Cost of Life Saved in Radiological Protection

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- ICRP – the International Commission on Radiological Protection
- The system of radiological protection
  - *Justification – optimisation of protection – application of limits*
- The importance, or otherwise, of the cost of life-saving
  - *CBA – non-parametric methods – common sense – collective dose matrix*
  - *Dose and risk constraints on optimisation*
- Some problematic issues

ICRP

ICRP: Produces Recommendations

- Established in 1928
- Objectives

prevent deterministic harm

'minimise' stochastic harm – doses as low as reasonably achievable

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ICRP in The Cosmic Scheme

UNSCEAR Reports on doses and effects

Science

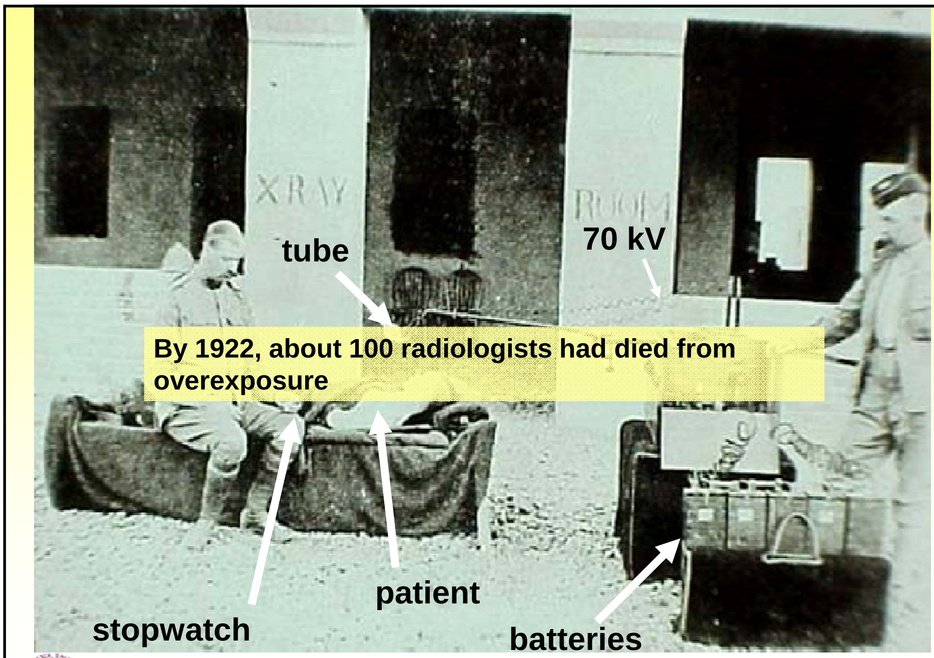
ICRP Recommendations

Policy

UN, EU Basic Safety Standards

Regulations

The System of Radiological Protection



By 1922, about 100 radiologists had died from overexposure

Early ICRP Recommendations

- At first: Occupational exposures in medicine

  Avoid deterministic harm

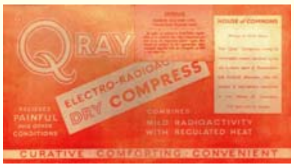
  1928: Working hours limited (~1000 mSv)

  1934: ~500 mSv

- Then: All occupational exposures

  1950: ~150 mSv

Spirit of the time: Radiation good, safe thresholds, no environmental concerns




INTERNATIONAL RECOMMENDATIONS ON RADIOLOGICAL PROTECTION

However, Things Changed

Accelerators

Reactors

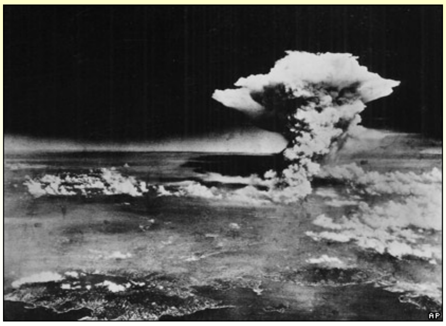
Fallout from weapons testing

'The Lucky Dragon'

1950: IXRPC re-named 'ICRP'

1955: Excess leukaemia observed in Hiroshima, Nagasaki survivors

Radiation – a concern for members of the public



Further ICRP Recommendations

- **Then: All human exposures**

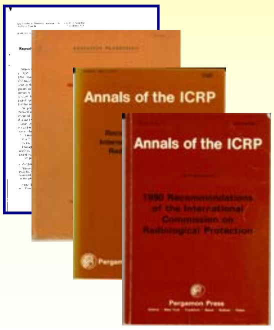
  Avoid deterministic and minimise stochastic harm

  1956/59: Publ. 1, 50 mSv workers; 5 mSv public

  1966: Publ. 9, reduce doses if readily achievable

  1977: Publ. 26, …if reasonably achievable

  1990: Publ. 60: 20 mSv, 1 mSv



***System of protection* developed:**

- **Justification**

  More benefit than detriment

- **Optimisation of protection**

  Doses As Low As Reasonably Achievable

- **Application of dose limits**

Optimisation in Publication 26 (1977)

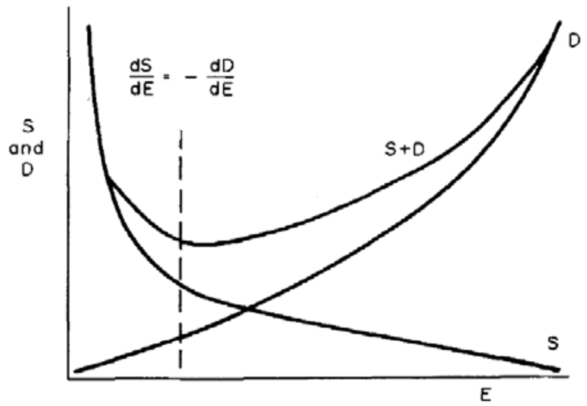


FIG. 1. Differential cost–benefit analysis.

E = a variable reflecting the exposure, possibly in man-rems,

S = total cost of achieving a value of E,

D = total cost of detriment associated with a value of E.

Optimisation in Publication 26 (1977)

- **Cost of protection**
  How much does it cost to remove 20 man.Sievert?
- **Cost of detriment**
  How much does it cost to be exposed to 20 man.Sv
  = How much does it cost to lose 1 statistical life
- **Optimum = lowest sum of the two costs**
  Always below dose limit
  Taking account of social & economic factors

Assessing The Marginal Cost of Life-Saving

- **The minimum level: production loss**
  Up to ~1 MUSD
- **The stakeholder choice: willingness to pay**
  Claimed WTP: can be ~10 MUSD
  Actual WTP: can be ~5 MUSD
- **The maximum level: per caput allocable funds**
  In the order of ~100 MUSD?

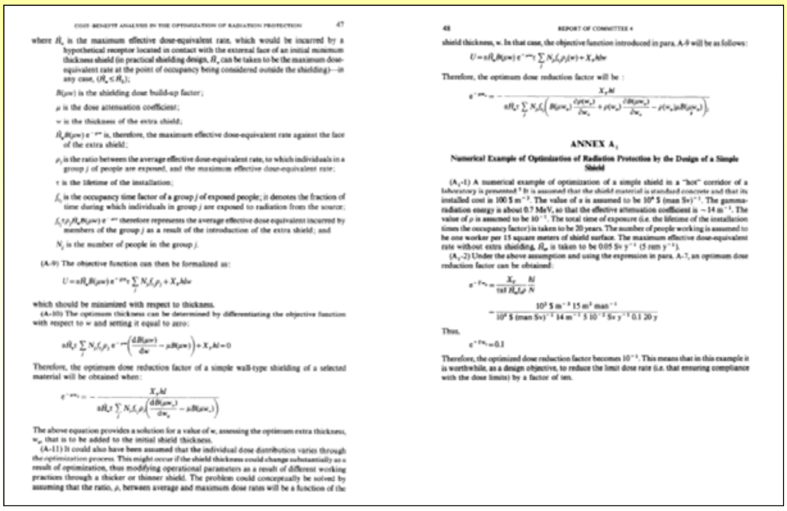
Typical Marginal Cost of Life-Saving

- **Recommended, Swedish Radiation Protection Authority 1997**
  Up to ~4 MUSD

- **Licensee willingness to pay**
  Nuclear industry: Up to ~10 MUSD
  Medical sector: Unspecified, but much less

- **Road traffic safety authority 2007**
  Up to ~4 MUSD

Optimisation in Publication 37 (1983)



Optimisation in Publication 37 *(1983)*

- **Cost-benefit analysis** (worked examples)

CBA is not the only quantitative method

Optimisation is not just the quantitative information

Collective Dose: Logical, But Is It Right?

Equates
many small doses to
few large doses…

Are 500 road traffic
casualties just as bad as
500 victims of one
plane crash?

The Importance, or Otherwise, of The Cost of Life-Saving

Optimisation in Publication 55 (1990)

- **Optimisation = decision aiding**

- **‘Have I done all that I reasonably can’**
  Safety culture

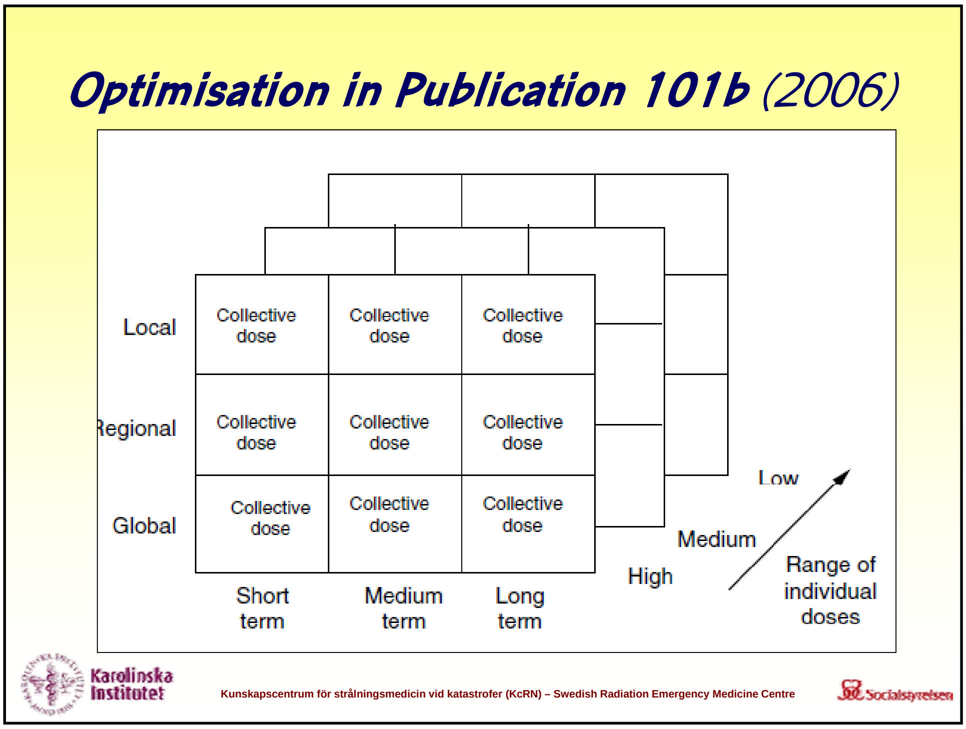
- **Different quantitative methods**
  Differential CBA *(explicit cost of life-saving)*
  Multi-attribute utility analysis *(implicit cost of life-saving)*
  Multi-criteria outranking analysis *(-”-)*

Optimisation in Publication 60 (1991)

- **Practices: ALARA, but restricted by dose constraints**
  - *Occupational: Dose constraints often = dose in well-managed operations*
  - *Public: Dose constraints must allow for other sources*
  - *Potential exposures: Apply risk constraints*
- **Interventions**
  - *Justify: The benefit of each protective action must exceed its disadvantages*
  - *Optimise: Choose method, scale, duration that maximises the benefit*
  - *Time of withdrawal is also part of the optimisation*

Optimisation in Publication 101b (2006)

- **Broadening the process**
  - *Invite stakeholders*
- **Apply to all exposure situation, in the same way**
- **Consider equity, safety culture**
- **Consider collective & individual dose distributions**



Optimisation in Publication 101b (2006)

	Short term	Medium term	Long term
Local	Collective dose	Collective dose	Collective dose
Regional	Collective dose	Collective dose	Collective dose
Global	Collective dose	Collective dose	Collective dose

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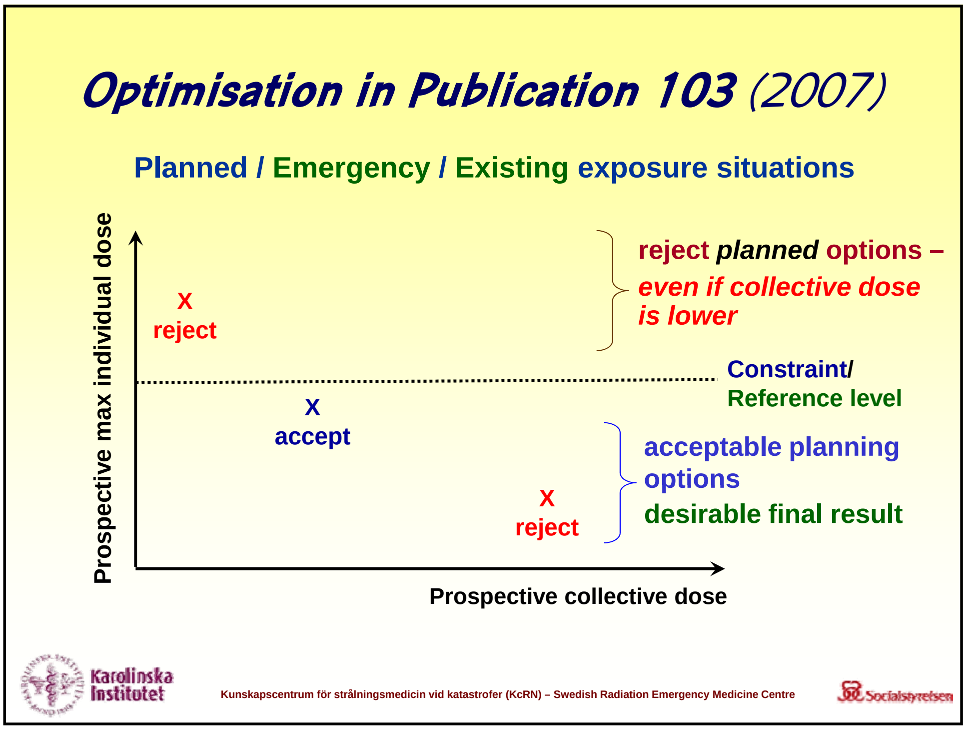
Socialstyrelsen



Optimisation in Publication 103 (2007)

Planned / Emergency / Existing exposure situations

reject *planned* options –
even if collective dose is lower

Constraint/
Reference level

acceptable planning options
desirable final result

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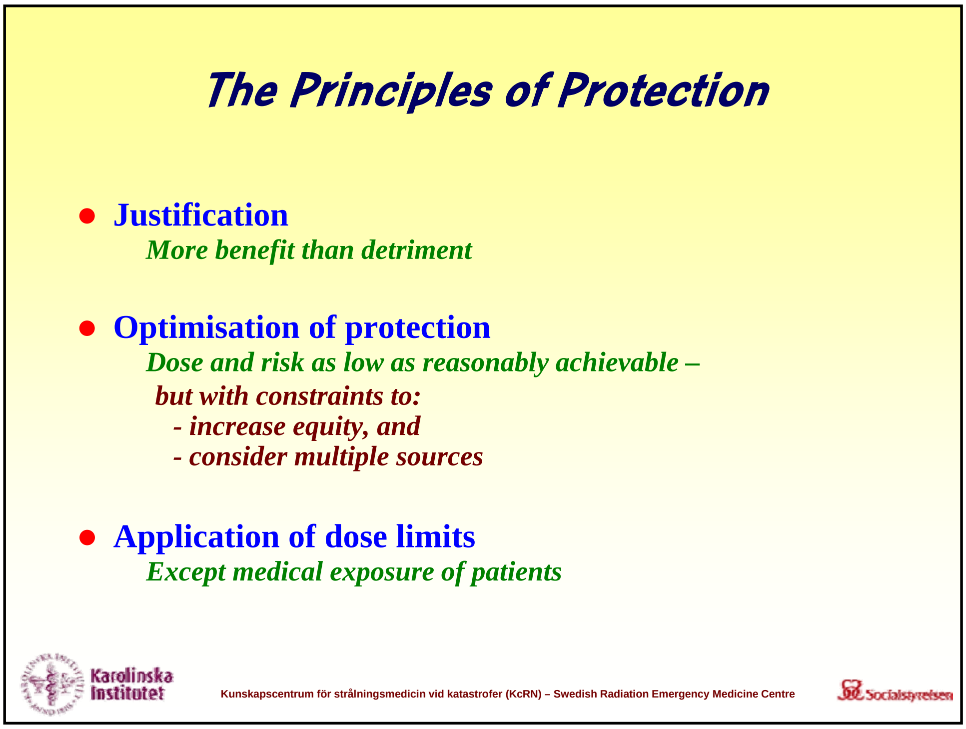
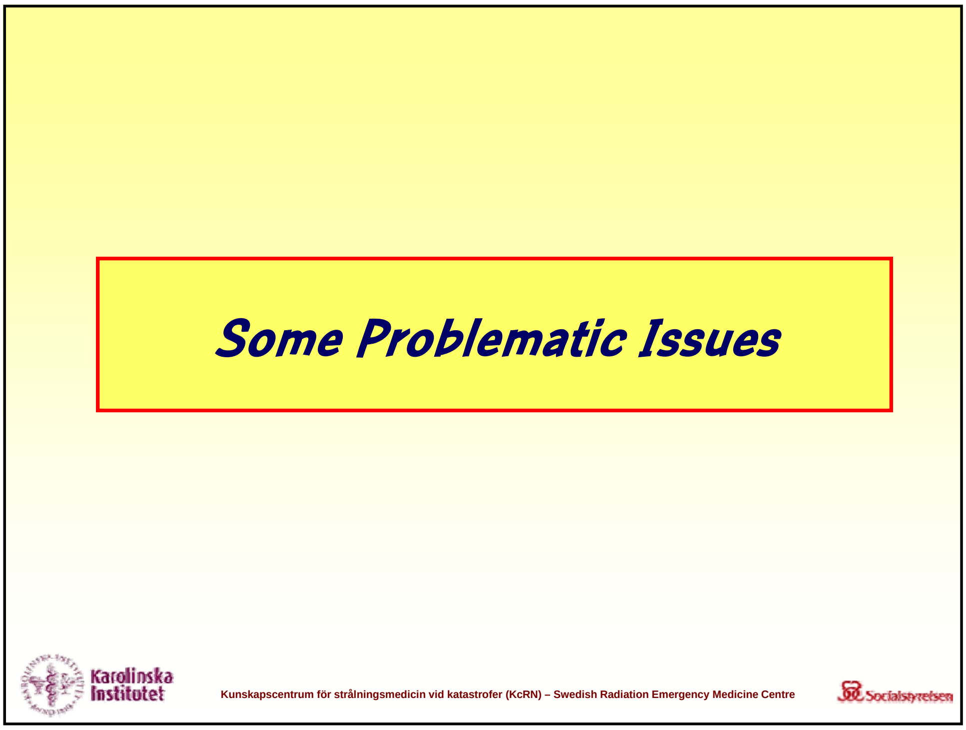


The Principles of Protection

- **Justification**
  More benefit than detriment
- **Optimisation of protection**
  Dose and risk as low as reasonably achievable –
  but with constraints to:
  - increase equity, and
  - consider multiple sources
- **Application of dose limits**
  Except medical exposure of patients



Some Problematic Issues

Optimised Protection, Huge Absolute Cost

- **Radon mitigation might cost 3 kUSD, save 1/50 statistical life**

- **Cost of a saved life: 0.2 MUSD**
  Only ~1/10 of highest recommended cost

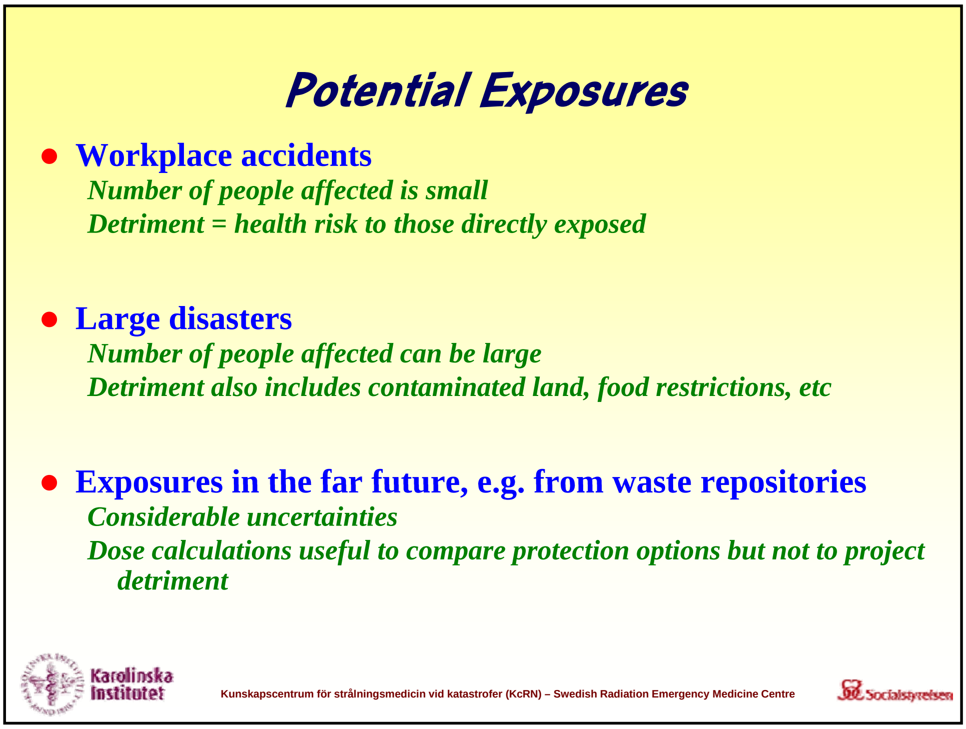
- **A lot of money**
  For individual home-owners *(1 month salary after tax)*
  For society *(if 100 000 homes, 20 000 MUSD)*

Trivial Cost, Protection Not Optimised

- **Shielding of waiting rooms at dental clinics**
  An extra plasterboard = 50 USD

- **Not much money**
  1 h work for an individual dentist
  7500 dentists in Sweden = 0.4 MUSD for sociaty

- **Not much effect**
  Maybe 1/50 000 life saved
  Cost per saved life 10 MUSD

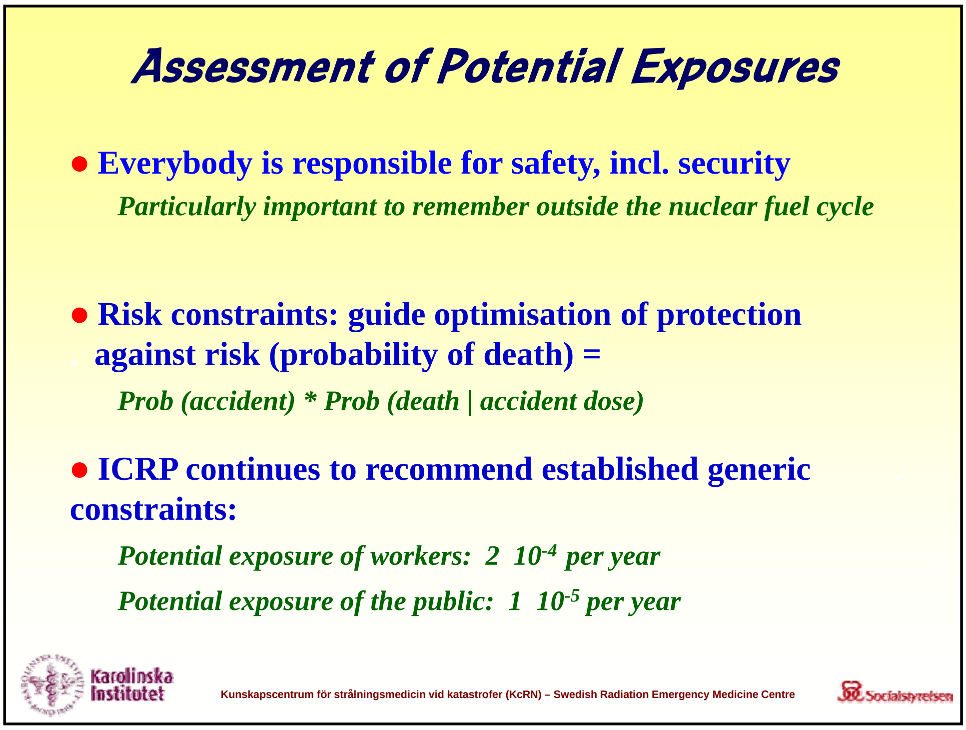


Potential Exposures

- **Workplace accidents**
  Number of people affected is small
  Detriment = health risk to those directly exposed

- **Large disasters**
  Number of people affected can be large
  Detriment also includes contaminated land, food restrictions, etc

- **Exposures in the far future, e.g. from waste repositories**
  Considerable uncertainties
  Dose calculations useful to compare protection options but not to project detriment



Assessment of Potential Exposures

- **Everybody is responsible for safety, incl. security**
  Particularly important to remember outside the nuclear fuel cycle

- **Risk constraints: guide optimisation of protection against risk (probability of death) =**
  *Prob (accident) * Prob (death | accident dose)*

- **ICRP continues to recommend established generic constraints:**
  Potential exposure of workers: $2 \ 10^{-4}$ *per year*
  Potential exposure of the public: $1 \ 10^{-5}$ *per year*

What Is The Size of The Risk?

ICRP Nominal Probability Coefficients (% Sv^{-1})

Exposed popula-tion	Cancer		Heritable effects		Total detriment	
	Publ 60	2007	Publ 60	2007	Publ 60	2007
Whole	6.0	5.5	1.3	0.2	7.3	**5.7**
Adult	4.8	4.1	0.8	0.1	5.6	**4.2**

What Is The Size of The Risk?

ICRP Nominal Probability Coefficients (% Sv^{-1})

For practical protection purposes,
the overall risk coefficient of ~5%
is still appropriate

Does ICRP Over- Or Underestimate Risk?

So What Was The Take-home Message?

- Optimisation is the most important aspect of protection
  Cost of life-saving is an input variable to CBA
  CBA is just one of many quantitative methods
  Qualitative methods may be more relevant
- Typical marginal cost of life-saving: ~5 MUSD
- Optimised protection does not always mean sensible
  Radon: Optimised protection but huge absolute cost
  Shielding: Sometimes, low absolute cost but little protection value
- Potential exposures & risk constraints need attention