Protection Principles in Ionizing Radiation as in ICRP Publication 103 (2007)

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This presentation has neither been approved nor endorsed by ICRP
The three pillars of the system of radiological protection

- Science
- Social and ethical values
- Experience
The aims of the system of radiological protection

- “… to contribute to an appropriate level of protection against the detrimental effects of ionising radiation exposure without unduly limiting the benefits associated with the use of radiation.” ICRP 103, § 26

- “… to manage and control exposures to ionizing radiation so that deterministic effects are prevented, and the risks of stochastic effects are reduced to the extent reasonably achievable.” ICRP 103, § 29

- Balancing benefits and risk is one of the most common ethical dilemmas. The potential benefits of any decision must outweigh the risks in order for the associated action to be ethical
The scientific basis of the system of radiological protection

- Epidemiology
- Radiobiology
- Anatomy
- Physiology
- Metrology

Risk coefficients
- Detriment

Value judgements

Dose equivalent
- Effective dose

System of radiological protection
The construction of the detriment

- Cohorts
- Excess risk models
- Nominal risk coefficients
- Aggregation morbidity and mortality
- Extrapolation to average population
- Detriment
- DDREF
The construction of the effective dose

- Male Phantom
- Measurement of intake or exposure
- Female Phantom
- Tissue doses
- Organ doses
- Effective dose

Measurement of intake or exposure connects the Male Phantom to the Female Phantom. Tissue doses are derived from both Male and Female Phantom. Organ doses are calculated from Tissue doses. Effective dose is derived from Organ doses.
A key value judgement: prudence

- « It is prudent to take uncertainties in the current estimates of thresholds for deterministic effects into account… Consequently, annual doses rising towards 100 mSv will almost always justify the introduction of protective actions ». ICRP 103, § 35

- « At radiation doses below around 100 mSv in a year, the increase in the incidence of stochastic effects is assumed by the Commission to occur with a small probability and in proportion to the increase in radiation dose… The Commission considers that the LNT model remains a prudent basis for radiological protection at low doses and low dose rates. » ICRP 103, § 36

- « There continues to be no direct evidence that exposure of parents to radiation leads to excess heritable disease in offspring. However, the Commission judges that there is compelling evidence that radiation causes heritable effects in experimental animals. Therefore, the Commission prudently continues to include the risk of heritable effects in its system of radiological protection. » ICRP 103, § 74
The prevention of deterministic effects

Probability of occurrence of an effect

Limit

Application of prudence

Threshold

Safety margin

Dose level
The management of stochastic effects

Probability of occurrence of an effect

Application of prudence

Statistical evidence

Extrapolation

Dose level
The main implications of adopting a **prudent attitude** with regard to stochastic effects (i.e. the Linear No Threshold model) are that:

- Exposing individuals is **justified** only if there is a benefit in return.

- Maintaining exposures below a limit is **not a guarantee of absence of risk**.

- Exposures must be kept **as low as reasonably achievable**.
### The inclusion of hereditary effects

<table>
<thead>
<tr>
<th>Exposed population</th>
<th>Cancer</th>
<th>Heritable effects</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole</td>
<td>5.5</td>
<td>0.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Adult</td>
<td>4.1</td>
<td>0.1</td>
<td>4.2</td>
</tr>
</tbody>
</table>

**Detriment-adjusted nominal risk coefficients** \(10^{-2}\text{ Sv}^{-1}\) for stochastic effects after exposure to radiation at low dose rate.
Prudence in summary

- The value of prudence is the **cornerstone of the system of protection**: it allows to take into account the inevitable uncertainties of radiation science and to **act judiciously and reasonably**

- Prudence implies a duty of vigilance regarding the effects of radiation: the requirement of **radiation and health monitoring** of exposed populations and the duty to relentlessly pursue **research in the fields of epidemiology and radiobiology**
The system of radiological protection

Exposure situations
- Existing
- Planned
- Emergency

Categories of exposure
- Medical
- Occupational
- Public

Principles of protection
- Justification
- Optimisation
- Limitation

Dose criteria
- Reference levels
- Dose constraints
- Dose limits

Requirements
- Information
- Training
- Monitoring
Exposure situations – Definition

- “The process causing human exposures from natural and man-made sources.”

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Source → Pathways → Exposures
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- “Protection can be achieved by taking action at the source, or at points in the exposure pathways, and occasionally by modifying the location or characteristics of the exposed individuals.”

ICRP103, § 169
Individual dose distributions associated with exposure situations
The 3 types of exposure situations

- **Existing exposure situations**: when exposures result from sources that already exist when decisions to control them are taken. Characterization of exposures is a prerequisite to their control.

- **Planned exposure situations**: when exposures result from the deliberate introduction and operation of sources. Exposures can be anticipated and fully controlled.

- **Emergency exposure situations**: when exposures result from the loss of control of a source. These situations require urgent and timely actions in order to mitigate exposures.
Exposure situations

• **Existing**
  - **Natural sources**: cosmic radiation, NORM and radon
  - **Man-made sources**: contaminated sites and areas

• **Planned**
  - Medical facilities
  - Research, industrial and nuclear installations

• **Emergency**
  - Loss of control of planned sources
  - Malicious acts
The categories of exposure

- **Medical exposure**: radiation exposures received by patients in the course of diagnostic, interventional, and therapeutic procedures

- **Occupational exposure**: radiation exposures incurred at work as a result of exposure situations that can reasonably be regarded as being the responsibility of the operating management

- **Public exposure**: encompasses all radiation exposures of the public other than occupational and medical exposure

*Remark: Although individuals may fall into the 3 categories respectively as workers, patients or members of the public, the management of each category is kept separated*
The principles of radiological protection

- **The principle of justification:** Any decision that alters the radiation exposure situation should do more good than harm.

- **The principle of optimisation of protection:** All exposures should be kept as low as reasonably achievable, taking into account economic and societal factors with restrictions on individual exposure to limit inequities in the dose distribution.

- **The principle of application of dose limits:** The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission.
Justification: « do more good than harm »

- « This means that, by introducing a new radiation source (Planned exposure situations), or by reducing existing exposure (Emergency and existing exposure situations)…. one should achieve sufficient individual or societal benefit to offset the detriment it causes. » ICRP 103, § 203

- Actions taken to help prevent or remove harms are called **beneficent** actions in ethics and those taken to avoid to do harms are called **non-maleficent**

- **Beneficence and non-maleficence** concerns human welfare with the objective to reduce the harms and optimise the benefit of social practices
Optimisation: « keep exposures as low as reasonably achievable and restrict inequities between individual exposures »

- As already mentioned reasonableness is closely related to prudence

- “Optimisation of protection may introduce a substantial inequity between one individual and another. This inequity can be limited by incorporating source-related restrictions on individual dose into the process of optimization.” ICRP 103, § 232

- Inequity/equity refer to fairness i.e. how radiation risks are distributed within the exposed individuals
The quest for reasonableness

- Recognition of uncertainties about the effects at low doses, prudent attitude, assumption of no-threshold - As Low As Possible - ALAP (1950)

- If an activity is justified, how far to reduce the risk without endangering the activity? - As Low as Reasonably Achievable - ALARA (1958)

  "As Low as" is the echo of the no-threshold assumption and "Reasonably Achievable" of the idea of avoiding carelessness and paralysis in front of the risk suspicion

- Attempt to found the reasonableness on the economic science: the cost-benefit model (1973)

Dose restrictions for optimisation

- Levels of individual dose, above which it is judged to be inappropriate to allow exposures to occur and below which the goal is to reduce all doses as low as reasonably achievable.

- Dose restrictions for optimizing protection in planned exposure situations are called **dose constraints** and in emergency and existing exposure situations **reference levels**.

- For the selection of an appropriate value for the dose constraint or the reference level one should consider the relevant **exposure situation** in terms of the nature of the exposure, the **benefits from the exposure situation to individuals and society**, ..., and the **practicability** of reducing or preventing the exposures (ICRP 103, § 242).

- “At doses higher than 100 mSv, there is an increased likelihood of deterministic effects and a significant risk of cancer. For this reason the Commission considers that the **maximum value for a reference value is 100 mSv** incurred either acutely or in a year.” (ICRP 103, § 236)
Bands of dose for selecting reference levels and dose constraints

- 100 mSv (acute or in a year): Inacceptable
  - Emergency exposure situations
- 20 mSv/y: Tolerable
  - Existing exposure situations
    - Planned exposure situations (occupational)
- 1 mSv/y: Planned exposure situation (public)
The principles of optimisation for existing and emergency situations

**PREVENTION**
Maintain exposure ALARA

1. Added dose

**MITIGATION**
Reduce exposure ALARA

2. Residual dose
The principles of optimisation for planned exposure situations

**PREVENTION**

Maintain exposure ALARA

- Optimisation
- 1. Added dose

**MITIGATION**

Reduce exposure ALARA

- Optimisation
- 2. Residual dose
Limitation: «ensure that no individual is exposed to unacceptable radiation risks in planned exposure situations»

- In order to prevent excessive individual risk in planned exposure situations the Commission is recommending the use of dose limits.

- "**Dose limits are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable in any normal circumstances.**" ICRP 60, § 112

- The limitation principle recognizes that each exposed individual has the **right** that the risk she/he is subjected do not exceed a level judged socially unacceptable.

- This position is consistent with the ethical **principle of egalitarian justice** which states that in similar situations individuals should be treated the same.
The quest for tolerableness

- **Publication 26 (1977)**: the risk associated with dose limits compared with safe occupation for occupational exposures and risk regularly accepted in everyday life (e.g. public transport) for public exposures.

- **Publication 60 (1990)**: introduction of the tolerability of risk model: difference between unacceptable, tolerable and acceptable. Use of a multi-criteria approach for the occupational dose limit and reference to the natural background for the public dose limit.

- **ICRP Committee 4** is currently considering the implications of the situation–based approach introduced in **Publication 103** with regard to the tolerability of risk model.
The principles of application of dose limits for planned exposure situations

**PREVENTION**
- Maintain exposure ALARA
- Dose limit
- Dose constraint
- Optimisation
- 1. Added dose

**MITIGATION**
- Reduce exposure ALARA
- Dose limit
- Dose constraint
- Optimisation
- 2. Residual dose
Dose criteria in summary

<table>
<thead>
<tr>
<th>Exposure situations</th>
<th>Medical exposure</th>
<th>Occupational exposure</th>
<th>Public exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>-</td>
<td>RL ≤ 20 *</td>
<td>RL ≤ 20 **</td>
</tr>
<tr>
<td>Planned</td>
<td>DRLs</td>
<td>DC ≤ 20</td>
<td>DC ≤ 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L = 20</td>
<td>L = 1</td>
</tr>
<tr>
<td>Emergency</td>
<td>-</td>
<td>RL ≤ 100</td>
<td>RL ≤ 100</td>
</tr>
</tbody>
</table>

RL = reference level; DC = dose constraint; L = dose limit

* RL = 10 mSv/y for radon

** RL = 10 mSv/y for radon, and lower part of the 1-20 mSv/y band with long term objective of 1 mSv/y for long term contaminated territories
Basic requirements

- Information
- Education/training
- Radiation assessment and monitoring
- Medical surveillance
Stakeholder engagement (1)

- ICRP mentions, “for the first time, the need to account for the views and concerns of stakeholders when optimising protection” in its 2007 recommendation (Pub 103, Editorial; see also § 224 in section 5.8 on optimisation)

- Why to engage stakeholders?
  - To take into account their concerns and expectations as well as the prevailing circumstances of the exposure situations
  - To favour their empowerment and autonomy i.e to promote their dignity
  - To diffuse radiation protection culture
  - To adopt more effective and fairer protection actions
Stakeholder involvement (2)

- Stakeholder engagement in radiation protection emerged in the **late 80s and early 90s** in the context of the management of exposures in contaminated areas by the **Chernobyl accident** and contaminated sites by **past activities**.

- **Publication 82** (1999) on the protection of the public in situations of prolonged radiation exposure is the first ICRP Publication mentioning explicitly stakeholder involvement.

Concluding remarks

- The system of radiological protection developed gradually during the XXth century integrating advances in knowledge about the effects of radiation, the evolution of the ethical and social values as well as the feedback experience from its practical implementation in all relevant domains.

- Until the Second World War the Commission was only dealing with the protection of medical staffs.

- After the war the focus was on nuclear energy and radiological protection developed to protect workers inside nuclear installations and the public outside. This resulted in a coherent and effective system based on solid concepts and principles (ICRP 60, 1990).

- The raising concerns on “existing exposure situations” (natural and man-made) in the nineties profoundly challenged the 1990 system and resulted in the principles presented in ICRP Publication 103.
Epilogue

- Apart from scientists, experts and professionals, citizens are rarely informed about radiation and radiological protection.

- The relationship of our contemporaries to radioactivity remains largely dominated by the spectre of Hiroshima and Nagasaki.

- The uncertainty about the effects of low doses feeds for decades an ongoing scientific and social controversy on the effects of radiation.

- “Risk communication” has globally failed to reduce the gap between experienced professionals and non-informed people.

- Lessons from engaging stakeholders during the last 2 decades (Chernobyl, Fukushima, contaminated sites from the past,…) tell us that we, as professionals, we must develop a narrative about radiation and radiological protection to reconcile citizens with this reality of daily life.

The basic function of language is not to inform but to relate events and to tell stories about individual and social life.
From radiation risk to radiation protection culture

- Seventies: Risk analysis
- Eighties: Risk perception
- Nineties: Risk communication
- Years 2000: Risk governance, Stakeholder engagement
- Years 2010: Radiation protection culture

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