Comprehensive Hazard Identification and Monitoring systEm for uRban Areas

CHIMERA

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RADIOAKTIVNÍ ODPADY

Quantification of personal exposure and its monitoring in case of radiation from radioactive waste

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Introduction

When dealing with radioactive waste, it is necessary to ensure adequate protection for people and minimise its impact on the surrounding environment. The paper provides an overview of quantities and units for these purposes, including the possibility of monitoring and identifying the radionuclides present. These quantities reflect not only the physical properties of radionuclides and the ionising radiation they emit, but also the biological effects of this radiation on the human body. In the case of radionuclide characteristics, the focus is on variables such as source emission, activity, specific activity, particle fluence, and energy fluence. The paper describes in detail the definitions of quantities and their interpretations for reflecting human exposure, with a

focus on exposure, kerma, dose, dose equivalent, effective dose, and several operational quantities intended for practical use to estimate the health effects of human exposure. Some problems in this area stem from the large number of quantities and only 2-3 units available, which, in practice, lead to inconsistencies in assessing actual radiation risk because it is not always clear to which quantity individual units are related.

Radioactive waste properties

Radioactive waste is characterised by its **radiological, physical, and chemical properties**, requiring specialised management based on its **activity level, half-life**, and heat generation. It ranges from **low-level waste** (clothing, tools) to **high-level**, heat-emitting waste (spent fuel) that requires deep geological disposal. Key hazards include **penetrating radiation**, chemical toxicity, and long-term environmental persistence

Classification by hazard level

Exempt Waste (EW): Minimal, non-hazardous levels, often disposed of in conventional landfills.

Very Short-Lived Waste (VSLW): Short half-lives, safe to store for decay.

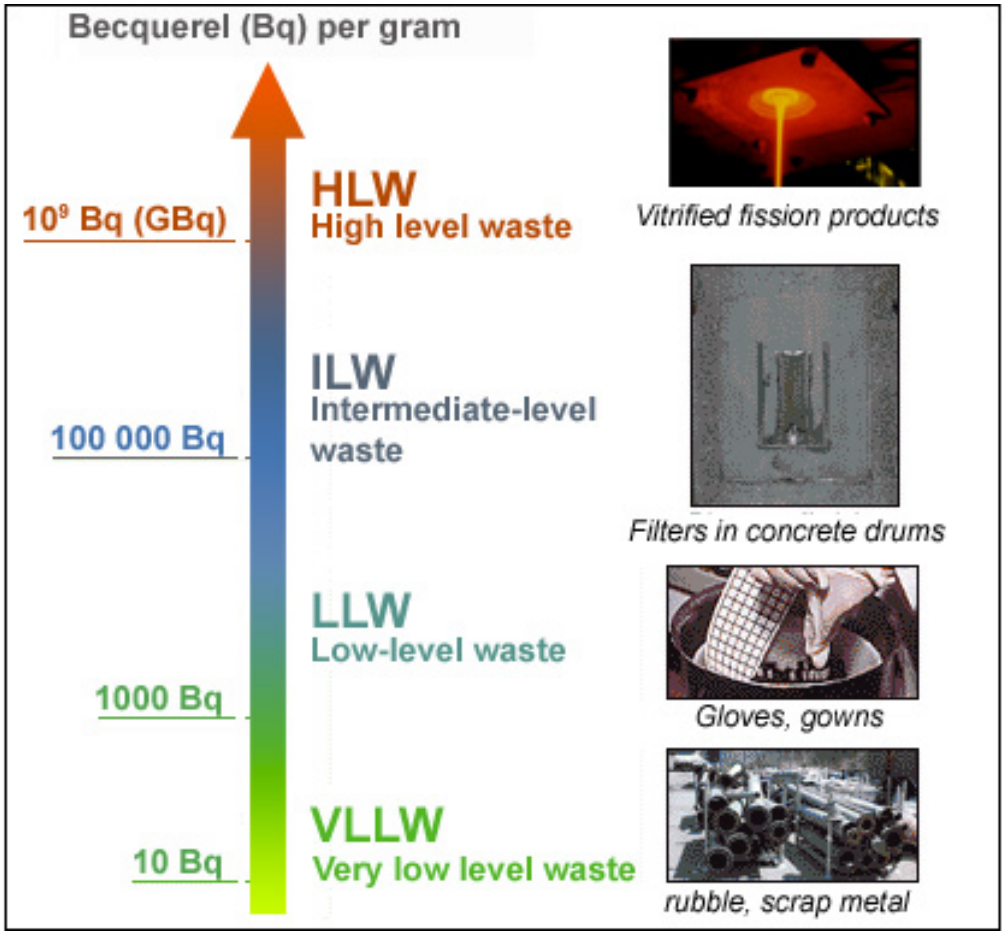
Very Low-Level Waste (VLLW): Low radioactive concentration, usually from decommissioning.

Low-Level Waste (LLW): Contains small amounts of mostly short-lived activity, often solidified.

Intermediate-Level Waste (ILW): Higher radioactivity, requires shielding but generally not cooling.

High-Level Waste (HLW): Highly radioactive, generates significant heat, requires long-term shielding, cooling, and deep geological disposal.

Radioactive materials differ in terms of their physical and chemical properties, the intensity and nature of the radiation they emit, and the risks they entail. The management of each waste category must suit its characteristics. For waste to be managed properly, a complete inventory of it must be compiled.



The radioactive waste management lifecycle

PLANNING AND PREPARATION

- Integrated waste management strategies
- Waste management plans
- Waste characterisation
- Waste inventories

TREATMENT AND PACKAGING

- Retrievals
- Sorting and segregation
- Size reduction
- Decontamination
- Treatment – thermal/ chemical/physical
- Conditioning/immobilisation
- Packaging

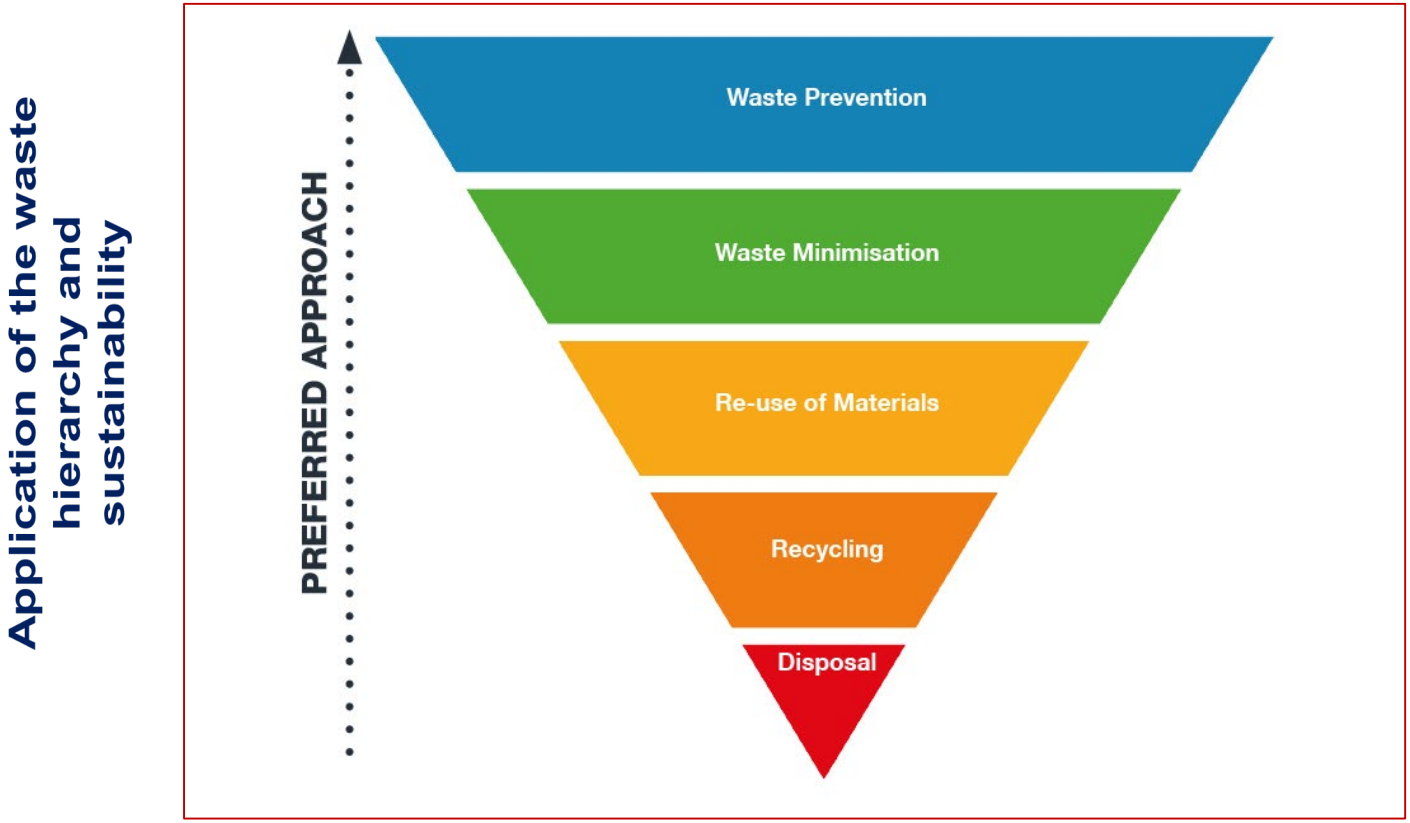
STORAGE

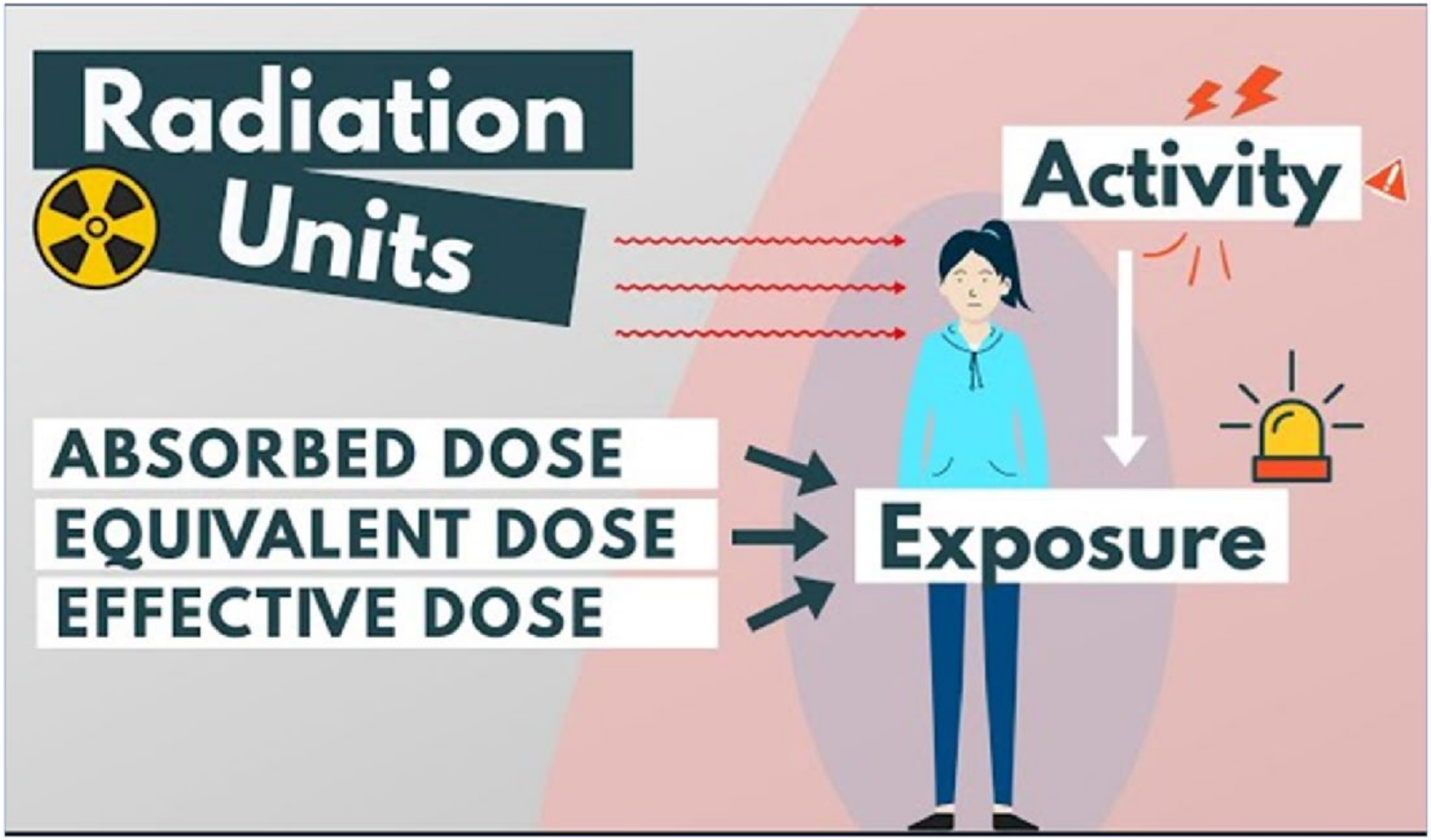
- Raw waste storage
- Conditioned waste storage
- Buffer storage
- Decay storage

DISPOSAL

- Landfill
- In situ
- On site
- Surface
- Near surface
- Geological

Waste producers must take sustainability into account and demonstrate the application of the waste hierarchy to manage waste effectively and help preserve disposal capacity, to achieve the best overall outcomes for people and the environment by optimising the management of radioactive waste. This should minimise the environmental impacts of waste treatment, including through the reuse or recycling of materials wherever possible, and provide for the effective and safe management of waste which is generated.




Radiation
Units
Activity
ABSORBED DOSE
EQUIVALENT DOSE
EFFECTIVE DOSE
Exposure

Radiation protection quantities

Absorbed – Equivalent – Effective Dose

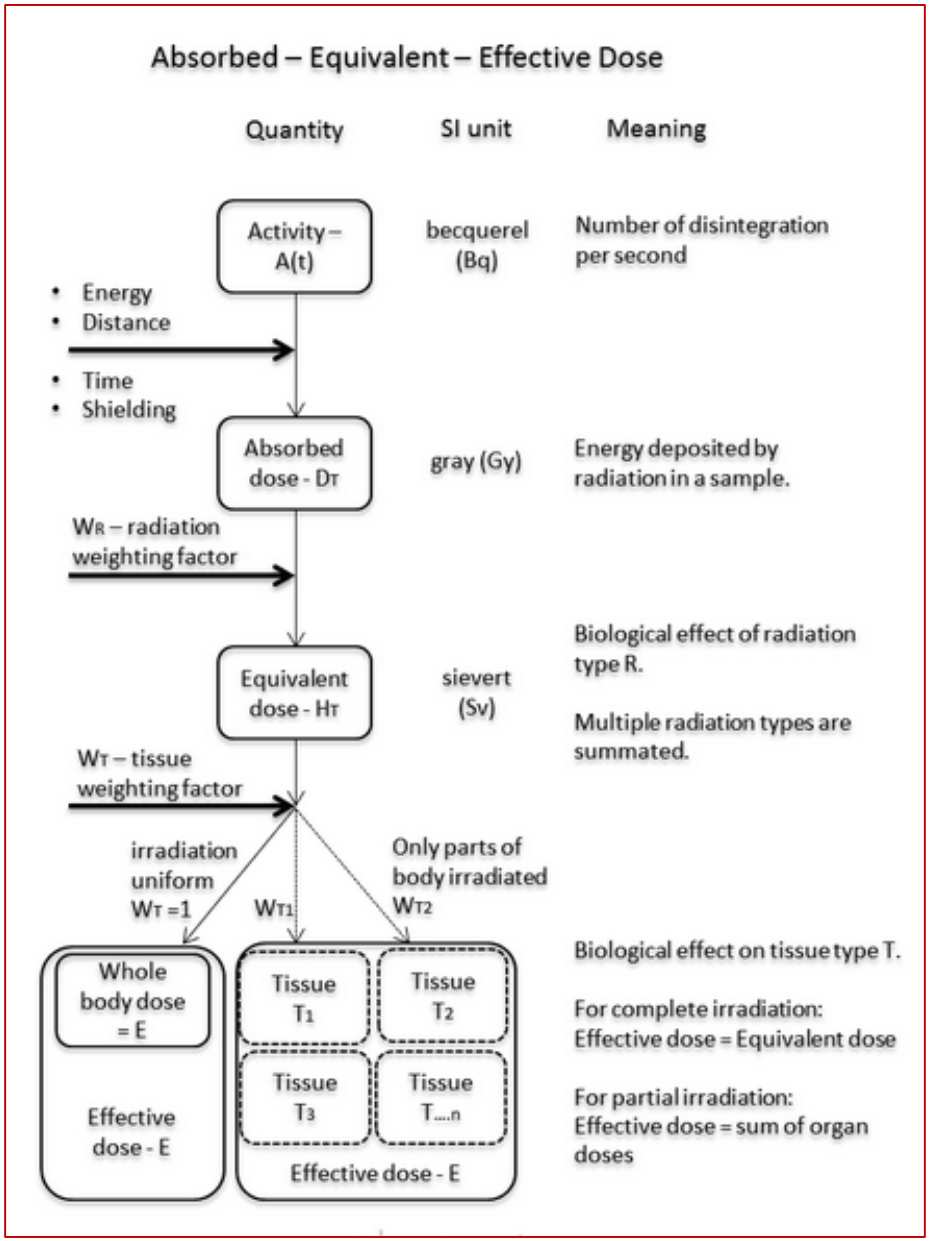
The **effective dose** is a dose quantity defined as the sum of the tissue-equivalent doses, weighted by the ICRP organ (tissue) weighting factors, wT, which account for the varying sensitivity of different organs and tissues to radiation.

$$E = \sum_T w_T H_T$$

$$= \sum_T w_T \sum_R w_R D_{T,R}$$

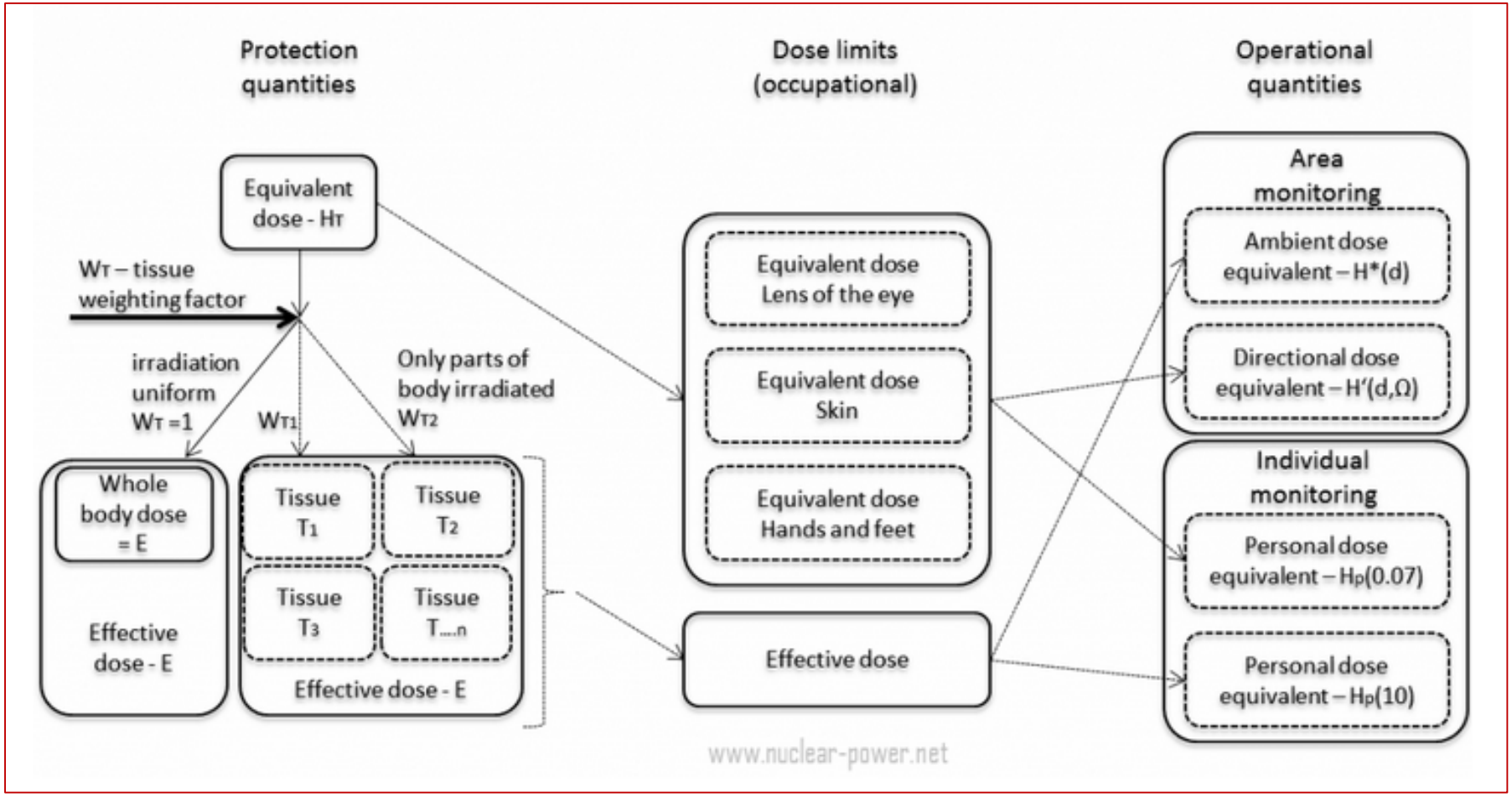
where

- H_T is the equivalent dose averaged over the tissue or organ, T, due to the incident radiation, R.
- $D_{T,R}$ is the absorbed dose averaged over the tissue or organ, T, due to the incident radiation, R.
- w_R the radiation weighting factor,
- w_T the tissue weighting factor.

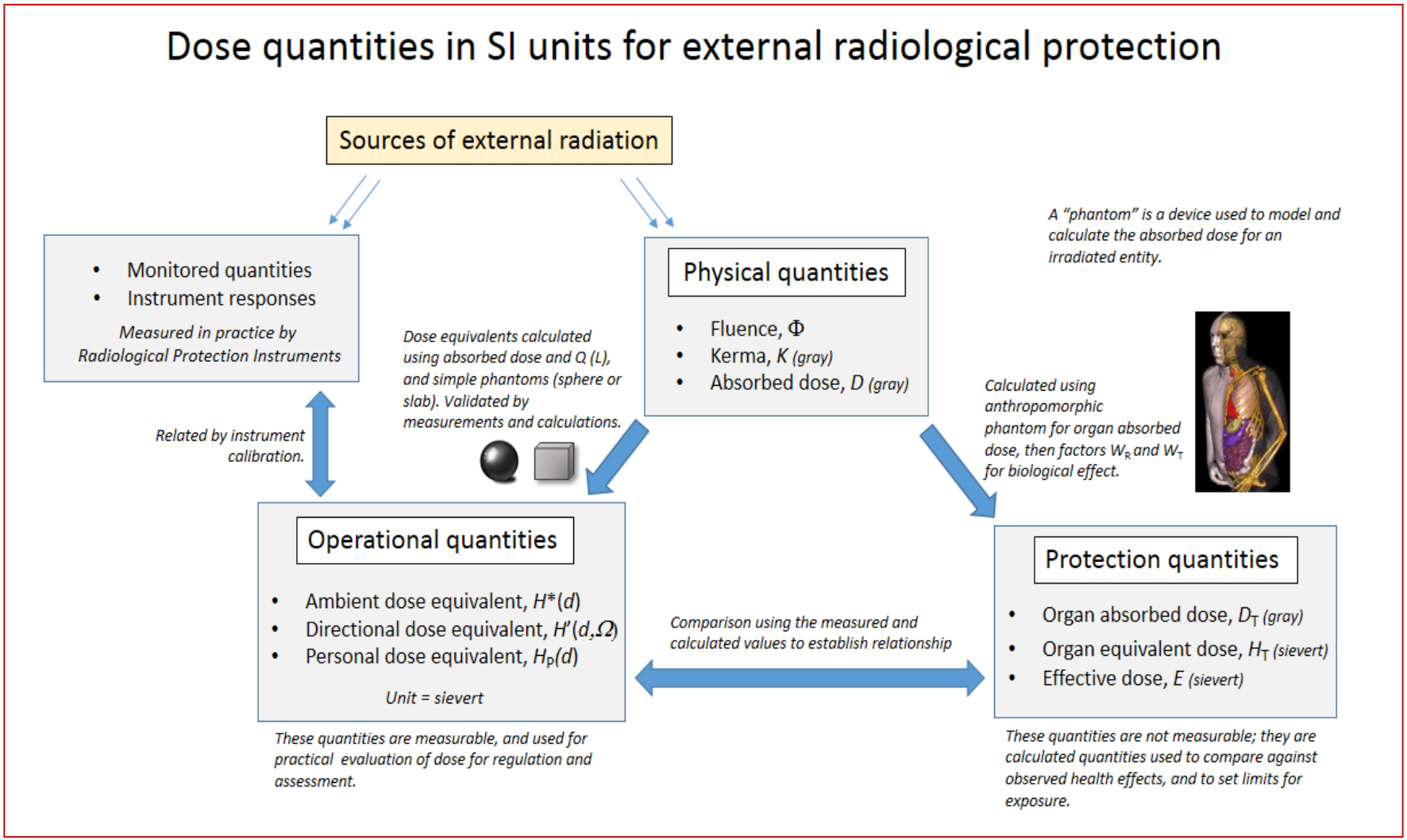


Radiation protection quantities

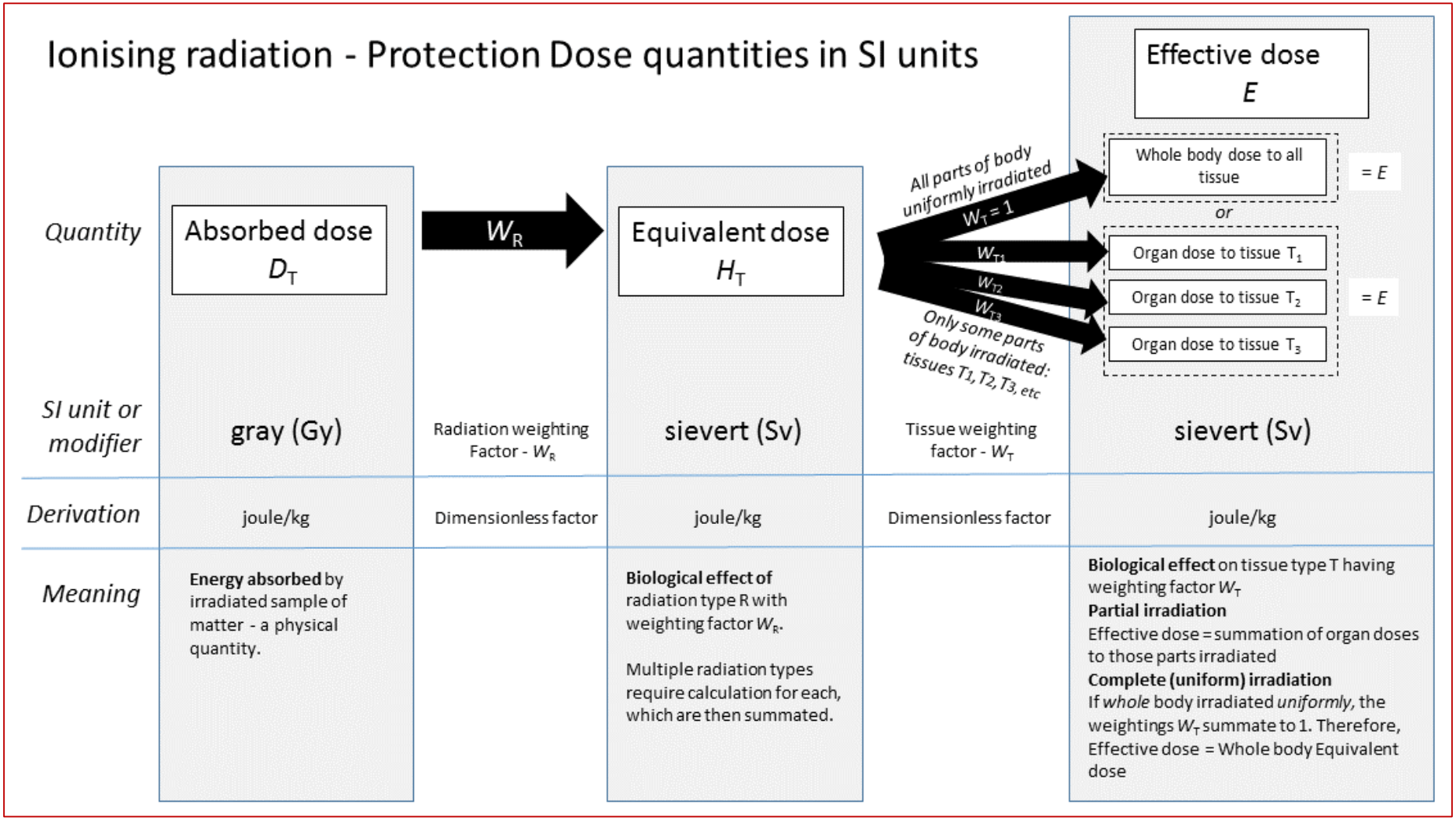
Personal dose equivalent, Hp(0.07). The Hp(0.07) dose equivalent is an operational quantity for individual monitoring of the dose to the skin, hands, and feet.
Personal dose equivalent, Hp(10). The Hp(10) dose equivalent is an operational quantity used for individual monitoring in assessing **effective dose**.



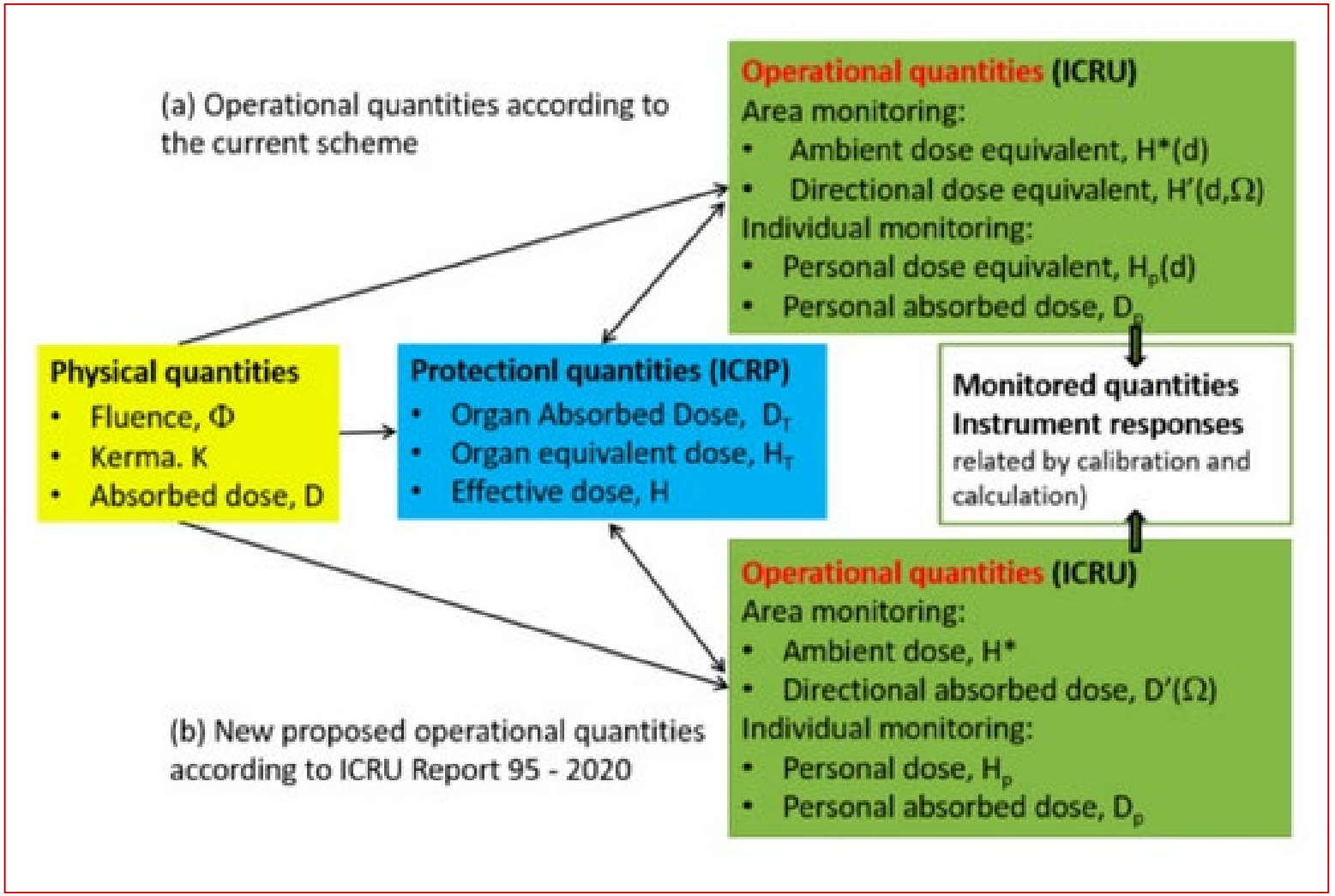
External dose quantities used in radiation protection and dosimetry



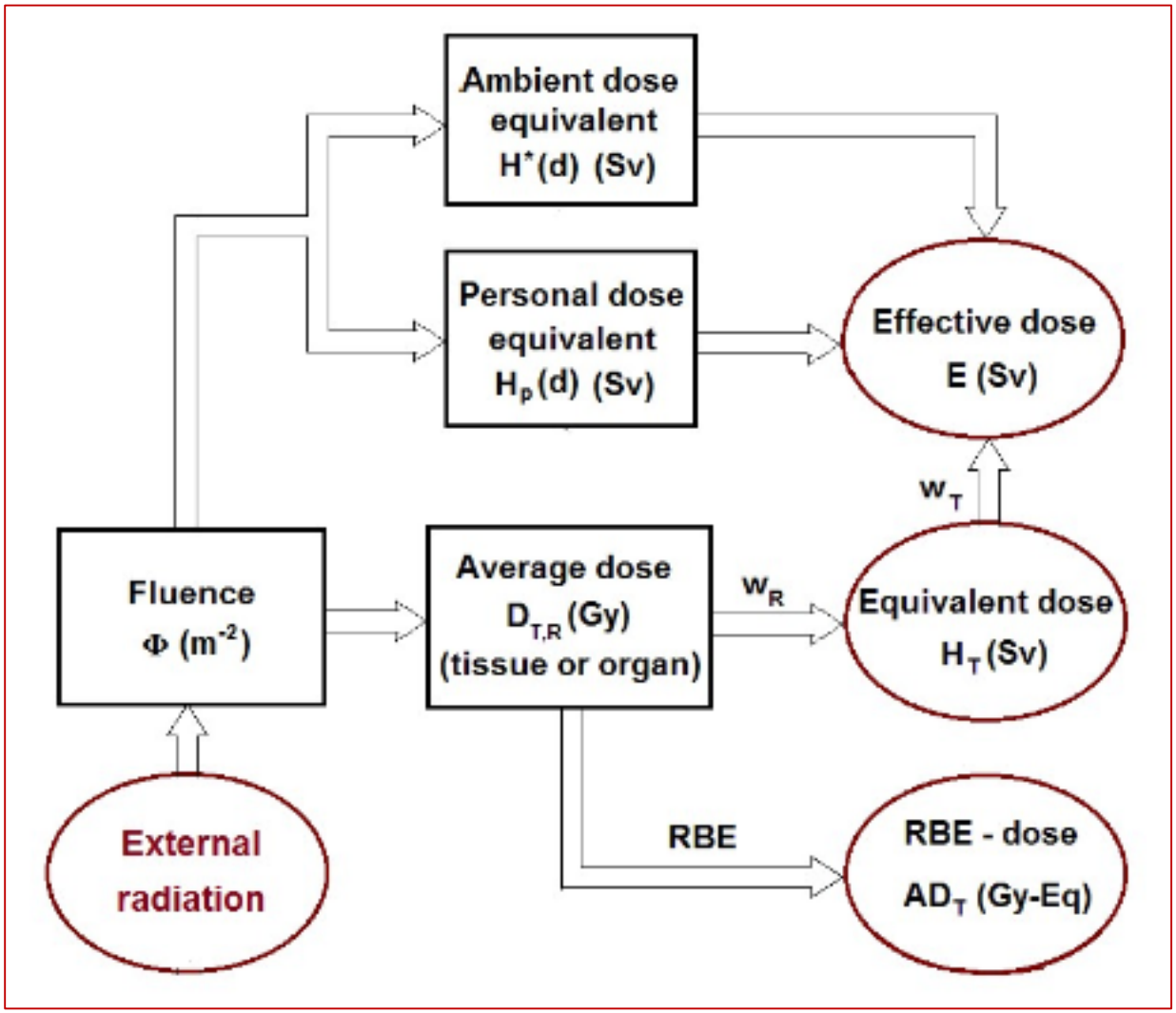
Relationship of ICRU/ICRP computed protection dose quantities and units



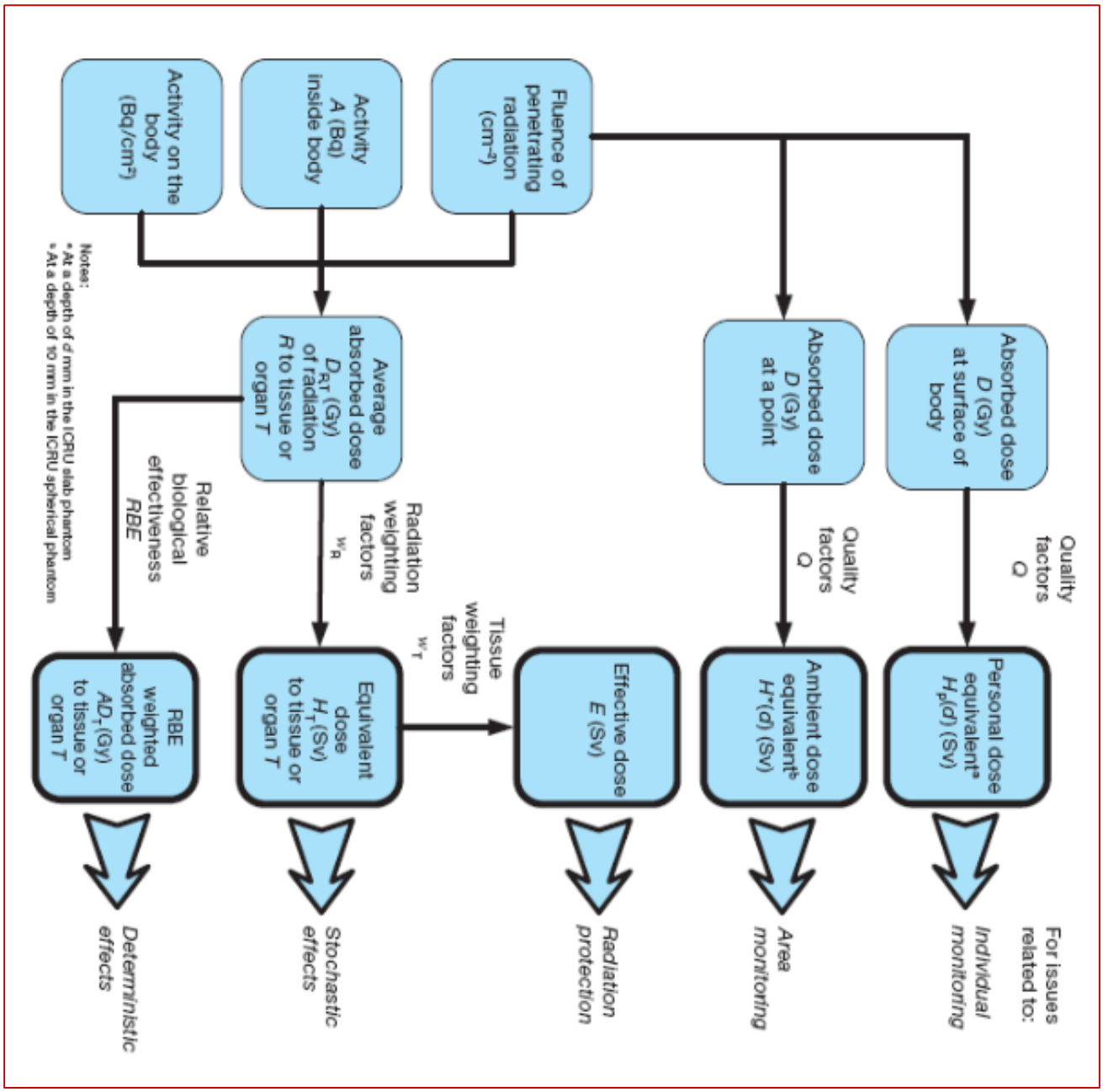
Relationship between the protection quantities of ICRP Publication 103 and the operational ones of ICRU according to (a), the current scheme; (b) Report 95, the new proposed operational quantities.



Relations between various radiation protection quantities used to assess stochastic and deterministic effects following external exposure



Main dosimetry and radiation protection quantities showing that the monitoring methods for external radiation exposure are not comparable to those for the assessment of internal exposure



Quantification of exposure due to external radiation and internal contamination via the inhalation or ingestion of radionuclides (there are no direct operational quantities for the assessment of internal exposure, which can be measured only through activity concentration in air and foodstuffs or by the measurement of body activity using a whole--body counter or bioassay analysis.

Exposure (irradiation)		Type of control	Operational quantities		
			Area monitoring	Individual monitoring	
External		Control of effective dose	$H^*(10)$	$H_p(10)$	
		Control of dose to the skin, lens, extremities	$H'(0.07)$	$H_p(0.07)$	
Internal	Inhalation (workers and population)	Control of committed effective dose (equivalent dose)	Radionuclide concentration in air	Inhaled activity (air samplers)	Body counters, bio-samples
	Ingestion (population)	Control of committed effective dose (equivalent dose)	Foodstuff activity concentration	-	Body counters, bio-samples

Quantities for the assessment of external and internal exposure, where presumably only the quantity RBE-weighted absorbed dose can be used for higher exposure associated with emergency situations

Dosimetric quantity	Symbol	Purpose
	Radiation protection quantities	
RBE weighted absorbed dose	AD_T	For evaluating deterministic effects induced as a result of exposure of an organ or tissue
Equivalent dose	H_T	For evaluating stochastic effects induced as a result of exposure of an organ or tissue
Effective dose	E	For evaluating detriment related to the occurrence of stochastic effects in an exposed population
	Operational quantities	
Personal dose equivalent	$H_p(d)$	For monitoring external exposure of an individual
Ambient dose equivalent	$H^*(d)$	For monitoring a radiation field at the site of an emergency


000.00
Nuclear Radiation Detector
OK
Real-time
0.12
Average
0.15
Total dose
0.59
BOSEAN
RADITION DETECTOR
OK
000.00
Nuclear Radiation Detector
OK


42.0
Radcal
MODEL 3A
ALARM
RESET
NZM
PULSECHO SYSTEMS
mR/Hr
GM TUBE
Milliroentgens


GammaTwin
90 nSv/h
1,03 µSv
Graetz
H*(10) 0,5µSv/h - 70mSv/h
E_{ph} 45keV - 1,3MeV


364.97


series 900 mini-monitor


P0224038
GPD150G
0,14 µSv
DLW
55 keV ≤ E_{ph} ≤ 1,3 MeV 1 µSv ≤ $H_p(10)$ ≤ 10 Sv
Graetz

Thank you for your attention