emission levels = release limits for planned situations (normal operations and „regular operational occurrences”) are given in [Bq/year] unit.
- Separate data sets for airborne and liquid releases
- Relation between maximum intakes and dose constraint:

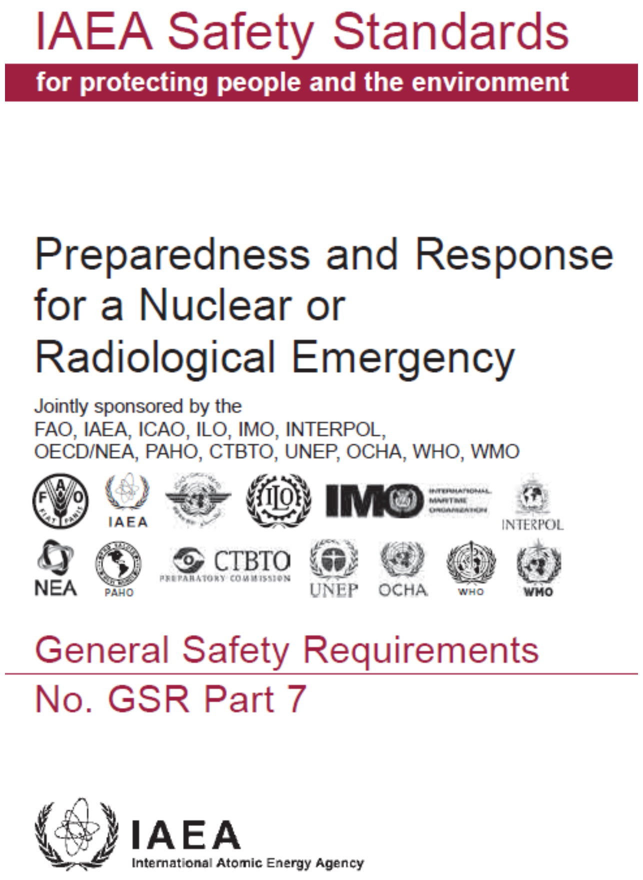
$$\sum_{i}\left(A_{i,max}\cdot e(g)_{i}\right)\leq DC$$

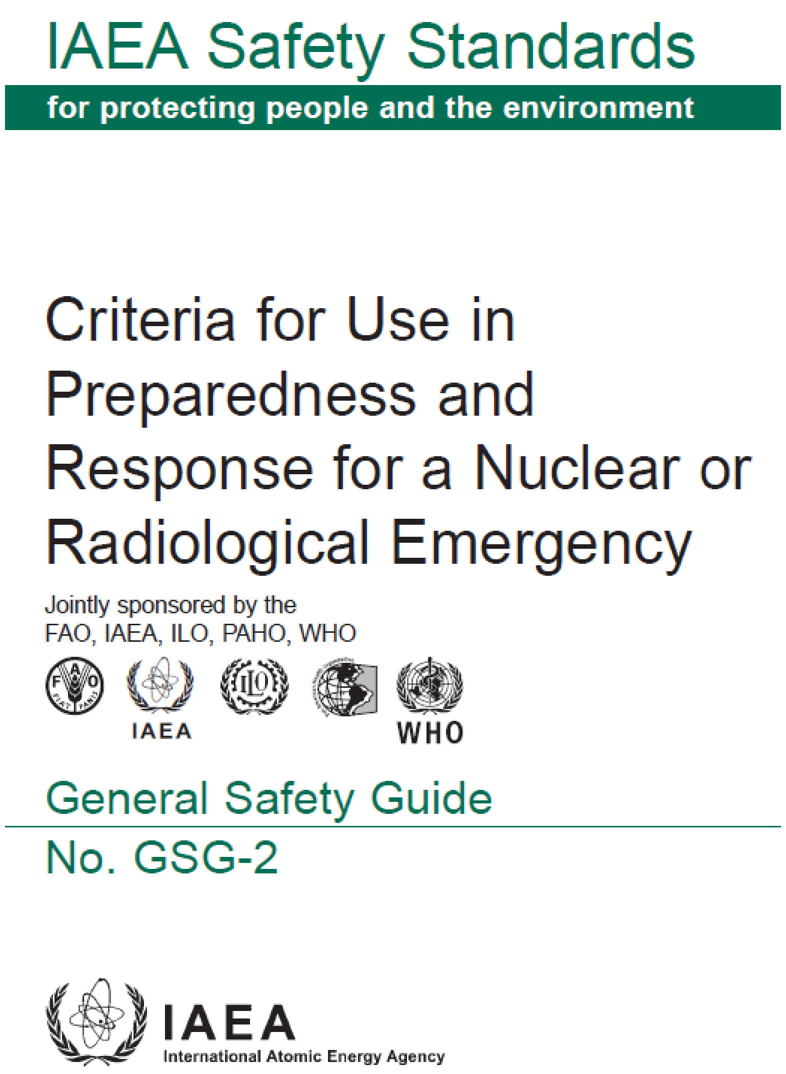
$A_{i,\,max}$ << $A_{i,out}$ – ratio to be determined with certified dispersion models

A_{max}: Maximum intake of the representative person from radionuclide i,
e(g): internal dose conversion factor (committed dose consequence of unit intake [Sv/Bq])

2) New challenges in Emergency Preparedness and Response (EPR)

- ❑ Guidance dose values and measurable amounts for limiting the exposure of responders and the public
- ❑ On-site and off-site response organizations and their responsibilities
- ❑ Emergency preparedness categories (EPC) of facilities and activities
- ❑ Emergency planning zones and distances
- ❑ Phases of an emergency
- ❑ Protective actions
- ❑ Monitoring during an emergency





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Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency

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General Safety Guide

No. GSG-2

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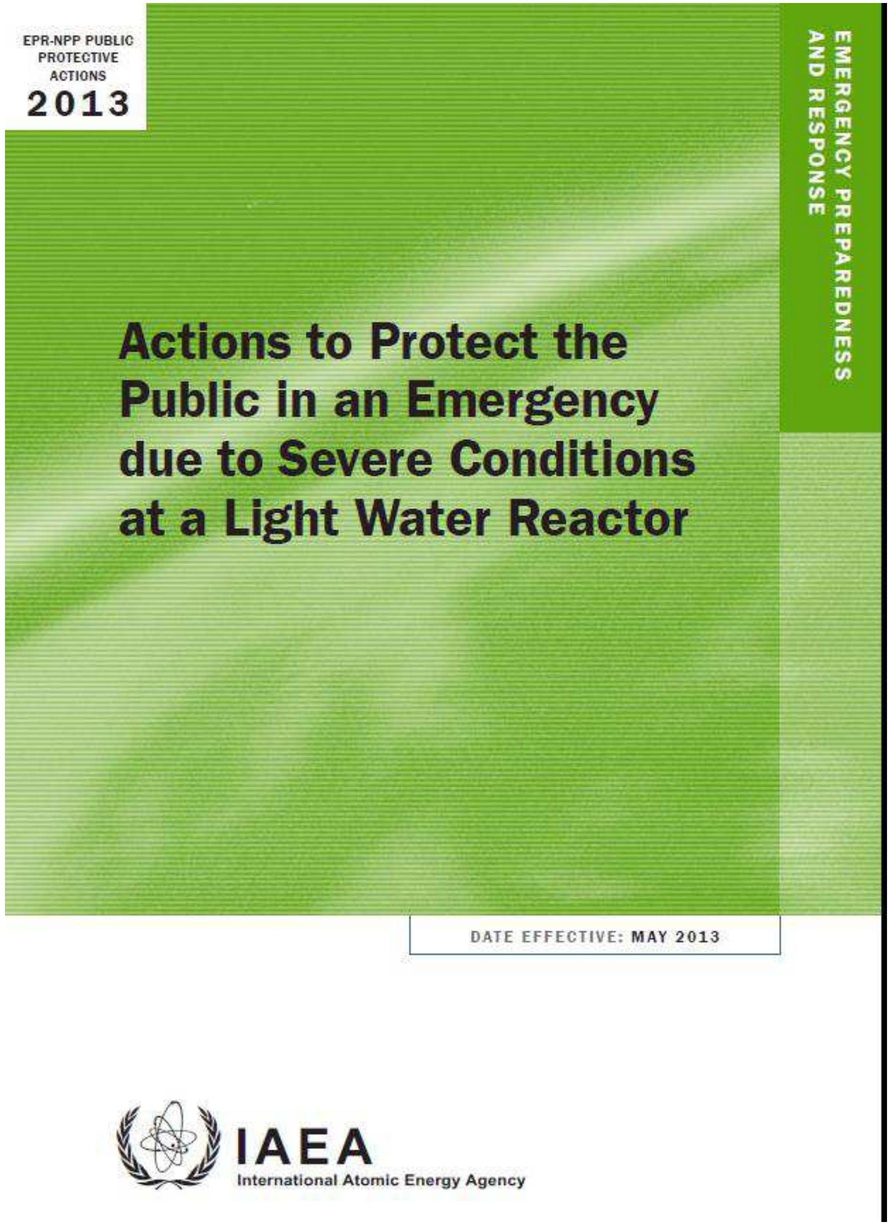

EPR-NPP PUBLIC PROTECTIVE ACTIONS
2013

EMERGENCY PREPAREDNESS AND RESPONSE

Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor

DATE EFFECTIVE: MAY 2013

IAEA
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Reference levels of dose exposures in emergency and existing situations

Reference levels: Effective dose of the most exposed members of the population

Health concerns

100 mSv

Emergency exposure situation

20 mSv

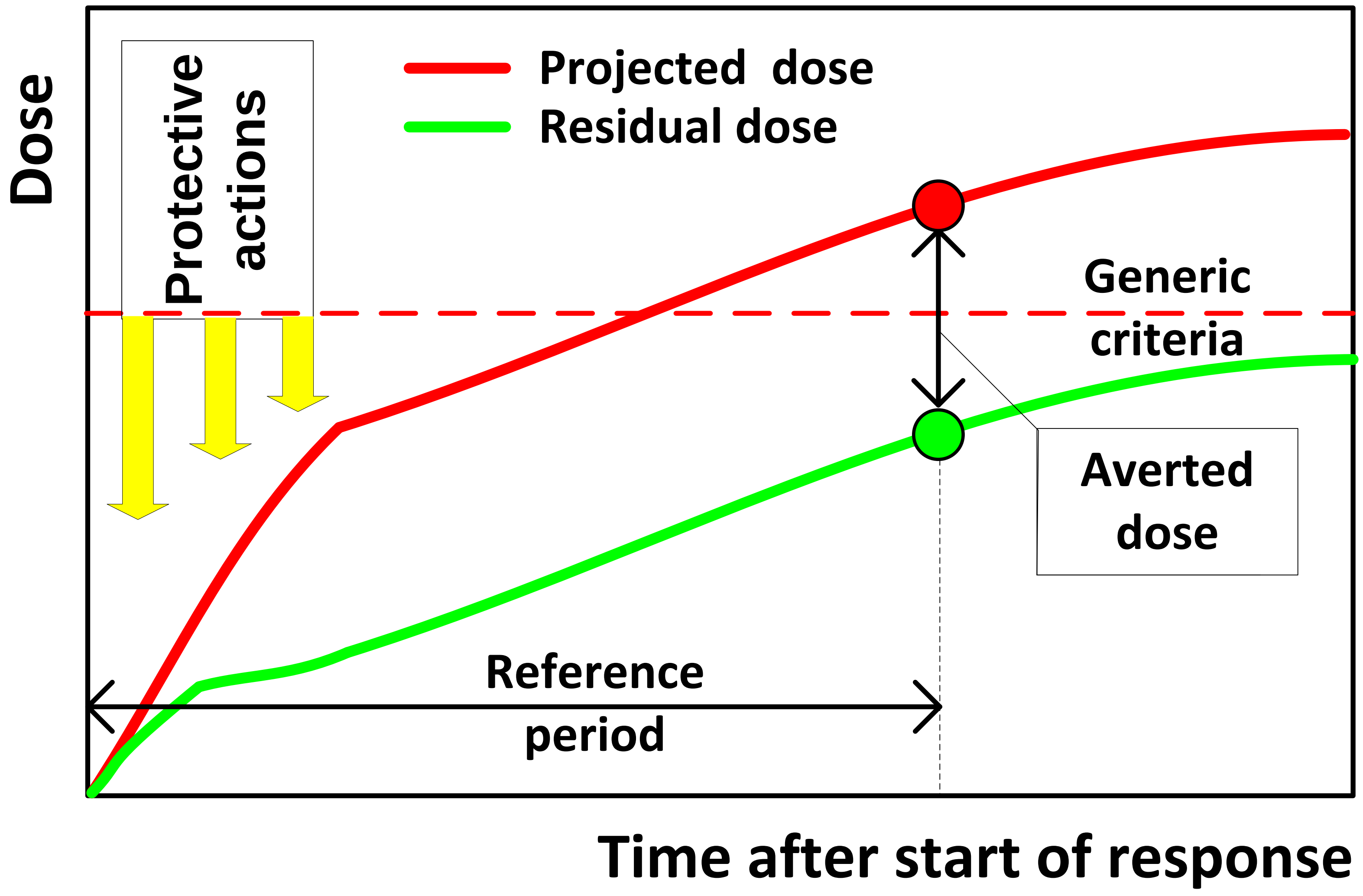
Existing exposure situation

1 mSv

Planned exposure situation

Values are set as projected dose: worst consequence without protective actions

Projected and residual dose

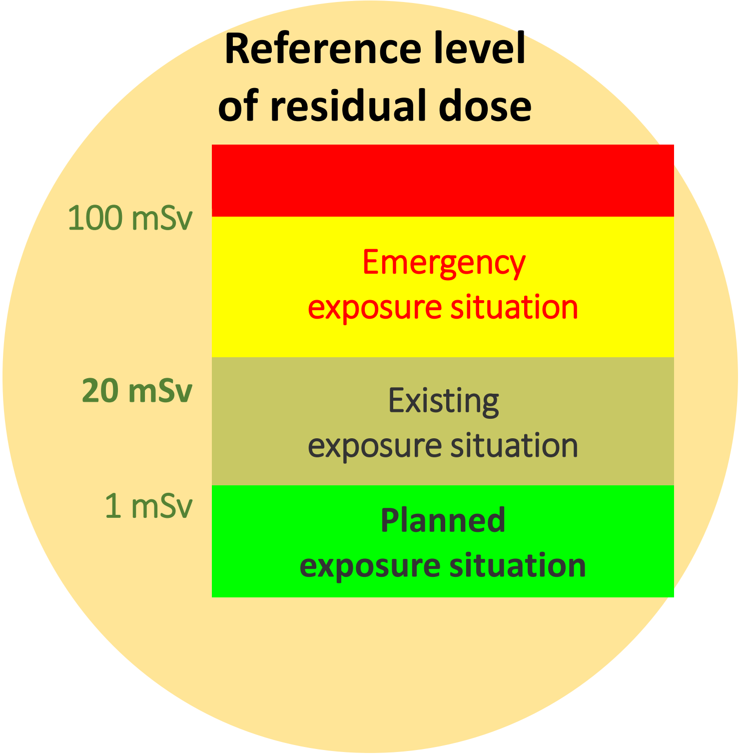


Protection Strategy

Set reference level of residual dose between 20 mSv - 100 mSv

Establish Generic Criteria of projected or received dose warranting specific protective actions and other response actions

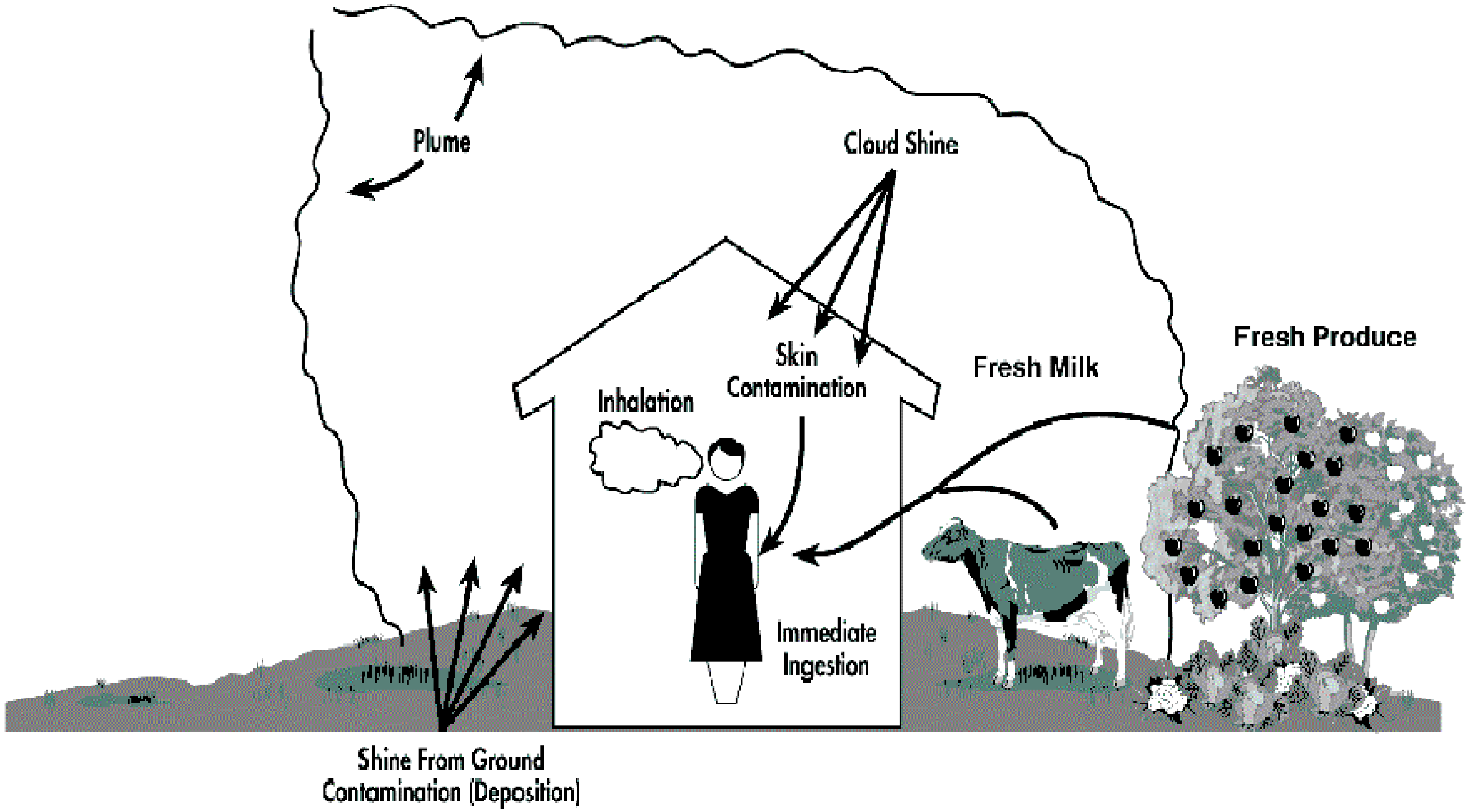
Develop default operational criteria: measurable parameters or observables (e.g. OILs, EALs)



Generic criteria: dose consequences of probable exposure scenarios and pathways: cloud shine, ground shine, inadvertent ingestion etc.

OIL = operational intervention level for monitoring off-site releases
EAL = emergency action level for on-site operators for observing the emergency

IMPORTANT EARLY DOSE PATHWAYS FOR REACTOR ACCIDENTS

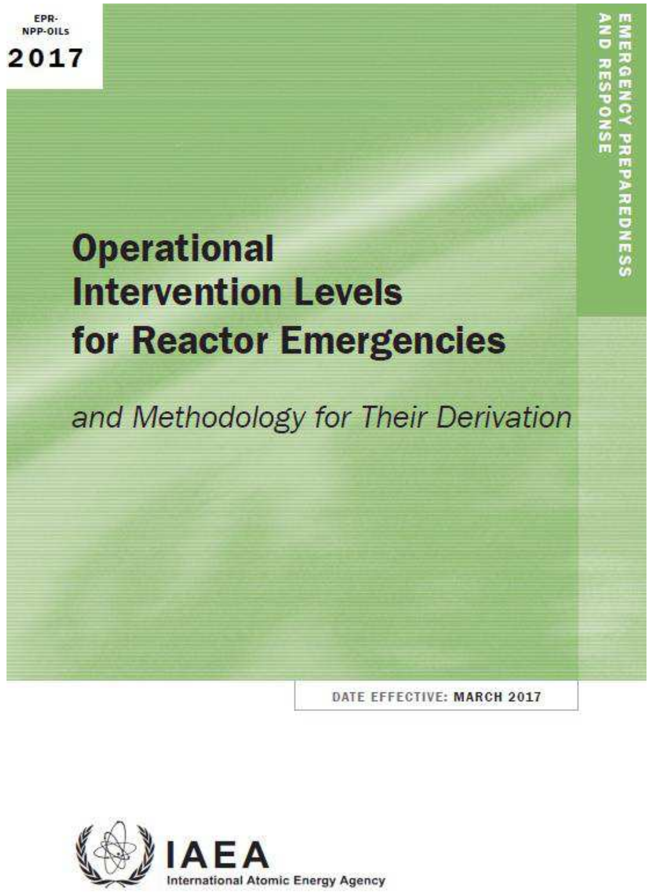


Reference level, generic criteria and intervention levels

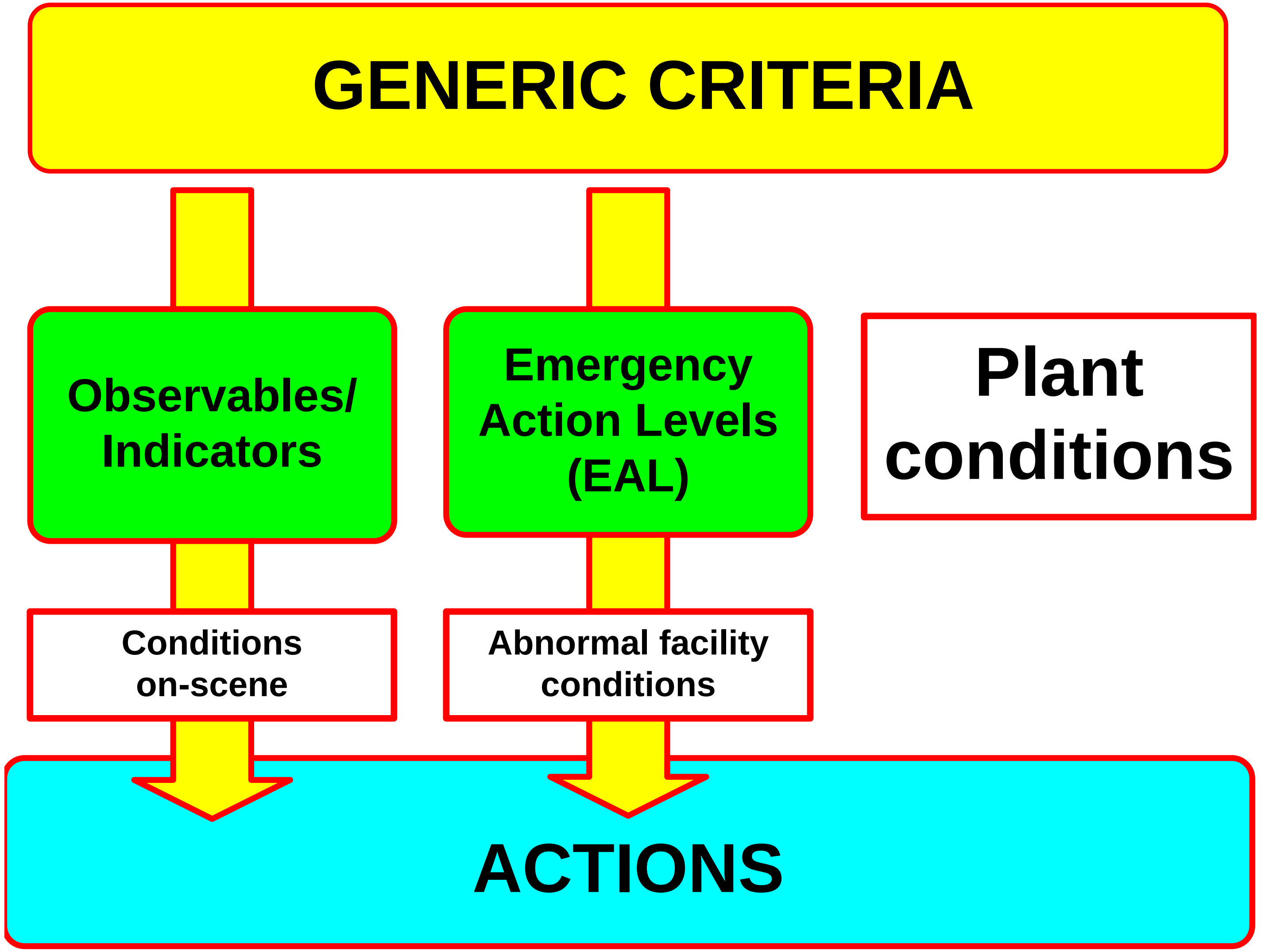
Generic criteria (GC) should be kept but cannot be measured directly – measurable quantities are required which are equivalent to GC's

Emergency action levels (EAL): dose rate [mSv/h], pressure, temperature, etc. - applied for on-site evaluations

Operational Intervention Levels (OIL): dose rate [µSv/h], activity concentration [Bq/kg] applied for off-site evaluations to help decision-making

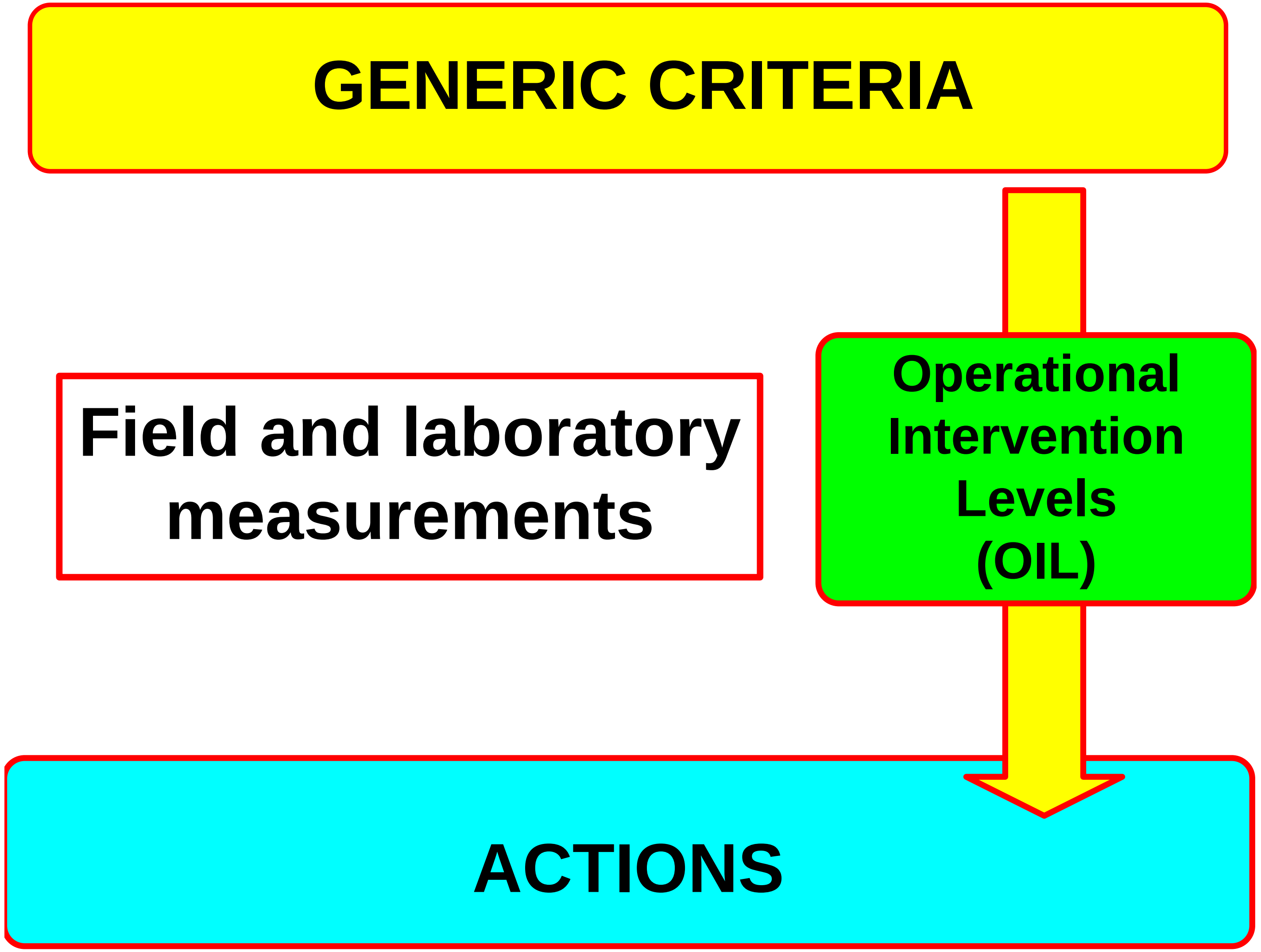


From generic criteria to actions (1)



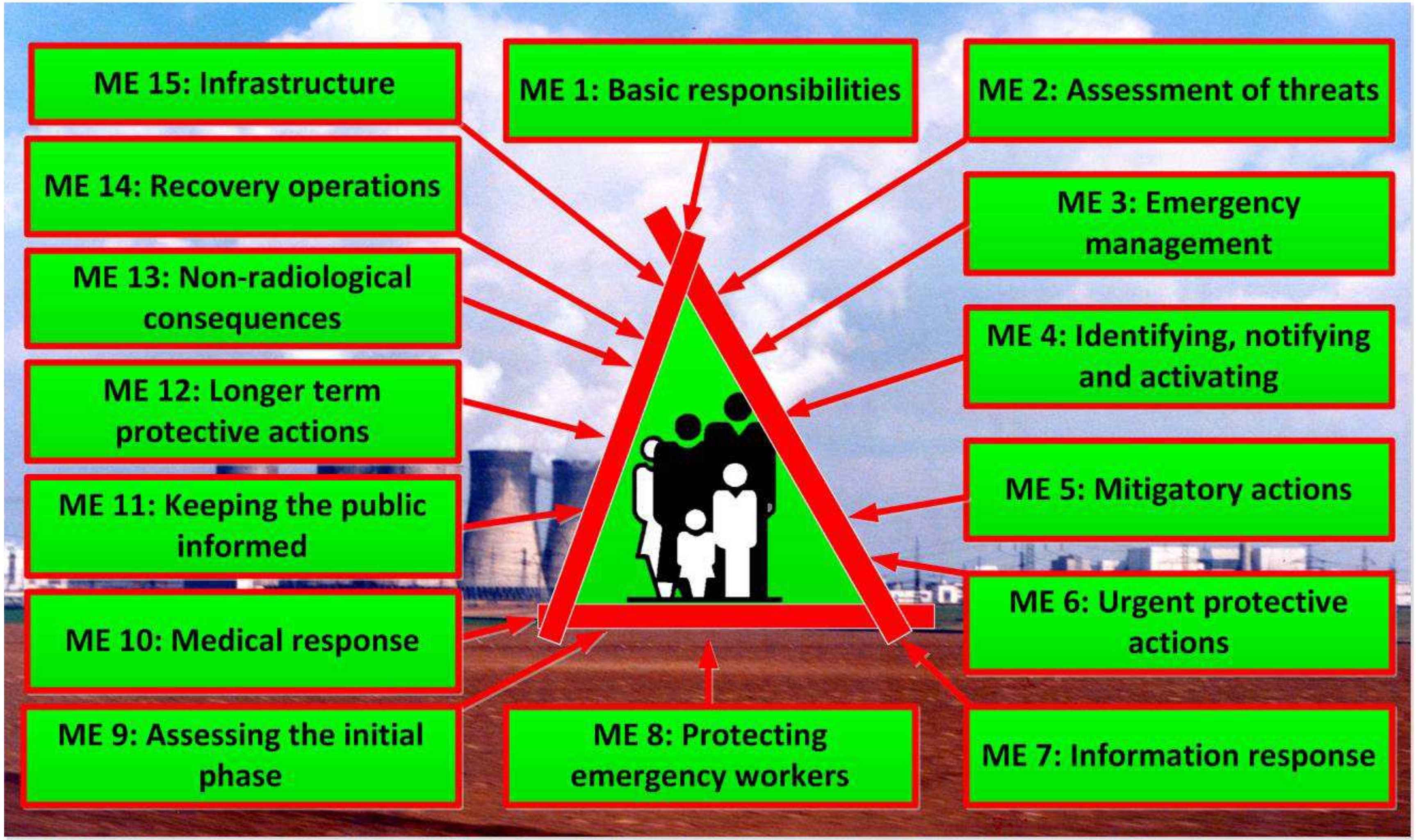
On-site

From generic criteria to actions (2)



Off-site

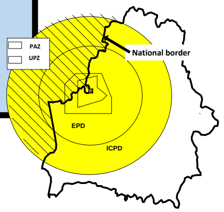
Framework of Emergency Preparedness and Response – major elements for planning and implementation



Emergency Preparedness Categories

Cat.	Description
I	Associated with facilities in which severe deterministic effects off-site are possible (e.g. reactors > 100 MW(th))
II	Associated with facilities that can warrant urgent protective actions off-site but severe deterministic effects are only possible on-site (e.g. reactors 2 – 100 MW(th)
III	Associated with facilities that can only warrant urgent protective actions on-site, severe deterministic health effects are possible only on-site (e.g. radiotherapy facility)
IV	Associated with activities and sources leading to an emergency at any location (e.g. mobile industrial radiography, transport)
V	Associated with areas affected by a transboundary contamination necessitating prompt response (areas within emergency planning zones and distances of neighbouring NPP)

FIG. 14. Very dangerous source from radiography camera (should never be picked up).



Classification of Emergencies

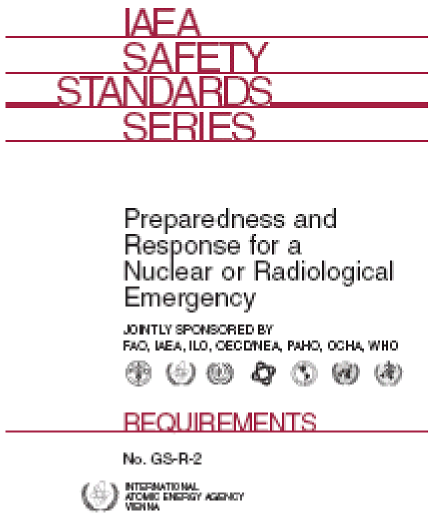
General emergencies at facilities in EPC I or II;

Site area emergencies at facilities in EPC I or II;

Facility emergencies at facilities in EPC I, II or III;

Alerts at facilities in EPC I, II or III;

Other emergencies at unpredictable locations associated with activities in EPC IV.



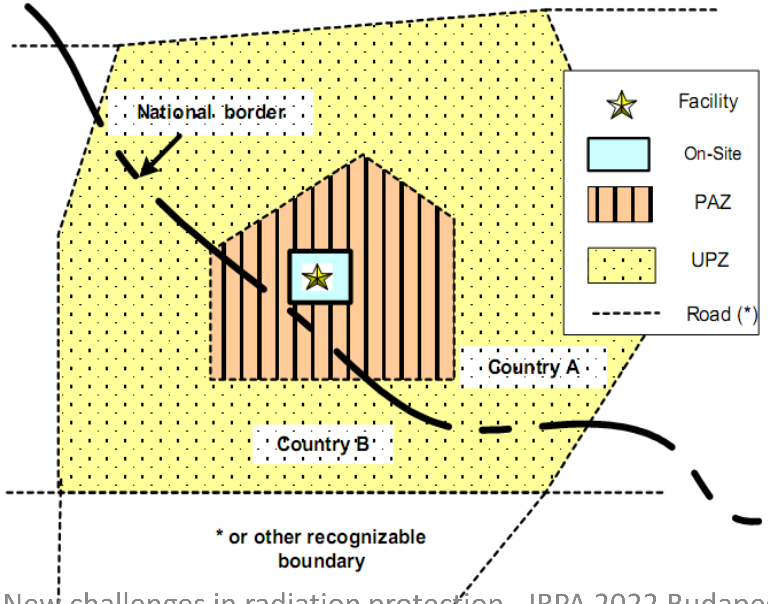
Phases of emergency response

Emergency planning zones and distances

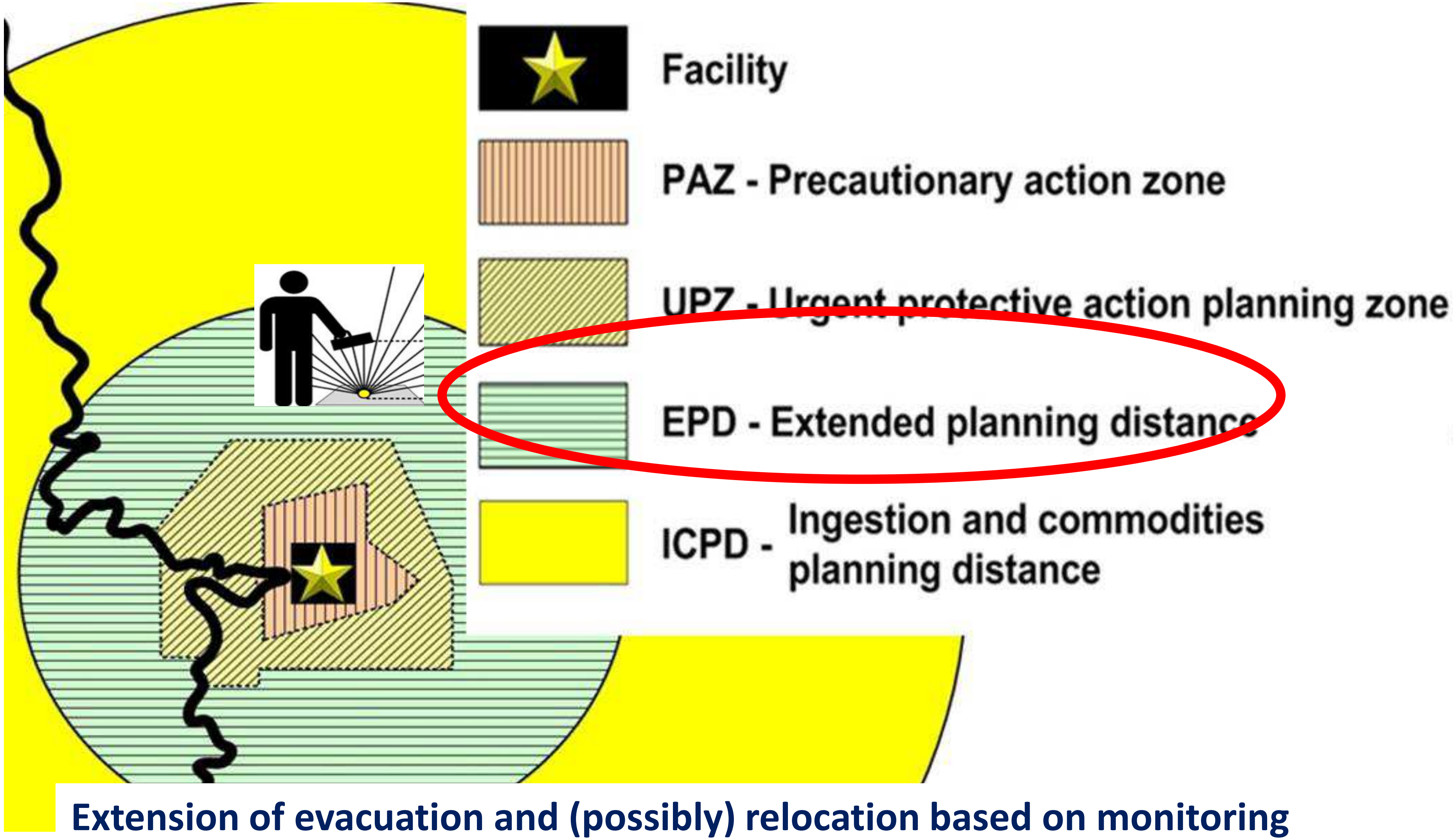
On-site area (e.g. reactor containment + controlled area)

Off-site zones and distances:

- Precautionary action zone (PAZ)
- Urgent protective action planning zone (UPZ)
- Extended planning distance (EPD)
- Ingestion and commodities planning distance (ICPD)



Extended planning distance (EPD) and ingestion and commodities planning distance (ICPD)



Extension of evacuation and (possibly) relocation based on monitoring results (in a max. distance of 50-100 km)

Interventions (protective actions) in case of general emergency

Purpose: reducing the risk of the most affected members of the public; protecting the health of the responders

Actions:

- Sheltering
- Evacuation
- Taking protective pills against iodine uptake (ITB)
- Relocation
- Restrictions on harvesting and consumption of local products (foodstuff, feeding stuff, commodities etc.)
- Medical services, record keeping, etc.

Generic criteria for protective actions in emergency exposure situations to reduce the risk of stochastic health effects

Projected total dose equivalent

Generic Criteria	Action
> 100 mSv in the first 7 days	**Sheltering, evacuation, decontamination, restriction of food, consumption**
> 100 mSv in the first year	**Temporary relocation, decontamination, replacement of food, milk and water, public reassurance**

Generic criteria for protective actions in emergency exposure situations to reduce the risk of stochastic health effects

Projected total dose equivalent in foetus

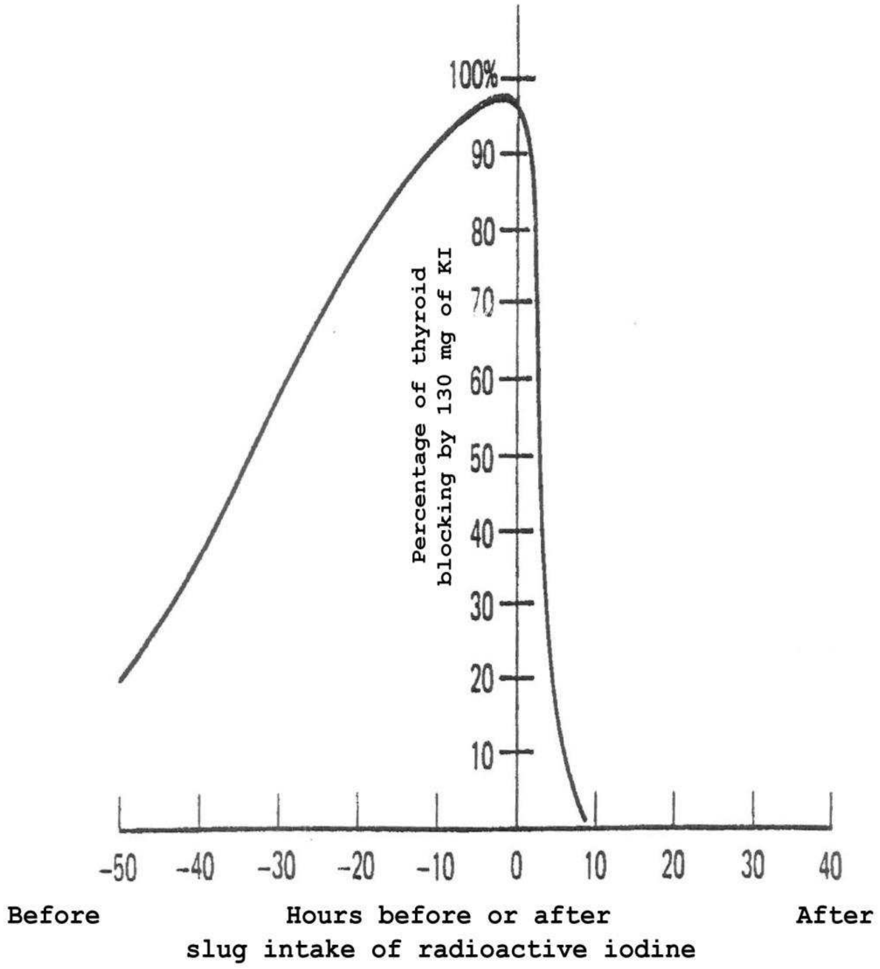
Generic Criteria	Action
> 100 mSv in the first 7 days	**Sheltering, evacuation, decontamination, restriction of food, consumption**
> 100 mSv per period of *in utero* development	**Temporary relocation, decontamination, replacement of food, milk and water, public reassurance**

Generic criteria for protective actions in emergency exposure situations to reduce the risk of stochastic health effects

Projected committed equivalent dose in thyroid

Generic Criteria	Action
> 50 mSv due to intake during the first 7 days	Iodine thyroid blocking

Stable iodine intake



Source: AEC-tr-7536, p. 224.

Effectiveness of thyroid blocking by 100 mg of iodine (130 mg of KI) vs. time of intake

Timeliness of implementation is clear – before exposure almost 100% effective

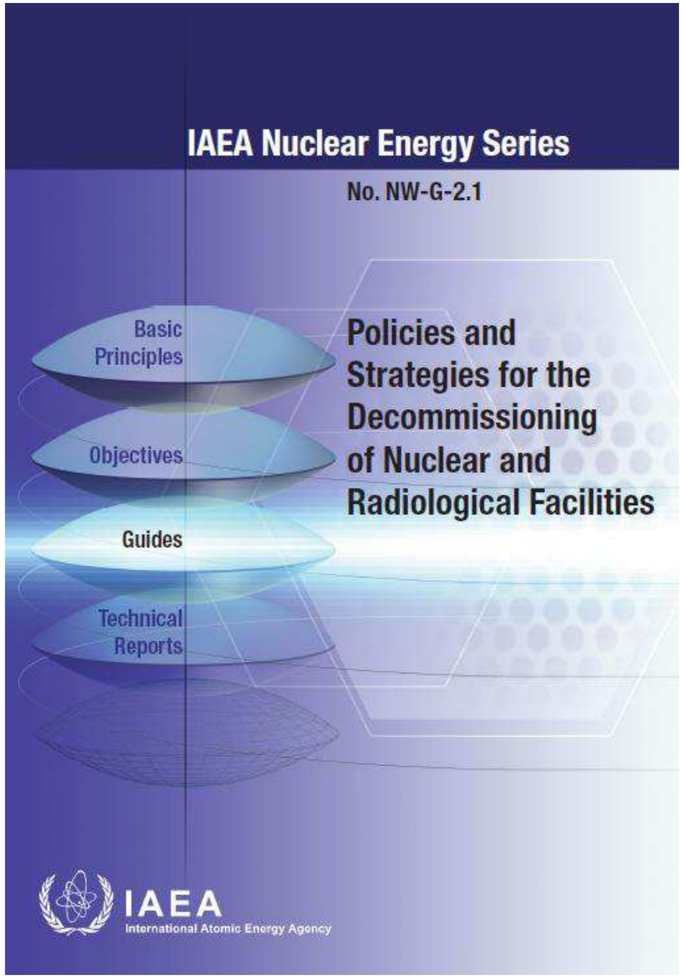
Guidance Values for Limiting Exposure of Emergency Workers

Action	$H_P(10)$
Life saving	**< 500 mSv**(*)
To prevent severe deterministic health effects **To prevent development of catastrophic conditions**	**< 500 mSv**
To avert a large collective dose	**< 100 mSv**

(*) This value may be exceeded under the circumstances where the benefit to others clearly outweighs the emergency worker's own risk and the emergency worker volunteers to take the action, and understands and accepts this risk

3) New challenges in decommissioning of facilities

- ❑ Strategies and phases of decommissioning
- ❑ Responsibilities of regulators and licensees
- ❑ Clearance of decommissioning wastes and non-dismantled buildings
- ❑ Example: A glance at the decommissioning plan of ESS



Strategies (approaches) of decommissioning of major facilities

- Immediate dismantling
- Deferred dismantling including one or more safe enclosure periods
- Entombment (sarcophagus) = On-site waste repository

IAEA Safety Standards
for protecting people and the environment

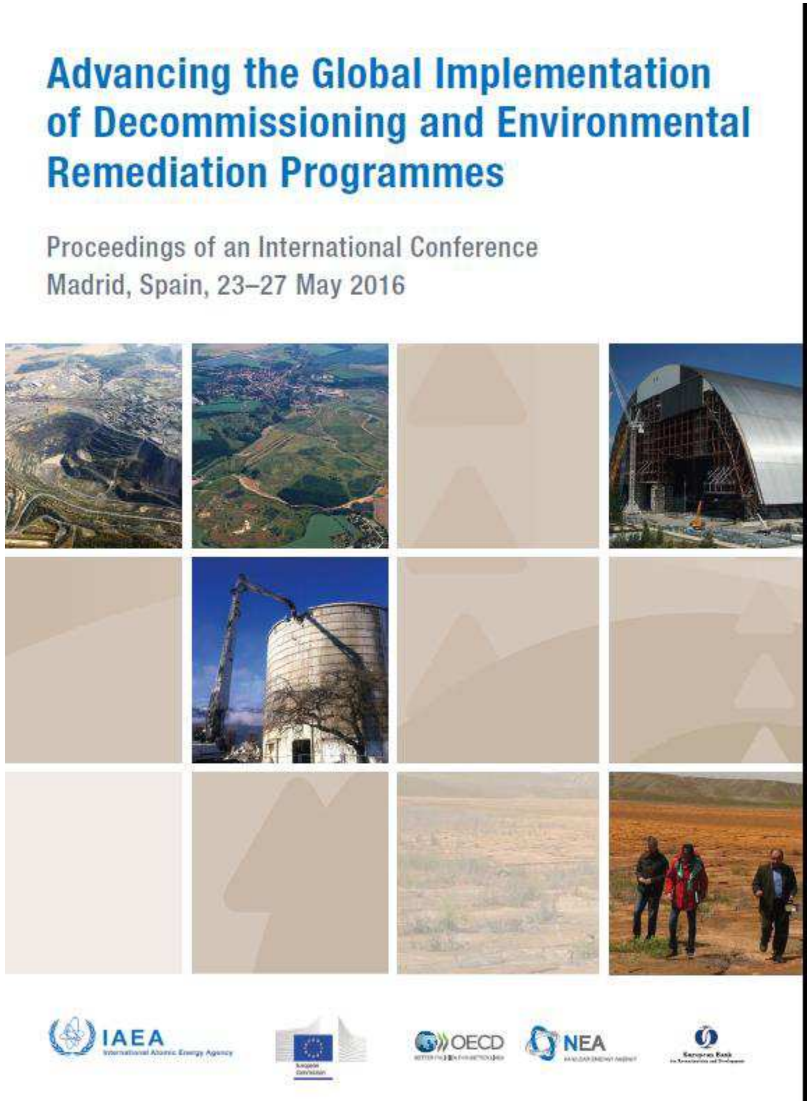
Decommissioning of Facilities

General Safety Requirements Part 6
No. GSR Part 6

IAEA
International Atomic Energy Agency

Phases and end-points of decommissioning

- ❑ Final shutdown (licensed)
- ❑ Nuclear reactors: removal of spent fuel
- ❑ Interim disposal site for decommissioning wastes
- ❑ Decontamination and dismantling to brown-field (Possible end-point)
- ❑ Dismantling to green-field (possible end-point)



Responsibilities of Regulatory Body - General

- Provide full control with regard to health, safety and environmental protection
- Must have a proper organization and resources
- The authority regulating operation normally regulates decommissioning
- Empowered to enforce legislation and regulations
- Provide general guidance on decommissioning
- Communicate with internal and external organizations

Responsibilities of Regulatory Body – Specific (I)

- Assist in developing legislation and policies regarding decommissioning and waste disposal
- Establish safety criteria for decommissioning including decisions on **<u>acceptable end point conditions</u>**
- Develop regulations and guides required to implement the national policy on decommissioning and **<u>waste disposal (+ clearance)</u>**
- Review the selected strategy and approve plans and submissions
- Issue **licences** or permissions for decommissioning (at least 2 licences: final shutdown and decommissioning)

Responsibilities of Regulatory Body – Specific (II)

- Assure compliance with regulatory requirements through inspections
- Ensure that decommissioning activities which generate waste will not be started unless there is a **waste management strategy** in place
- **Establish limits and conditions for the removal of material from regulatory control**
- Ensure maintenance of long term records concerning **clearance of facilities**
- Ensure adequate training is provided for those involved with decommissioning activities

Responsibilities of Licensee (Operator or Owner) - General

- Responsible for the safe decommissioning of the facility including actions of contractors

- Submit a decommissioning plan to the regulatory body for review and/or approval

- No decommissioning activity shall begin without the appropriate approval of the regulatory body

Responsibility of Licensee – Specific (I)

- Ensure adequate **protection of the workers, general public and the environment** from all types of hazard
- Submit a preliminary decommissioning plan during license application and update during life of facility
- Facilitate decommissioning during design and construction
- Establish and maintain necessary records to support decommissioning
- Characterize the facility and the site after completion of operations so final decommissioning plans can be made

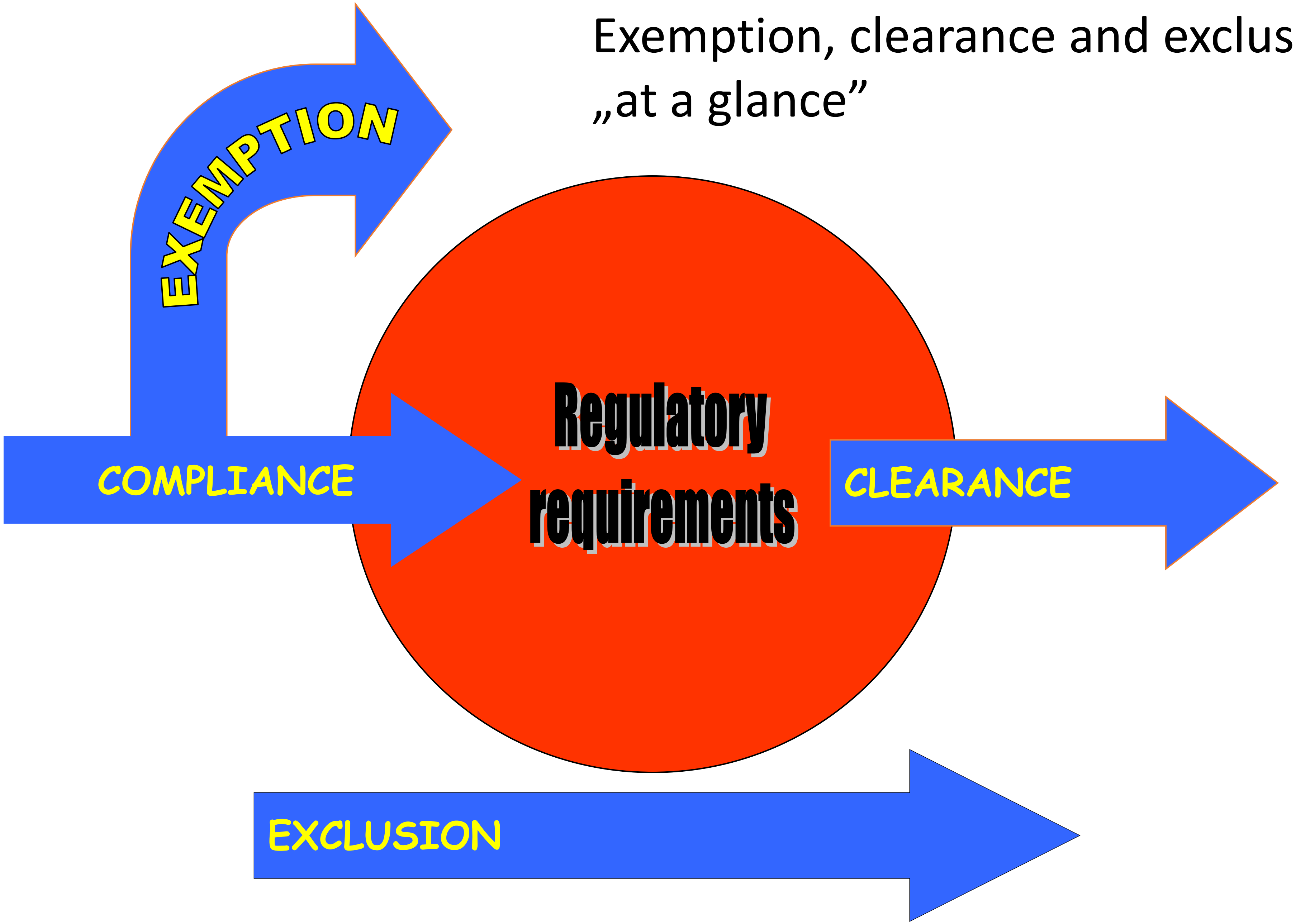
Responsibilities of Licensee – Specific (II)

- Prepare the final decommissioning plan including
  - QA/QC programme
  - Safety assessment
  - **Environmental assessment**
  - **Radiation protection programme**
  - **Waste management plan**
  - Other supporting documents
- Ensure suitable staff, equipment and financial resources are available
- Comply with all legal requirements

Responsibilities of Licensee – Specific (III)

- Propose solutions for disposal or storage of decommissioning waste
- Ensure waste can be transported and disposed of safely
- Conduct the decommissioning activities
- Submit final report of decommissioning project
- Ensure all end point criteria are defined
- Plan for contingencies & emergencies

Exemption, clearance and exclusion „at a glance”



Exemption and clearance

Exemption: A material does not fall in the scope of health physics regulations on the basis of an *a priori* decision if

a) the total activity **or**

b) the mass specific activity concentration

is less than the exemption level given in legislation.

Exemption level [Bq] and [Bq/g] – any application of the material cannot lead to a dose consequence exceeding the negligible dose (= **10 – 30 µSv/year**) under any circumstances (**scenario)**

Exemption and clearance

Clearance level

Activity concentrations [Bq/kg] or [Bq/m^2] defined by the authority below which the **previously controlled materials** can be released (cleared) from control. Conditional clearance: clearance is connected to certain **scenarios** of further use or disposal.

Previously controlled (= dose consequences were limited by instructions) radioactive materials and wastes are cleared according to radioactive decay and/or successful purification so their dose consequence will be negligible (= **10 – 30 μSv/year**)

Deduction of clearance levels (=bulk exemption levels)

Practical use of the concepts of clearance and exemption RADIATION PROTECTION RP#122 Part I.
EU Directorate General – Environment (2000) – further EURATOM materials on clearance: RP#113, RP#114

Table 3–1: Results of dose calculations for all nuclides (in [(µSv/a)/(Bq/g)])

		External Irradiation			Inhalation		Ingestion		Skin	Max.	limiting
Nuclide	$T_{1/2}$ [a]	EXT-A	EXT-B	EXT-C	INH-A	INH-B	ING-A	ING-B	SKIN		scenario
H-3	1.2E+01	0.0E+00	0.0E+00	0.0E+00	8.9E-05	7.1E-06	8.4E-04	1.2E-02	0.0E+00	1.2E-02	ING-B
Be-7	1.5E-01	1.4E+00	3.8E-01	1.3E-01	9.3E-05	5.3E-06	5.6E-04	2.8E-03	7.4E-05	1.4E+00	EXT-A
C-14	5.7E+03	0.0E+00	0.0E+00	0.0E+00	1.3E-03	1.7E-04	1.2E-02	1.6E-01	2.4E-02	1.6E-01	ING-B
F-18	2.1E-04	3.5E-03	7.6E+00	0.0E+00	1.9E-04	8.6E-06	9.8E-04	1.1E-09	7.2E-02	7.6E+00	EXT-B
Na-22	2.6E+00	7.0E+01	1.9E+01	7.9E+01	4.3E-03	2.0E-04	6.4E-02	1.3E+00	6.8E-02	7.9E+01	EXT-C
Na-24	1.7E-03	4.7E+01	3.7E+01	0.0E+00	1.1E-03	4.8E-05	8.6E-03	1.8E-04	7.9E-02	4.7E+01	EXT-A
Si-31	3.0E-04	5.3E-05	8.0E-03	0.0E+00	2.4E-04	1.5E-05	3.2E-03	7.7E-08	8.0E-02	8.0E-02	SKIN
P-32	3.9E-02	0.0E+00	0.0E+00	0.0E+00	6.3E-03	4.6E-04	4.8E-02	1.0E-01	7.4E-02	1.0E-01	ING-B

Headlines: exposure scenarios (external, inhalation, ingestion, skin)
Data: Annual dose per unit concentration for each scenario

Comparison of exemption and clearance levels

Table 3–2: Calculation results for general clearance levels and rounded general clearance levels[6]

Nuclide	Calculation results for clearance levels (CL) [Bq/g]	Clearance levels rounded [Bq/g]	Exemption values (EV) [CEU 96] [Bq/g]	Comparison of exemption values and rounded clearance levels EV/CL
H-3*	8.6E+02	(1000)	1.0E+6	1000
Be-7	6.9E+00	10	1.0E+3	100
C-14*	6.3E+01	(100)	1.0E+4	100
F-18	1.3E+00	1	1.0E+1	10
Na-22	1.3E-01	0.1	1.0E+1	100
Na-24	2.1E-01	0.1	1.0E+1	100
Si-31	1.2E+02	100	1.0E+3	10
P-32	9.8E+01	100	1.0E+3	10
P-33	2.3E+02	100	1.0E+5	1000
S-35	5.7E+01	100	1.0E+5	1000
Cl-36*	1.6E+01	(10)	1.0E+4	1000
Cl-38	7.3E-01	1	1.0E+1	10
K-40	1.5E+00	1	1.0E+2	100
K-42	4.0E+00	10	1.0E+2	10
K-43	7.3E-01	1	1.0E+1	10
Ca-45	4.0E+01	100	1.0E+4	100
Ca-47	3.2E-01	1	1.0E+1	10
Sc-46	1.5E-01	0.1	1.0E+1	100

Missing:
^{41}Ca, ^{133}Ba …

Radiation Protection 122

PRACTICAL USE OF THE CONCEPTS OF CLEARANCE AND EXEMPTION – PART I

Guidance on General Clearance Levels for Practices

Recommendations of the Group of Experts established under the terms of Article 31of the Euratom Treaty

European Commission

Clearance levels are lower = more severe than exemption levels by 1 - 3 orders of magnitude (GSR Part 3 „bulk" = clearance „moderate" = exemption levels for classification of radioactive waste

Example: initial decommissioning plan of the European Spallation Source (ESS) Lund, Sweden 2012 – approved by the Swedish regulatory body

5.5 Summary of radwaste at shut-down

The sum-up of waste arising from entire ESS facility as decommissioning waste is provided in Table A3. 5 (ANNEX#3).

Decommissioning waste is breaking down in two big categories:

- 11000 tons of metal waste, mainly Fe from the target monolith and the linac components dismantling likely to be SFR type waste;
- 1000 tons of waste may potentially be SFL type coming from parts of ILW from accelerator machine (10% from the total amount) and TS shielding monolith placed closest to the target (20% from the total);
- 3500 tons of concrete waste originating from the internal side of accelerator tunnel wall (37% from the total concrete wall waste);
- 32000 tons of concrete VLLW from the dismantling of the shielding of the NBLs and instruments to be free released on site after to the storage for decay, if necessary;
- 800 tons of concrete VLLW from the dismantling of the Target monolith;
- 4000 tons of soil surrounding the concrete wall of the linac to be free released on site after to the storage for decay, if necessary.

Total generated decommissioning waste = 58200 tons

Total decommissioning waste to be sent for disposal = 15500tons

Total decommissioning waste to be free released on site = 42500 tons (72 % from the total waste generated)

EUROPEAN SPALLATION SOURCE

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Initial decommissioning plan for ESS

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Thank you for your attention!