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Refresher Course 2a
Justification, Optimisation and Decision-Aiding in Existing Exposure Situations
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Outline of presentation

• system of protection for practices
• system of protection for interventions
• decision-aiding/-making in radiation protection
• societal aspects and radiation protection
• stakeholder involvement in decision-making
• upcoming ICRP recommendations
• summary and conclusions
Characterising practices

Any human activity that:

- introduces additional sources of exposure or exposure pathways
- extends exposure to additional people
- modifies the network of exposure pathways from existing sources, so as to:
  - increase the exposure of people
  - increase the likelihood of exposure of people
  - increase the number of people exposed
Examples on practices

• nuclear power plants
• nuclear research facilities
• nuclear fuel fabrication plants
• radioactive waste treatment facilities
• nuclear fuel reprocessing plants
• departments for radiation diagnostic and therapy
• radioisotope production facilities
• workplaces with elevated natural radiation
System of protection - Practice

Dose

Pre-practice total dose

Addition of a practice

Post-practice total dose

Introduction of a practice

Added dose, \( +\Delta E \), from practice
SOURCE- AND INDIVIDUAL-RELATED PROTECTION FOR PRACTICES
Source-related protection - practices

critical group

ΔE

practice
Dose constraints for practices

\[ \Delta E \leq f \cdot E_{\text{limit}} \]
Individual-related protection - practices
Dose limits for practices

\[ \sum \Delta E \leq E_{\text{limit}} \]
Dose constraints and dose limits for public exposure from practices

• **Typical dose constraints:**
  
  $0.1 - 0.3 \text{ mSv/a as effective dose}$

• **Dose limit:**

  $1 \text{ mSv/a as effective dose}$
Characterising interventions

Any action intended to:

• reduce or avert exposure to sources, or
• reduce or avert the likelihood of exposure to sources,

which are not part of a controlled practice or which are already existing and out of control, e.g. as a consequence of an accident
Existing exposure situations which might require intervention

• natural gamma-emitters in buildings and soil
• radon in dwellings
• past activities and practices
• military operations and nuclear weapons testing
• nuclear or radiological accidents
• waste and by-products from NORM-industries
System of protection - Intervention

Averted dose, $-\Delta E$, by intervention

Introduction of an intervention

Pre-intervention total dose

Post-intervention total dose

Dose

Time
SOURCE- AND INDIVIDUAL-RELATED PROTECTION FOR INTERVENTIONS
Source-related protection - interventions

avertable collective dose per unit mass of foodstuff

$-\Delta S \text{ [man} \cdot \text{Sv/kg]}$

contaminated foodstuffs
Individual-related protection - interventions

Radiological and nuclear accidents

$-\Delta E$ [Sv/unit time]

Past events

Radon in dwellings
Practices versus interventions

• Practices ADD exposures

• Interventions SUBTRACT exposures
Distinguishing practices from interventions

The ability to choose a priori whether to accept beneficial sources and the consequent exposures:

• If a choice is still available, the exposure can usually be said to be due to a practice

• The control of annual doses attributable to the practice can and should be planned in advance

• Subsequent steps to reduce the annual doses attributable to the practice are improvements in the practice and not necessarily an intervention

• If there is no choice, because the sources already exist, any action taken to reduce exposures is an intervention
DOSE QUANTITIES FOR INTERVENTION
Avertable and averted dose

avertable dose  averted dose

prospectively  retrospectively

Time
Avertable and projected dose

- Look ahead ONLY for avertable doses
- Look back for projected (total) doses
Avertable and projected dose over time

Averted dose

Projected dose

Time after accident

Dose rate

Background dose rate
Example on avertable dose by relocation

Measured outdoor effective dose rate in an urban area from deposited long-lived activity:

\[ 20 \, \mu\text{Sv/h} \]

Time-averaged location factor accounting for indoor and outdoor occupancy and shielding by buildings:

\[ 0.3 \]

Avertable effective dose from relocation in a month:

\[ E_{\text{avertable}} = 0.3 \times 20 \, \mu\text{Sv/h} \times 720 \, \text{h/month} = 4 \, \text{mSv/month} \]
PRINCIPLES FOR INTERVENTION
Justification of intervention

The proposed intervention should do more good than harm, i.e. the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs of the intervention.
Radiation protection attributes

• individual and collective radiation risks to population
• individual and collective physical risks to population by the protective measures
• individual and collective risks to personnel carrying out the protective measures
• monetary costs of the protective measures
Non-radiation protection attributes

- perception of risk
- anxiety and other psychological impacts
- reassurance by protective measures
- individual and social disruption
- political considerations
- many others
Justification of intervention

Before intervention

Benefit components

Benefit, \( b \)

- dose
- anxiety
- other
Justification of intervention

Benefit components

After intervention

Benefit, $b$

reassurance

costs

other

anxiety

dose

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Net benefit of intervention

\[ \Delta B = \sum_i b_i \text{(after)} - \sum_i b_i \text{(before)} \]

\( b_i \) are the benefit components (positive and negative)

\( \Delta B > 0 \iff \text{the intervention option is justified} \)
Optimisation of protection

The form, scale, and duration of the intervention should be optimised so that the net benefit of the reduction of dose, less the detriment associated with the intervention, should be maximised.
Optimisation of protection

From the justified protection options select that for which:

\[ \Delta B = \sum_{i} b_i \text{(after)} - \sum_{i} b_i \text{(before)} \]

is maximised
Justified and non-justified options

Justified

Non-justified

Net benefit, $\Delta B$

Remediation option

1 2 3 4 5 6 7 8 9

no action optimum
**Intervention level, *IL***

An *Intervention Level* is the level of avertable dose at and above which a *specific* protective action should be taken in an emergency or a prolonged exposure situation.
Intervention Level, $IL$

$\Delta E \geq IL \Rightarrow$ intervention

Dose

Pre-intervention total dose

Post-intervention total dose

Averted dose, $-\Delta E$, by intervention

Introduction of an intervention

Time
Recommendations from the ICRP
Recommendations from the IAEA
### Intervention levels for accidents

<table>
<thead>
<tr>
<th>Urgent measures (reduce doses &gt; 10 - 100 mSv in days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuation</td>
</tr>
<tr>
<td>Sheltering</td>
</tr>
<tr>
<td>Iodine prophylaxis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Long-term measures (reduce doses &gt; 10 mSv in a year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiating temporary relocation</td>
</tr>
<tr>
<td>Terminating temporary relocation</td>
</tr>
<tr>
<td>Permanent resettlement</td>
</tr>
<tr>
<td>Initial foodstuff restrictions</td>
</tr>
<tr>
<td>Long-term foodstuff restrictions</td>
</tr>
</tbody>
</table>
## Intervention levels for relocation

<table>
<thead>
<tr>
<th>Protective action</th>
<th>Generic intervention levels of avertable dose by relocation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICRP</td>
</tr>
<tr>
<td>Temporary relocation</td>
<td>&gt; 5 - 15 mSv/month</td>
</tr>
<tr>
<td>Permanent resettlement</td>
<td>&gt; 1 Sv in a lifetime or if temporary relocation time exceeds 1 - 2 years</td>
</tr>
<tr>
<td></td>
<td>BSS, IAEA</td>
</tr>
<tr>
<td>Temporary relocation</td>
<td>initiate at &gt; 30 mSv/month suspend at &lt; 10 mSv/month</td>
</tr>
<tr>
<td></td>
<td>EU</td>
</tr>
<tr>
<td>Temporary relocation</td>
<td>&gt; 10 mSv/month</td>
</tr>
<tr>
<td>Permanent resettlement</td>
<td>&gt; 1 Sv in a lifetime</td>
</tr>
</tbody>
</table>
DECISION-AIDING AND DECISION-MAKING IN EXISTING EXPOSURE SITUATIONS
Decision-aiding

Decision-aiding process based on radiological protection considerations:

Input to a wider decision-making process that:

- involves relevant stakeholders
- searches for their informed consent
Decisions on radiation protection in existing exposure situations

- Integrating societal aspects into radiation protection decisions

OR?

- Integrating radiation protection into societal decisions
Decision-making versus decision-aiding

• decision-making is out of the scope of the radiation protection community as of any other scientific bodies

• scientific bodies have no mandate to make societal decisions
Decision-making versus decision-aiding

- Radiation protection professionals should provide clear advice based on science and judgement.

- The professional radiation protection advice would form only one of several inputs to decision-making.

- Other inputs to the decision-making process include psychological, social and political issues.
Sub-optimisation of overall health protection

- Radiological protection attributes → optimisation of radiation protection → sub-optimised overall health protection
- Non-radiological protection attributes → optimisation of non-radiation protection → decision-maker

Radiation protection experts
Social science experts
Optimisation of overall health protection

radiation protection experts

radiological protection attributes

social science experts

non-radiological protection attributes

decision-maker

optimisation of overall health protection based on radiological and non-radiological protection attributes

optimised overall health protection
Decisions on radiation protection in existing exposure situations

- Integrating societal aspects into radiation protection decisions
- Integrating radiation protection into societal decisions

OR?
Decision-making in radiological protection

Radiological protection umbrella:
- Monetary costs
- Social disruption
- Anxiety
- Risk perception
- Reassurance

Societal umbrella (overall protection):
- Monetary costs
- Social disruption
- Reassurance
- Risk perception
- Anxiety
- Radiological protection
Role of the radiation protection community

- to develop guidance on interventions after a nuclear or radiological accident being based solely on radiation protection considerations

- to develop a common language explanation that clearly state the residual risk of radiation exposure after the implementation of protective measures

- to develop as input to the decision-making process a common language explanation of the concepts of ‘safe’, ‘safe living conditions’ and ‘return to normality’
NEW ICRP RECOMMENDATIONS
Existing ICRP recommendations

YAWN... PERHAPS I'LL READ THIS TOMORROW...

AS SEEN BY THE ICRP!
Arguments for a change

• biological assumptions need updating (minor)
• unnecessarily complicated, confusing terminology
• shifting values: emphasising individual over society
• the dose limits for the public are unhelpful
• focusing on man alone is insufficient
• existing recommendations need to be consolidated
• simplification by reducing the number of numerical figures (approximately 30 values)
Arguments for a change

*Dose limits for the population:*

- sum of contribution from many sources
- doses can only be regulated at the source
- do not include the dominant natural background
- do not apply to interventions
- do not apply in emergencies

DO NOT APPLY AT ALL!

\[ \sum \Delta E \leq E_{\text{limit}} \]
Arguments for a change

*Practice versus intervention*

- some situations can be difficult to characterise as either a practice or an intervention
- the difference between the concepts of dose limits and intervention levels difficult to grasp
- affected populations are demanding the “same standard” of radiation protection as in practices
- dose reduction below constraints in all situations is easier to understand
New ICRP recommendations

<table>
<thead>
<tr>
<th>Concern</th>
<th>Proposed constraints</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>risk not justified</td>
<td>&gt; 100 mSv/a</td>
</tr>
<tr>
<td>Raised</td>
<td>concern begin to be raised</td>
<td>&gt; a few tens mSv/a</td>
</tr>
<tr>
<td>Low</td>
<td>benchmark for judgement about additional exposures</td>
<td>1 - 10 mSv/a</td>
</tr>
<tr>
<td>Very low</td>
<td>not of concern to the individual</td>
<td>&lt; 1 mSv/a</td>
</tr>
<tr>
<td>None</td>
<td>risk negligible, protection assumed to be optimised</td>
<td>&lt; 0.01 mSv/a</td>
</tr>
</tbody>
</table>
New ICRP recommendations

More an “intervention-like” than “practice-like” system

Dose constraints:
- 200 mSv (abnormal situations)
- 20 mSv (single source with direct benefit)
- 1 mSv (single source without direct benefit)
- 0.01 mSv (exclusion)

reduce individual doses

dose constraint

dose reduction
ICRP – from dual to single-line system

**PRACTICES**

- Pre-practice total dose
- Pre-intervention total dose
- Time
- Introduction of a practice

**INTERVENTIONS**

- Post-practice total dose
- Post-intervention total dose
- Time
- Introduction of an intervention

New ICRP system in 2005 as a single line system

Reduce individual doses in normal and abnormal situations

**Dose Constraints**

- 200 mSv (abnormal situations)
- 20 mSv (single sources with direct benefit)
- 1 mSv (single sources without direct benefit)
- 0.01 mSv (exclusion)

Dose reduction
New ICRP Recommendations

GEE, THESE ARE INTERESTING RECOMMENDATIONS!

AS SEEN BY THE ICRP!
Summary and conclusions

• Justification of intervention and optimisation of protective actions are applicable to any existing exposure situation of both man-made or natural origin (present system of protection)

• In the new ICRP system of protection, maximum source-related dose constraints are expressed as individual doses at which protective measures to avert (reduce) doses are almost always justified; the actual level of protection should be optimised
Summary and conclusions

• Only minor differences between the present and the new system of radiological protection seem to exist regarding the principles of radiological protection in existing exposure situations.

• The dose constraints in the new system could be regarded in the same way as action levels in the present system of radiological protection.
Summary and conclusions

• In the present system of radiological protection, justification and optimisation should be assessed by a decision-aiding process

• The result of this process is meant to be used as input to a wider decision-making process (not performed by radiation protection professionals)

• The decision-making process should result in an optimisation of the overall health protection of the affected population
Summary and conclusions

- The fundamental question still stands if societal aspects should be integrated into radiation protection or if radiation protection should be an integral part of societal decisions.

- The integration of societal aspects into radiation protection appears to be incorrect as the radiation protection community (or any other scientific community) has no mandate to make societal decisions.
Summary and conclusions

• From past experience it is evident that some methodology is needed in which all relevant protection attributes can be included to reach an optimised (final) decision on countermeasures.

• The final decision should be taken by a decision-maker not being a radiation protection professional.

• The decision-making process and the involvement of relevant stakeholders is being addressed in the new ICRP recommendations but it appears to be somewhat vague.