IAEA Post Graduate Educational Course in Radiation Protection and Safety of Radiation Sources

Intervention for Chronic and Emergency Exposure Situations

General Principles and Types of Events

Principles of Intervention

Lecture

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Introduction

- In the event of an accident doses to individuals in the population can only be reduced by intervention
- Broad international accord on the principles and objectives of interventions has been achieved
- The objective of the lesson is to present internationally recognized system of radiation protection for interventions

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Content

- Intervention versus practice
- Basic principles of intervention
- Projected and avertable dose
- Major protective actions
- Intervention and action levels
- Operational intervention levels
- Emergency workers – basic philosophy
- Summary

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Intervention Situations

- Emergency exposure situations requiring protective actions to reduce or avert temporary exposures (examples ...)
- Chronic exposure situations requiring remedial actions to reduce or avert chronic exposure (examples ...)

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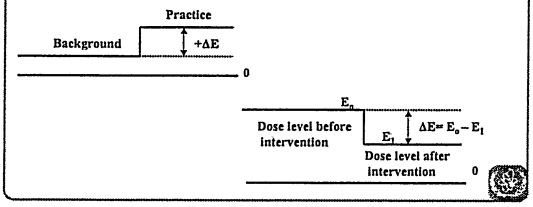
Intervention Versus Practice

- Practices cause or increase the exposure of individuals
- Interventions reduce the exposure



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Practices and Interventions

Systems for Radiation Protection

- Each practice should be justified
- The doses adding up in a practice should be kept as low as reasonably achievable
- The sum of doses in a practice should be kept below specified dose limits

- Each protective action should be justified
- The level of protective actions resulting in dose subtraction should be optimized

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Basic Principles of Intervention

- All possible efforts should be made to prevent serious deterministic health effects
- The intervention should be justified, in the sense that introduction of the protective action should achieve more good than harm
- The levels at which the intervention is introduced and at which it is later withdrawn should be optimized, so that protective action will produce a maximum net benefit

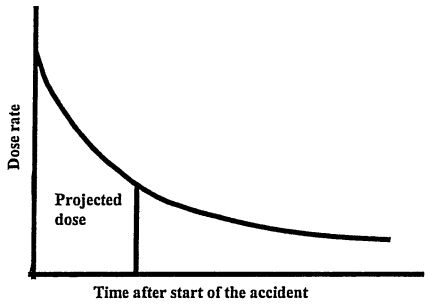
Factors Entering Optimization

Benefit	Harm
• Avertable individual risk	• Individual physical risk
• Avertable collective risk	• Collective physical risk
• Reassurance	• Monetary costs
	• Social disruption
	• Individual disruption
	• Countermeasure anxiety
	• Worker risk

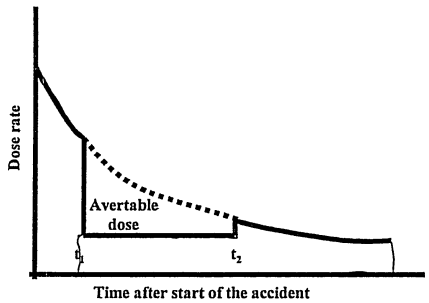
Projected and Avertable Dose

- Because of different nature of deterministic and stochastic effects, two types of dose quantity are needed to be able to discuss the need for protective action
  - projected dose (usually in Gy)
  - avertable dose (usually in mSv)

Projected Dose



Avertable Dose



Intervention and Action Levels

- Intervention level is the level of avertable dose at which a specific protective action or remedial action is taken in an emergency exposure situation or a chronic exposure situation
- Action level is the level of dose rate or activity concentration above which remedial actions or protective actions should be carried out in chronic or emergency exposure situation

Principles for Intervention Levels

- The dose quantity to express the intervention level is the avertable dose
- Only pathways and doses that can be influenced by the protective action should be taken into account
- The estimate of avertable doses should be as realistic as possible and for an average member of the affected population

Principles for Intervention Levels (Cont'd)

There are two distinct phases.

- In the phase of planning and preparedness, a generic optimization of protective actions should be studied, based on a generic accident scenarios. This should result, for each protective action and each selected scenario, in an optimized generic intervention level (GIL), which is meant to be the first criterion for action to be used immediately and for a short time after the occurrence of an accident.
- Some time after a real event, specific information on the nature and likely consequences of the accident would become available. More specific optimization analysis can be carried out on the basis of actual data and efficiency of protective actions. This could result in a specific intervention level for each protective action, to be used as a criterion in the medium and long term.

Dose Limits and Intervention Levels

- Dose limit (control of practices)

$$\sum_{all\ practices} (+\Delta E_i) < E_{limit}$$

- Intervention level (for deciding the need for intervention)

$$\left| -\Delta E \right| > IL$$

Total background and residual dose after intervention are out of scope of the ICRP system.

Cost-Benefit Philosophy

- Cost-benefit theory has been adopted as the rationale for developing generic inter intervention levels
- Total benefit of a particular protective action compared with taking no action can be expressed as

$$B = Y_o - (Y + R + X + A_i + A_s - B_c)$$

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- B net benefit associated with any course of action;
- Yo expression of the detrimental effects due to radiation (stochastic & deterministic) associated with taking no action;
- Y expression of the residual detrimental effects due to radiation (stochastic & deterministic) when the action is taken;
- R expression of the physical risk of any protective action;
- X expression of the resources and effort needed to implement the protective action;
- Ai expression of individual anxiety and disruption caused by the protective action;
- As expression of social disruption caused by the action;
- Bc expression of the reassurance benefit from the action

All of these terms are presumed to be functions of the number of people affected and the time for which a protective action is carried out and to have varying degrees of associated uncertainties.

Cost Equivalent of Avertable Doses

- Avertable individual dose

$$\Delta E = E_o - E_1$$

- Avertable collective dose

$$\Delta S = N \cdot \Delta E$$

$$N = number\ of\ people\ exposed$$

- The cost equivalent of the avertable dose

$$\Delta Y = \alpha \cdot \Delta S = \alpha \cdot N \cdot \Delta E$$

α is the monetary cost of avoiding a unit dose.

Monetary Value α

- Cancer risk per unit dose:

$$R = 0.05\ cancer\ Sv^{-1}$$

- Loss of life expectancy per cancer

$$L = 15\ years\ cancer^{-1}$$

- Monetary value

$$\alpha = R \cdot L \cdot GNP$$

- And

$$\frac{\alpha}{GNP} \approx 1\ year\ Sv^{-1}$$

The level of health care in any country is proportional to the county's average annual GNP per head.

Net benefit of Protective Actions

- Gross benefit, B_g, of protective action

$$B_g = \alpha(E_o - E_1) + B_c = \Delta Y + B_c$$

- Gross cost, C_g, of protective action

$$C_g = C + R + A$$

- Net benefit, B, of the protective action

$$B = B_g - C_g$$

Eo = dose level before intervention
E1 = dose level after intervention
C = the monetary cost
R = the cost equivalent of the risk
A = the cost equivalent of the anxiety

Optimization of Protection

- Net benefit, B, at intervention level, IL

$$B(IL) = B_g(IL) - C_g(IL)$$

- Maximum net benefit when

$$\frac{dB(IL)}{dIL} = \frac{dB_g(IL)}{dIL} - \frac{dC_g(IL)}{dIL} = 0$$

Optimization of Protection – cont'd

- Optimized Intervention Levels based on avertable dose and monetary costs

$$IL_{opt} = \frac{C}{\alpha}$$

C = the cost of the protective action
α = the monetary value of a unit dose

Major Protective Actions

- Urgent protective actions (i.e plume exposure pathways)
  - sheltering
  - evacuation
  - iodine prophylaxis
  - precautionary restrictions of certain foodstuffs
- Longer term protective actions (i.e ground deposition exposure pathways)
  - temporary relocation
  - permanent resettlement
  - foodstuff restrictions

Other protective Actions

- control of access and aggress,
- decontamination of persons and clothing,
- improvised respiratory protection,
- control of contaminated livestock,
- restrictions or prohibitions on the use of contaminated products (for fertilization, combustion, soil improvement, etc.),
- decontamination of land, buildings and roads,
- decontamination of property (belongings, vehicles, etc.), decontamination of vehicles and means of public transport (trains, aircrafts, etc.),.
- restrictions of feedstuffs for animals (e.g. transfer from pasture to indoor feeding).

Intervention Levels – Working Premises

- National authorities will spend the same resources on radiation health risks as on other similar health risks
- Physical risks from the action are taken into account
- Disruption to individuals, such as livelihood or to recourses, is considered
- "good" and "harm" of psychological nature are excluded
- Political, cultural, and other social factors are excluded (they are considered separately)

Generic Intervention Levels (may require adjustment)

Protective action	GIL
Sheltering	10 mSv in two days
Evacuation	50 mSv in one week
Iodine prophylaxis	100 mGy
Temporary relocation	30 mSv in 1st month, then 10 mSv in a month, for, say, six months
Permanent resettlement	1 Sv in a lifetime

It is unlikely that even much higher doses than those specified in the intervention levels would result in any detectable increase in cancers following a major release. If levels 1/10 of those recommended by IAEA were used, the protective action would clearly do more harm than good.

Operational Intervention Levels (OIL)

- Quantities that can be more easily assessed at the time of decision on intervention such as dose rate, activity concentration, etc
- OILs are related to the dose that could be averted – to intervention levels

Operational Intervention Level

$$\Delta E = \Delta E(q)$$

$$OIL = \frac{IL}{\Delta E(q=1)}$$

ΔE = avertable dose
q = operational quantity
IL = intervention level
OIL = operational intervention level

Operational Quantities

Protective action	Operational quantity
Sheltering	Dose rate Radionuclide concentration in air
Evacuation	Dose rate Radionuclide concentration in air
Iodine prophylaxis	Iodine concentration in air
Precautionary food restrictions	Dose rate Surface contamination density
Relocation	Surface contamination density
Foodstuff restrictions	Activity concentration in food

Example of Some Generic OILs
Nuclear accident

Protective action	Generic OIL	Operational quantity
Evacuation Substantial shelter	1 mSv/h	Dose rate in plume
Iodine prophylaxis Sheltering	0.1 mSv/h	Dose rate in plume
Precautionary food restriction	0.1 μSv/h	Dose rate from deposition
Consumption restrictions (general food)	I-131: 10 kBq/m² Cs-137: 2 kBq/m²	Ground deposition levels

Emergency Workers – Basic Philosophy

- Members of the public will receive doses unless some action is taken to prevent it
- Emergency workers will not receive doses unless a decision is made to expose them to the source (except during the initial course of an accident)

Emergency Workers – cont'd

- The exposure to the source of radiation should be justified
- The protection against radiation from the source should be optimized
- Three categories of working conditions are defined

Categories of Accident Related Work

- Category 1: Saving life and/or preventing severe consequences (plant personnel & emergency service workers as firemen)
- Category 2: Short term recovery operations and/or urgent protective actions affecting the public (police, medical personnel, drivers and crew of vehicles used for evacuation and similar groups)
- Category 3: Longer term recovery operations (exposed workers)
- Work not directly connected to the accident (all types of work should be assessed from the point of view of increased radiation exposure)

Summary

- System for radiation protection for practices is completely separated from the system for interventions
- Protective actions have to be justified and optimized (form, scale and duration) – benefits have to outweigh the harm
- Approach in optimization is the cost-benefit philosophy
- Emergency worker protection follows basically the same "intervention" principles

Where to Get More Information

Intervention Criteria in a Nuclear or Radiation Emergency
Safety Series No. 109, IAEA, Vienna (1994)