SESSION 1

THE NEW ICRP GENERAL RECOMMENDATIONS

Chair: Yasuhito SASAKI
Co-Chair: Jacques LOCHARD

The new draft ICRP recommendations was presented by the ICRP chair, Professor Lars-Eric Holm. His presentation was followed by presentations by Japanese members of the various ICRP committees, discussing their views of the draft recommendations based on their own technical experience. After these presentations, questions from the floor raised many of the key issues of the conference: dose constrains, the LNT hypothesis, dose bands, etc. This showed that the conference participants had carefully and completely read the draft, and were very interested in building a final ICRP recommendation that appropriately addresses all their concerns. These issues were also discussed throughout the entire conference.

THE NEW ICRP SYSTEM OF RADIOLOGICAL PROTECTION

Lars-Erik HOLM
Chair, International Commission on Radiological Protection

ICRP's Recommendations

The first recommendations were issued in 1928 and concerned the protection of medical staff against occupational exposure.

General recommendations have appeared in

- Publication 1 (1959)
- Publication 6 (1964)
- Publication 9 (1966)
- Publication 26 (1977), and
- Publication 60 (1991).

Since 1991, nearly 30 different numerical restrictions on dose have appeared in a number of publications.

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ICRP Main Commission 2005 - 2009

L-E Holm (Chair), Sweden	J.D. Boice Jr, USA
R Cox (Vice-Chair), UK	A Gonzá lez, Argentina
RJ Preston (C 1), USA	J-K Lee, Korea
C Streffer (C 2), Germany	Z Pan, PR China
C Cousins (C 3), UK	Y Sasaki, Japan
A Sugier (C 4), France	N Shandala, Russian Federation
RJ Pentreath (C 5),UK	

Emeritus Members: RH Clarke, UK; CB Meinhold, USA; F Mettler, USA; B Lindell, Sweden; WK Sinclair,USA

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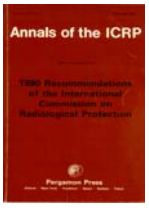
The Work of the ICRP Committees

- Committee 1: Biological & medical effects
- Committee 2: Doses from radiation exposures
- Committee 3: Medical radiation exposures
- Committee 4: Application of ICRP recommendations
- Committee 5: Protection of the environment

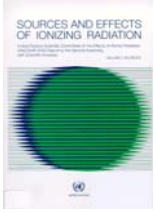
International Basic Safety Standards

- There is a close connection between ICRP's recommendations and the BSS since 1962.
- The BSS have followed the establishment of new ICRP recommendations:

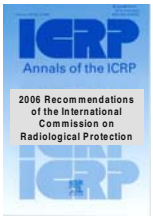


- The 1990 recommendations were the basis for the 1996 BSS.

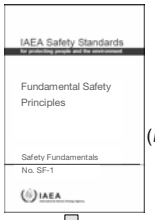
UNSCEAR - ICRP - IAEA



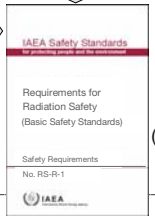
Effects of radiation



Recommendations for protection



Essential principles (*moral obligation*)



Essential requirements (*legal obligation*)

The Need for Revision

- The radiation risks have not changed substantially.
- Biological and physical assumptions need updating.
- Existing recommendations need to be consolidated and simplified.
- Non-human species should receive more emphasis than in the past
- There is no hurry.

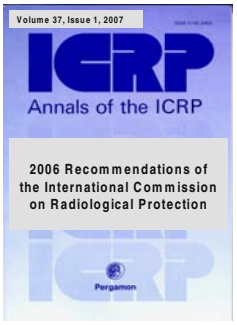
The 2006 Recommendations

The Commission has decided to issue the revised recommendations having three primary aims in mind:

- To take account of new biological and physical information and of trends in the setting of radiation safety standards;
- To improve and streamline the presentation of the recommendations; and
- To maintain as much stability in the recommendations as is consistent with the new scientific information.

ICRP's 2006 Recommendations

- Aims and scope
- Biological aspects
- Dosimetric quantities
- The system of radiological protection
- Medical exposure of patients
- Exposure to natural sources
- Potential exposures
- Emergency and existing situations
- Protection of the environment
- Implementation of the recommendations
- Glossary
- References



What Is New?

There is more continuity than change!

Most recommendations will remain – because they work and are clear.

Some recommendations are to

- Be explained– because more guidance is needed;
- Be added– because there has been a void; or
- Differ– because understanding has evolved.

The Aim of the Recommendations

- To provide an appropriate standard of protection for people and the environment, without unduly limiting the beneficial actions giving rise to radiation exposure.

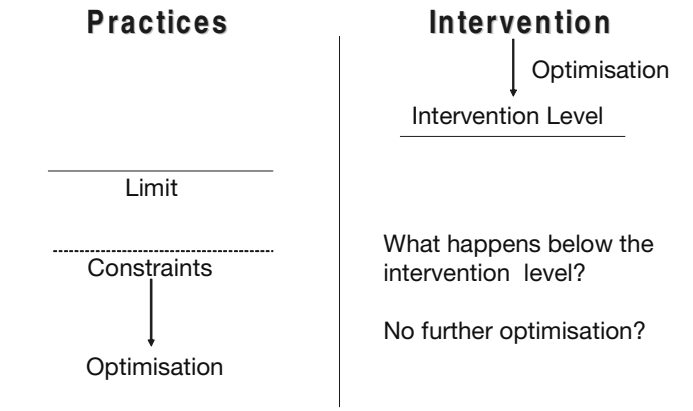
* * * *

- The 2006 recommendations consolidate and add to previous recommendations issued in various ICRP publications.
- The existing numerical recommendations in the policy guidance given since 1991 remain valid unless otherwise stated.

Major Features

- Maintaining the fundamental principles of radiological protection, and clarifying how they apply to sources and the individual;
- Updating the weighting factors and the radiation detriment;
- Maintaining the dose limits;
- Extending the concept of constraints in the source-related protection to all situations.

Practices and Intervention in ICRP 60



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Are Practices and Interventions Different?

In both cases

- There is a maximum level of dose above which the regulator will demand action.
- Optimisation of protection is seen to reduce the level of dose at which action is taken.
- No action to further reduce doses is taken below the optimised level of protection.

CONCLUSION: There is no procedural difference

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Types of Exposure Situations

- Replacing the concepts of “practice” and “intervention” with three types of exposure situations that address all conceivable circumstances:
  - Planned situations
  - Emergency situations
  - Existing situations.

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Foundation Documents and Building Blocks

Foundation documents:

- Biological and Epidemiological Information on Health Risks Attributable to Ionising Radiation (C1)
- Basis for Dosimetric Quantities Used in Radiological Protection (C2)

Building blocks:

- Low-Dose Extrapolation of Radiation-Related Cancer Risk (C1)
- Radiological Protection in Medicine (C3)
- Optimisation of Protection (C4)
- Assessing Dose to the Representative Individual (C4)
- The Scope of Radiological Protection Regulations: Exclusion and Exemption (MC)

Scope of the Recommendations

The recommendations

- cover exposures to both natural and artificial sources that are controllable
- apply to control of sources or to pathways leading to doses in individuals.

Protection concerns

- exposure to incremental doses to natural background, and
- risks primarily at levels in the order of a few mSv in a year.

The System of Protection

- Types of exposure situations;
- Types of exposure;
- Identification of the exposed individuals;
- Source-related and individual-related assessments;
- The three fundamental principles of protection;
- A description of levels of individual dose that require protective action;
- A delineation of the conditions for the safety of radiation sources; and
- The implementation of the recommendations.

Quantities for Radiological Protection

Absorbed dose, *D*

↓

Protection quantities defined in the body and related to risk from stochastic effects

Equivalent dose, H_T, in an organ or tissue T

↓

Effective dose, *E*

↓

Committed dose, $H_T(\tau)$
Collective dose, $S(\tau)$

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Linear-non-threshold (LNT) Hypothesis

The LNT hypothesis is the basis for:

- Averaging and summing up of doses;
- The concept of effective dose;
- The concept of committed and collective dose;
- Individual dosimetry with integrating detectors; and
- The system of dose record keeping.

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Radiation Weighting Factors, w_R

Type and energy range	Publication 60	2006
Photons, all energies	1	1
Electrons and muons, all energies	1	1
Protons	5	**2**
Alpha particles, fission fragments, heavy nuclei	20	20
Neutrons	Stepwise function	**Continuous function**

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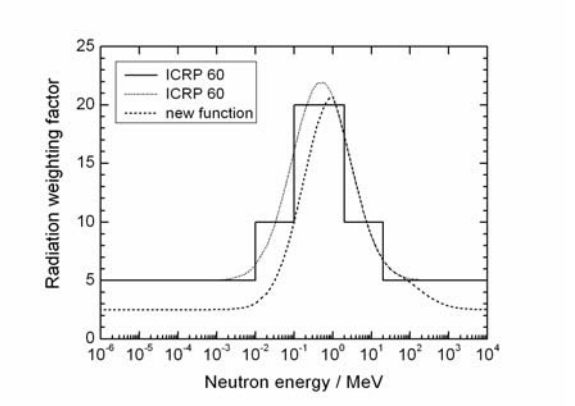
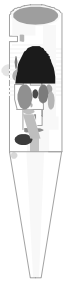
New w_R for Neutrons

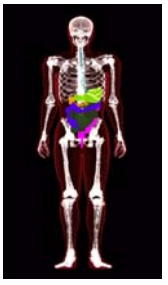


New Reference Phantoms

MIRD Phantom



Voxel Male and Female Phantoms



New dose coefficients in 2008

Effective Dose (*E*)

- *E* is calculated by using reference values for a reference person or group. Weighting factors are averaged over age and gender.
- *E* should be used only for compliance of constraints and dose limits to control stochastic effects.
- *E* should mainly be used for planning in prospective situations.
- *E* should not be used for more detailed retrospective dose and risk assessments on exposure of individuals.
- *E* should not be used for epidemiological studies.

Main Conclusions on Biology

Dose-response for stochastic effects: A simple proportionate relationship between dose and risk at low doses.

DDREF: 2.

Genomic instability, bystander effects, adaptive response: Still insufficient knowledge for protection purposes.

Genetic susceptibility: Known disorders too rare to distort risk estimates; impact of weak genetic determinants cannot be judged.

In-utero cancer risk: Life time risk similar to that of young children (a few times higher than that of the whole population).

Main Conclusions on Biology

Nominal probability coefficients for cancer: Based on incidence and not mortality.

Nominal probability coefficients for heritable diseases: Based on UNSCEAR 2001 and up to 2nd generation.

Tissue reactions in adults: Revised judgements but no major changes.

Risks of non-cancer diseases (A-bomb LSS): Great uncertainty on dose response < 1 Sv; no judgement on low dose risk possible.

The Tissue Weighting Factors

- Determine lifetime cancer incidence for rad.-assoc. cancers.
- Apply DDREF.
- Transfer risk estimates across populations (ERR:EAR weights).
- Apply weighted risk estimates to and average across seven Western and Asian populations to provide nominal risk coefficients.
- Adjust for lethality, quality of life and for years of life lost to obtain the radiation detriment for each type of cancer.
- Normalize to unity and obtain the relative radiation detriments.
- These are grouped into four categories broadly reflecting the relative detriments, i.e. **the tissue weighting factors**.

Tissue Weighting Factors, w_T

Tissue	w_T	? w_T
Bone-marrow, breast, colon, lung, stomach, remainder tissues[1]	0.12	0.72
Gonads	0.08	0.08
Bladder, oesophagus, liver, thyroid	0.04	0.16
Bone surface, brain, salivary glands, skin	0.01	0.04

[1] Nominal w_T divided equally between 14 tissues.

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Nominal Risk Coefficients for Stochastic Effects (% Sv^{-1})

Exposed population	Cancer		Heritable effects		Total	
	1990	2006	1990	2006	1990	2006
Whole	6.0	5.5	1.3	0.2	7.3	6
Adult	4.8	4.1	0.8	0.1	5.6	4

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The Genetic Risk Estimate – 1991 and Now

- In 1991: based on UNSCEAR 1988, DD in mice, extrapolated to theoretical equilibrium (many generations).
- Now: based on UNSCEAR 2001, DD based on humans and mice, 2 generations only since extrapolation to equilibrium makes incorrect assumptions.
- UNSCEAR 2001, BEIR VII also used 2 generations and arrived at similar risks.
- Radiation-induced multigene deletions have very low fitness ⟶ selection will remove almost all in 2 generations ⟶ 2-generation risk must be close to theoretical equilibrium.

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The Genetic Risk Estimate – Now

Keeping gonadal doses ALARA is

still strongly recommended!

Summary of Radiation Risks

- The nominal risk estimates are now slightly smaller than in 1990, but the risk is in the same order of magnitude as before.
- The overall risk coefficient of 0.05 Sv^{-1} (0.00005 mSv^{-1}) continues to be appropriate for purposes of radiological protection.

Principles of Protection

SOURCE RELATED

JUSTIFICATION

Any decision that alters the radiation exposure situation, e.g., by introducing a new radiation source or by reducing exposure, should do more good than harm, i.e., yield an individual or societal benefit that is higher than the detriment it causes.

Principles of Protection

SOURCE RELATED

OPTIMISATION

The level of protection should be the best under the prevailing circumstances, i.e., maximising the margin of good over harm. To avoid serious inequities resulting from the optimisation procedure, there should be restrictions on the doses or risks to individuals from a particular source (dose or risk constraints).

Thus, optimisation involves keeping exposures as low as reasonably achievable, taking into account economic and societal factors, as well as any inequity in the distribution of doses and benefits amongst those exposed.

Principles of Protection

INDIVIDUAL RELATED

DOSE LIMITS

In planned situations, the total dose to any individual from all regulated sources should not exceed the appropriate limits specified by the Commission.

Dose Constraint

- Is the most fundamental level of protection for the most exposed individuals from a single source within a type of exposure.
- Applies to all situations;
- Is used prospectively as the starting point of the optimisation process;
- Is not a form of retrospective dose limitation;

Dose Constraint

- In planned exposure situations, it is less than limits;
- In emergency or existing exposure situations, it represents the level of dose/risk where action is ***almost always*** warranted;
- The chosen value will depend upon the circumstances of the exposure;
- It will be established at the national or local level by regulators or operators.

Dose Constraint

- The numerical criteria recommended by ICRP in Publication 60 and thereafter can be regarded as constraints.
- The values fall into three defined bands: 0.01-1 mSv, 1-20 mSv and 20-100 mSv.
- These bands will enable selection of an appropriate value for a constraint for a specific situation that has not been addressed explicitly by ICRP.

Dose Constraint

BANDS OF PROJECTED DOSE	REQUIREMENTS
20 - 100 mSv	Exceptional situations. Benefit on a case-by-case basis. Information, training and individual monitoring of workers, assessment of public doses.
1 - 20 mSv	Individual direct or indirect benefit. Information, training and either individual monitoring or assessment.
Under 1 mSv	Societal benefit (not individual). No information, training or individual monitoring. Assessment of doses for compliance.

Dose Constraint

BANDS OF PROJECTED DOSE	EXAMPLES
20 - 100 mSv	Action to reduce exposures in a radiological emergency. Exposure situations involving abnormally high levels of natural background radiation.
1 - 20 mSv	Occupational exposure in planned situations. Radon. Countermeasures (e.g., sheltering and iodine prophylaxis) in the event of an accident.
Under 1 mSv	The exposure of members of the public from planned situations.

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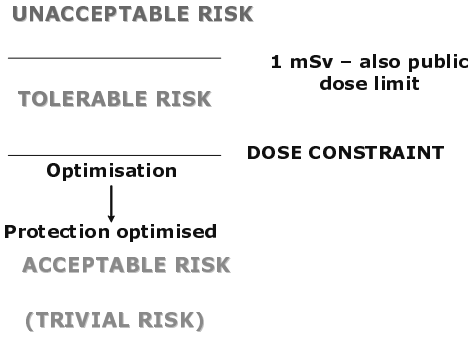
Additional Radiation Dose and Risk

0.01 – 1 mSv



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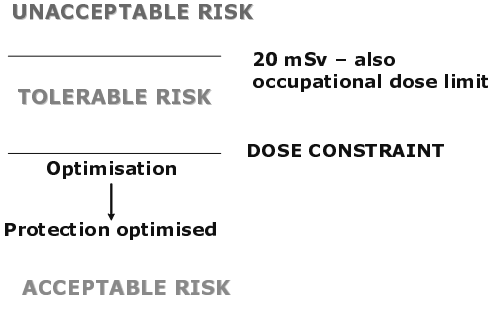
Additional Radiation Dose and Risk

1 – 20 mSv



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Constraints for Radon

ICRP's policy is based upon setting a level of effective dose from radon where action would be warranted:

10 mSv per year

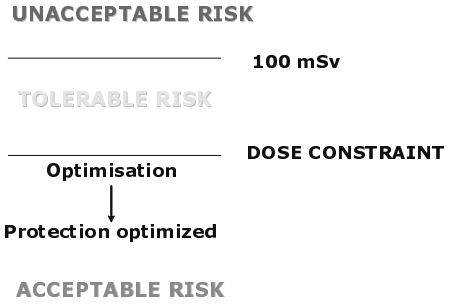
ICRP's constraints are set where action is almost always warranted:

Home	**600 Bq m^{-3}**
Work	**1500 Bq m^{-3}**

National regulators apply the optimisation of protection to arrive at the level at which to act.

Additional Radiation Dose and Risk

20 – 100 mSv



The Collective Dose

- Is an instrument for optimisation, for comparing radiological technologies and protection procedures.
- Is not intended as a tool for epidemiologic risk assessment. It is therefore inappropriate to use it in risk projections based on epidemiological studies.
- The computation of cancer deaths based on collective doses involving trivial exposures to large populations is not reasonable and should be avoided. Such a use was never intended and is an incorrect use of the collective dose.

The Collective Dose

For decision aiding, more information is often necessary, e.g. for the workforce:

- Number exposed, mean dose, dose range, task-related dose, etc.
- When, where, how and by whom are exposures received?

For decision making, it may be reasonable to give more weight to doses that are:

- Moderate or high;
- Received in the near future.

Exclusion and Exemption

A legislative system for radiological protection should establish

- What should be within the legal system and what should be excluded from the law and its regulations;
- What could be exempted from some regulatory requirements because regulatory action is unwarranted.

The legislative framework should provide the regulator with the authority to exempt situations from specified regulatory requirements.

Exclusion from Legislation

Exposures that may be excluded from radiological protection legislation include

- Uncontrollable exposures, e.g., ^{40}K in the human body, and
- Exposures that are essentially not amenable to control regardless of their magnitude, e.g., exposure to cosmic rays at ground level.

Exemption

Principles that should govern the process of exemption:

- The individual risk attributable to the exposure must be insignificant (for man-made sources, this is judged to correspond to an annual dose of around 10μSv);
- Radiological protection, including the efforts for the regulatory control, must be optimised;
- The practice must be justified and its sources should be inherently safe.

Recommended Exemption

- Devices emitting adventitious radiation of max. 5 keV and max. 1 μSv h^{-1} at 0.1 m from any surface of the device;
- Radionuclides in activity concentrations smaller than those specified by FAO and WHO for foodstuff and drinking water, and by the IAEA for non-edible commodities, for radiation sources and for materials in transport.

Implementation Takes Time...

ICRP 1977 Recommendations (Publication 26)
International standards 1984
National standards ~1989

ICRP 1990 Recommendations (Publication 60)
International standards 1996
National standards ~2000

ICRP 2006 Recommendations
International standards 2010?
National standards 2015?

Time Schedule

- June – 15 Sept 2006: New consultation on draft recommendations.
- November 2006: Earliest possible date of adoption of the recommendations in Rabat, Morocco.
- 2007: Publication of the new recommendations.

VIEWS ON THE NEW ICRP RECOMMENDATIONS FOCUSING ON THE RADIATION EFFECTS

Ohtsura NIWA
Kyoto University, Radiation Biology Center

Will be discussing

The New Recommendations
1. What's new?
2. What's the problem?
3. What to do with the problem?
4. What's Asian views?

1. What's new ?
New and old in the New Recommendations

What's new and what's the same ?

Pagagraph 11 - 12

"Keep the fundamental principles"
"Updating the details"

Updating the biology in the New Recommendation - tissue weighting factors, W_T -

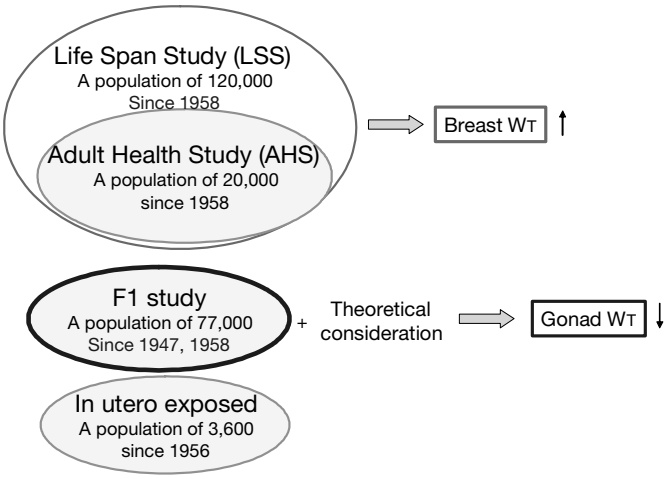
1990

tissue	w_T	Σw_T
gonad	0.20	0.20
Bone marrow, colon, lung, stomach	0.12	0.48
Bladder, breast, esophagus, liver, thyroid	0.05	0.25
Skin, bone surface	0.01	0.02
remainder tissues	0.05	0.05

This time

tissue	w_T	Σw_T
Bone marrow, colon, lung, stomach, breast, remainder tissues	0.12	0.72
gonad	0.08	0.08
Bladder, esophagus, liver thyroid	0.04	0.16
Bone surface, brain, salivary gland, skin	0.01	0.04

New understandings from Hiroshima & Nagasaki



2. What's the problem? The old problem of uncertainty

ICRP risk evaluation system

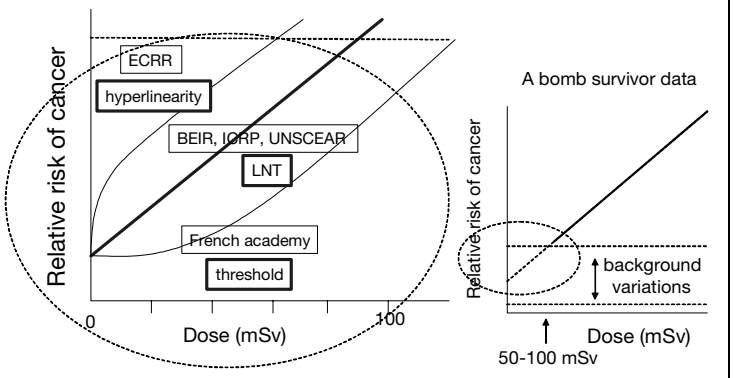
LNT: a theoretical foundation of radiation protection
Risk = cumulative dose x risk estimates x DDREF x W_R x W_T
Data: A bomb survivor data

dose:	measurements + estimation (uncertain)
risk estimate:	Cross population risk transfer (uncertain
DDREF:	varies with biological endpoints (uncertain)
W_R:	varies with biological endpoints (uncertain)
WT:	round up values (uncertain)

Those in blue are all uncertain, more or less

Uncertainty particularly large for low doses and dose rates

3. What to do with the problem?
- the good old principle of LNT hypothesis -



LNT: powerful hypothesis with limitations

Two foundations of LNT
- with their limitations -

Epidemiological studies on A bomb survivors

dose → detriments

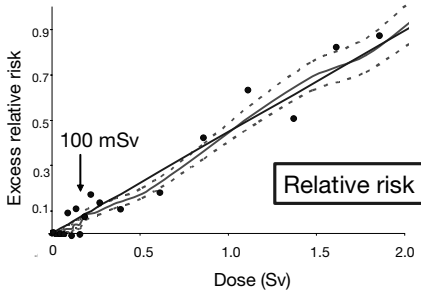
"no power for low doses/dose rates"

Radiation biology

dose → damage → detriments

"too naïve a view"

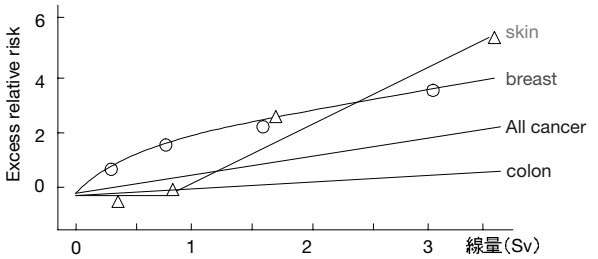
Epidemiological studies
Dose response of A bomb survivors



Relative risk = 1.5/ Sv

Linear increase of the risk above 100 mSv
Uncertain below 100 mSv
Trends do not exclude LNT in low dose range

Shape of the dose response
- tumor type dependent -



All	oral	digestiv	oesoph	stomach	intestine	colon
0.63	0.29	0.38	0.25	0.32	0.72	0.21
liver	gall	Pancre	respirat	lung	skin	breast
0.49	0.12	0.18	0.50	0.95	1.0	1.6
uterus	ovary	prostate	urinary	bladder	thyroid	brain
0.15	0.98	0.29	1.2	1.0	1.2	0.26

Thompson *et al.*
Radat. Res. 1994

Uncertain low risks in epidemiology
- Size of the study population -
- Homogeneity of the study population -

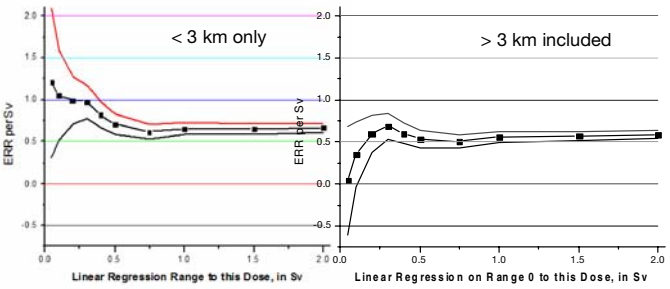
Estimated population size

Dose (mSv)	Background risk	Excess risk	Total risk	Size of population
1 000 mSv	10%	10%	20%	67
100 mSv	10%	1%	11%	5 728
10 mSv	**10%**	**0.1%**	**10.1%**	**558 000**
1 mSv	10%	0.01%	10.01%	55 700 000

⇩ by Charles Land

Evaluation of 10 mSv risk not possible even with 100 000

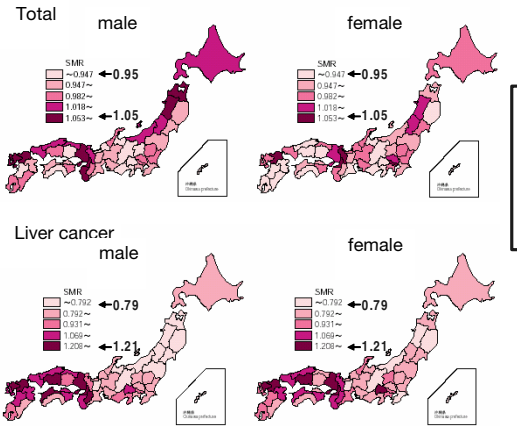
Uncertainty of low dose risk values
ERR/Sv of solid cancer, the survivor data



Left-hand panel based on proximal (< 3 000 m) survivors only; in right-hand panel the distal (> 3 000 m) survivors also contribute, resulting in higher zero-dose baseline

Based on data of Pierce & Preston (Radiat Res, 154, 178, 2000), by C Land

Limitation of epidemiology
- heterogeneity of study population -



Regional variations in cancer mortality Over 10 %

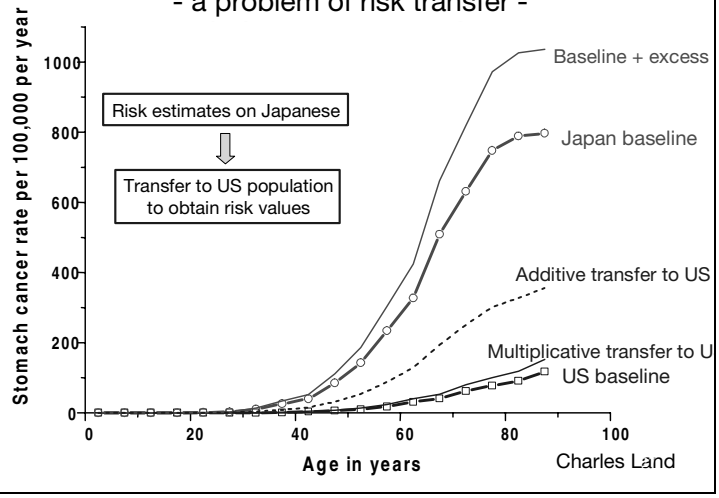
⇩

Difficulty in detecting variations of a few %

ICRP

Risk values for world average

Uncertainty in risk estimates
- a problem of risk transfer -

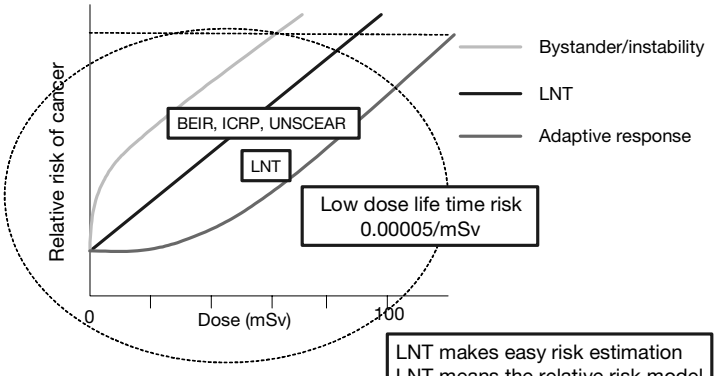


Risk estimates on Japanese

⇩

Transfer to US population to obtain risk values

LNT hypothesis as the standard of ICRP systems
- for its strength and with its limitations -



Low dose life time risk 0.00005/mSv

LNT makes easy risk estimation
LNT means the relative risk model
LNT means robability of causation
LNT with uncertainty

3-2. What to do with the problem?
ICRP well aware of the uncertainty

ICRP is very careful in using LNT, collective dose, and (cumulative dose)

Pagagraph 29
"LNT is - - - to manage risk from radiation exposure"

Parageraph 146 - 147
"- in the case of low individual doses with wide geographical areas/long time scales, the use of collective dose for risk estimation - - is not reasonable and should be avoided"

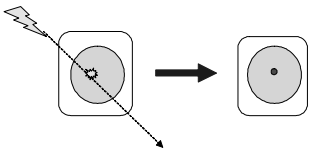
Some differences between ICRP and BEIR VII

ICRP: pragmatic, realistic and conservative
LNT as a tool, not truth
supplemented with real data
BEIR VII: theoretical, idealistic and radical
LNT as science
based mainly on theory

⇧

BEIR VII Report on page 30
"The Committee concludes that the current scientific evidence is consistent with the hypothesis that there is a linear, no-threshold dose-response relationship ---"

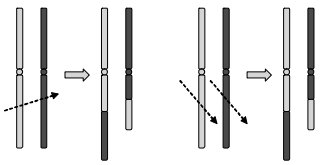
Heavy dependence of BEIR VII on theory
example of DDREF values

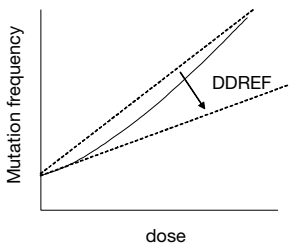


Dose response of chromosome mutation
MF = $\alpha D + \beta D^2$ high dose rate (LQ)
MF = αD low dose rate (L)

LNT hypothesis + LQ model
DDREF = $\alpha D + \beta D^2/\alpha D = 1 + \beta/\alpha D$
valid for chromosome mutation

Linear term (one hit event) + Quadratic term (two hit events)



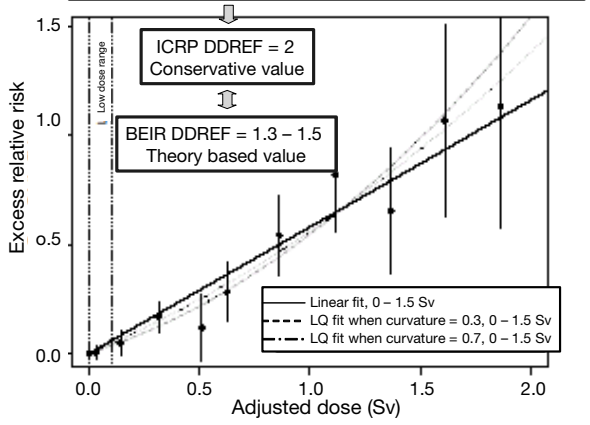


BEIR VII DDREF calculation

A wider distribution of observed DDREF = 2 – 4, sometime 10

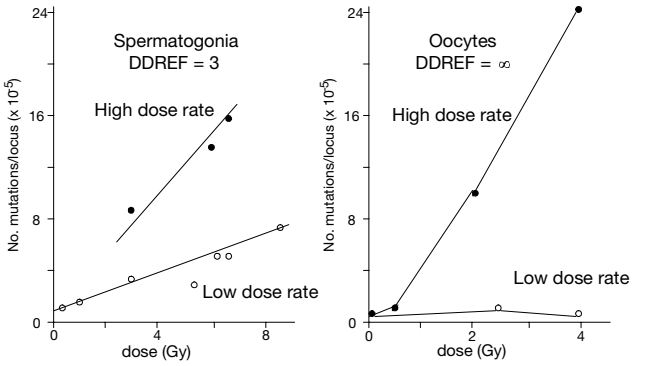
ICRP DDREF = 2
Conservative value

BEIR DDREF = 1.3 – 1.5
Theory based value



Experimental approach to obtain DDREF

Mouse germline mutation



Even the linear portion dose rate sensitive!

Adv. Radiat. Biol.4, 131, 1974

3-3. What to do with the problem?
Further improvement of the recommendations

The New Recommendations by no means perfect

⇩

<u>Need to be improved</u>

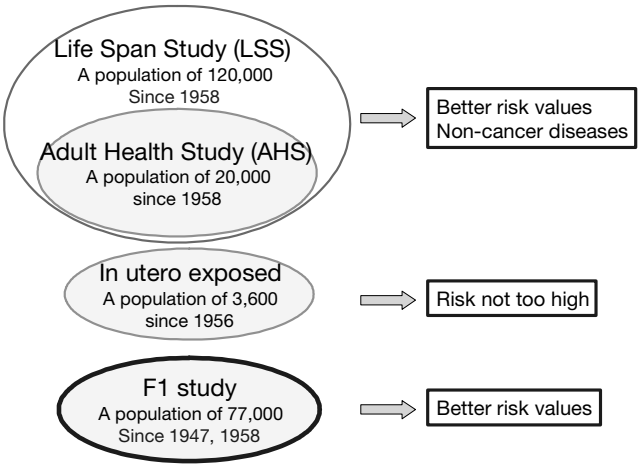
Ex. Protection of individuals
genetic predisposition, gender and age

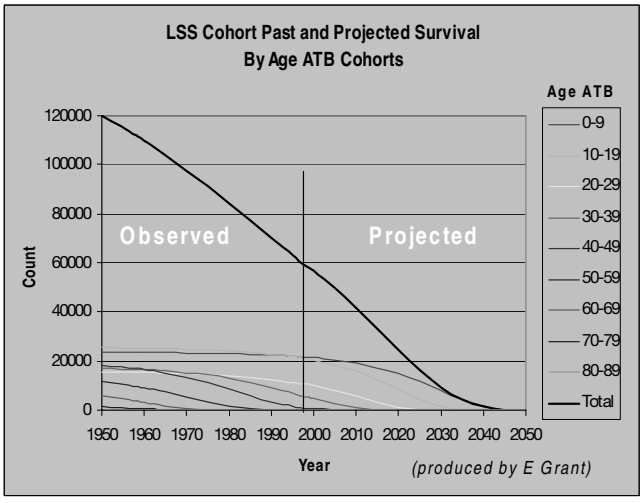
⇩

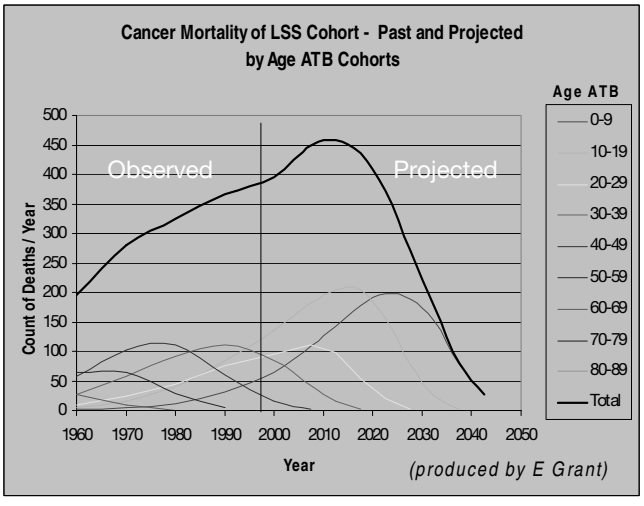
<u>Research needs</u>

Epidemiological studies on low dose risk
Mechanistic understandings of low dose effects

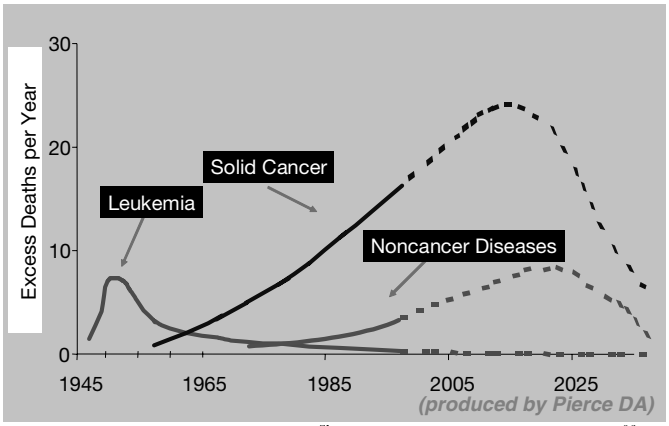
More to come out from Hiroshima & Nagasaki







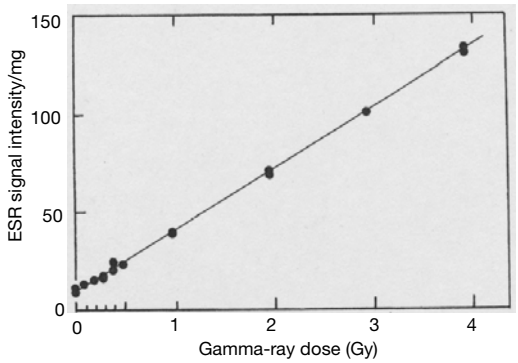
LSS radiation-associated deaths by time period: Observed and anticipated



Shore 23

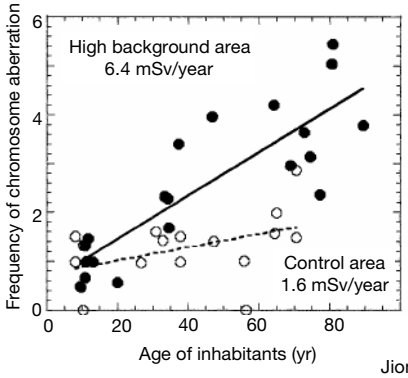
Even the dose estimation is improving

ESR based dose estimation on tooth



Int J Radiat Biol. 73, 619-627, 1998

From China: the high natural radiation area studies - not one of those ecologic studies -



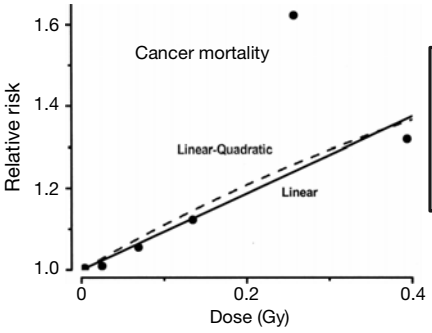
Relative risk of cancer mortality

Dose (mSv)	cases	RR	95% CI
0-99	142	1.00	-
100-199	261	0.83	0.65-1.06
200-299	211	0.98	0.76-1.26
300-399	263	0.90	0.68-1.18

A population of 125,000
Reliable dose estimation
⇩
Chromosome mutation: increase
Cancer mortality: no increase

Jiong *et al.* J. Radiat. Res. 41, 63, 2000
Sun *et al.* J. Radiat. Res. 41, 43, 2000

Techa river cohort with risk higher than the survivors - higher risk values without DDREF correction -

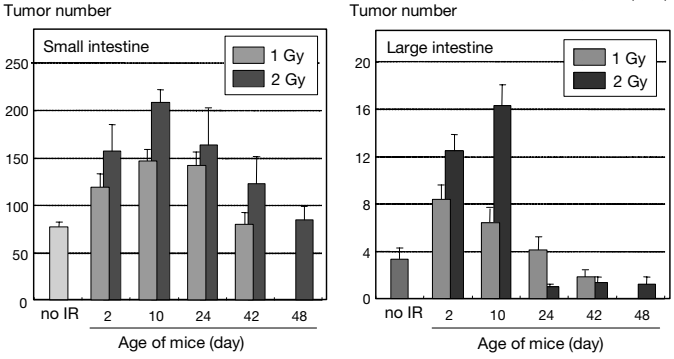


A population of 30,000
Dose estimation not accurate
⇩
Dose dependent increase
No power below 0.3 Sv
ERR = 0.92/Sv
Without DDREF correction !

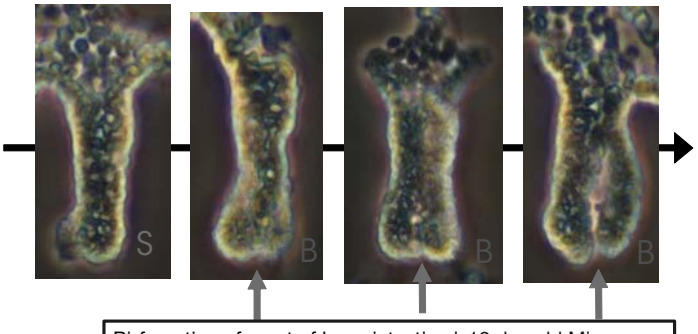
Krestinina *et al.* Radiat Res 164, 602, 2005

3-4. What to do with the problem The power of basic studies - an example of the Min mouse system -

M. Okamoto and H.Yonekawa
J Radiat. Res. 46, 83-91 (2005)



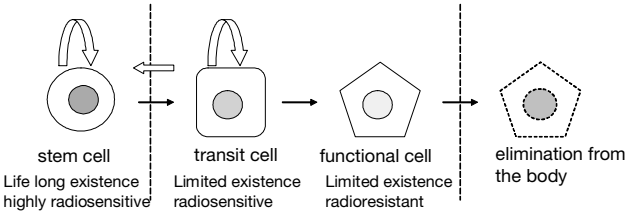
Radiation susceptibility only during expansion of stem cells in Min mouse



Bi-furcation of crypt of large intestine in12 day old Min mouse

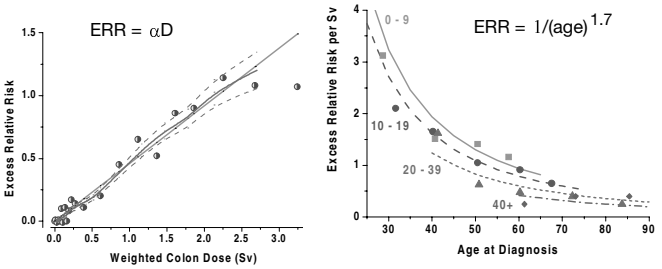
M. Tatematsu and Tsukamoto, unpublished

The power of basic studies
Tissue stem cells and tissue turnover



Radiosensitivity and turnover rate of target cells
highly sensitive stem cells or transit cells
⇩
Age dependency of radiation carcinogenesis
Cumulative dose: life long or with limitation?
decline of risk: due to tissue turnover?

Observed time trend of cancer risk
in the LSS population



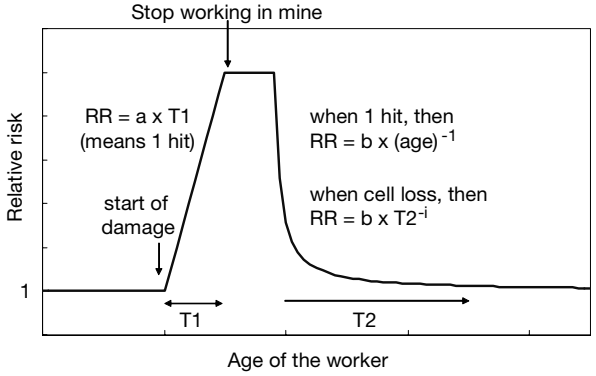
Pierce & Vaeth, Biostatistics 4, 231, 2003

Linear increase means 1 hit
→ ERR declines by 1/age

however ⇨

The real rate = 1/(age)^2
→ Loss of initiated cells?
Due to tissue turnover?

Trend of risk decline in uranium miners



If the rate of decline = 1/(age)^1
then Loss of initiated cells?

4. What's Asian view?
The way to deal with the uncertainty

ICRP risk evaluation system

LNT: a foundation with a certain limit
Risk = cumulative dose x risk estimates x DDREF x W_R x W_T
Data: A bomb survivor data

⇩

Low dose risk far from certain
Step by step clarification of uncertainty
yet
Regulations/policies needed

Basic principle and tradition of ICRP

ICRP

C1 tires to make uncertainty to certainty
C4 & MC tries to bring better regulations
even in the face of uncertainty

⇩

Fully consistent with Asian view!

Asian views

Tradition of balance, realism and pragmatism

孔子 (Confucius, B.C. - 552)
「知之爲知之不知爲不知是知也」
to know not knowing is knowing

莊子（Zhuangzi, B.C. - 275）
「小知間々大知閑々」
Small knowledge separates things, large knowledge glues things together

Darai Lama (2005)
"When a Buddhist teaching contradicts science, revise the teaching"

VIEWS ON THE NEW ICRP RECOMMENDATIONS FOCUSING ON THE DOSES FROM RADIATION EXPOSURE

Nobuhito ISHIGURE
Nagoya University

BASIS FOR DOSIMETRIC QUANTITIES USED INRADIOLOGICAL PROTECTION (Annex B of Main Recommendations)

Contents

Quantities for Radiological Protection

In radiological protection practice, one needs quantities

- a single quantity
- specifying the "amount" of exposure
- related to the probability of stochastic effects
- for all types of radiations
- both for acute and chronic exposures
- both for external and internal exposures

However, this demand is **not** achievable in a strict scientific sense.

Quantities for Radiological Protection

The present approach to establish dose quantities is pragmatic for radiological protection with a justified scientific basis.

- The approach is based upon the assumption of a linear, no threshold, dose-response relationship (LNT).
- Microdosimetric considerations or the three-dimensional track structure are not taken into account.

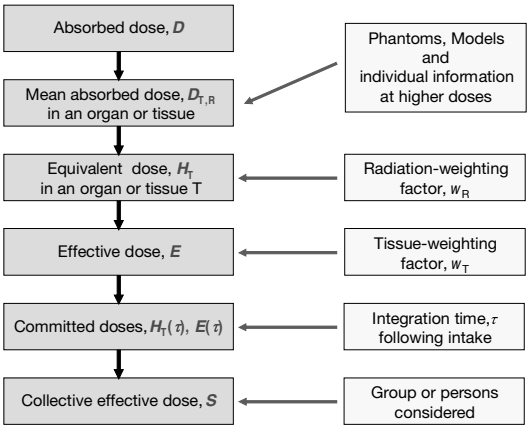
Quantities for Radiological Protection

The initial step : Energy transfer to biological material
⇒ Absorbed energy per unit of mass
(absorbed dose)

However, it is **not** reasonable to use absorbed dose as a protection quantity,
because radiation effects depend on

- the type of radiation;
- the time and space distribution of energy absorption;
- the sensitivity of the exposed tissues or organs.

Dose Quantities for Radiological Protection



Radiation Weighting Factor

Radiation type	Radiation weighting factor, w_R	
	New Recommendations	ICRP 1991
Photons	1	1
Electrons Muons	1	1*)
Protons**)	2	5
Charged pions	2	—
Alpha particles Fission fragments Heavy nuclei	20	20
Neutrons	A continuous curve depending on neutron energy	< 10 keV : 5
		10 keV to 100 keV : 10
		> 100 keV to 2 MeV : 20
		> 2 MeV to 20 MeV : 10
		> 20 MeV : 5

*) Excluding Auger electrons emitted from nuclei bound to DNA
**) Other than recoil protons, energy > 2 MeV

Radiation Weighting Factor for Photons

In *in vitro* investigations
Effects: low energy X-rays > ^{60}Co-gamma rays

However, w_R = 1 for all photons because of

- a much lower ratio observed in animal experiment;
- epidemiological data not showing clear difference;
- degradation by Compton scattering in human body;
- strong attenuation of low-energy photons close to the body surface; and
- operational dose quantities providing a conservative estimation in mammography.

Radiation Weighting Factor for Low Energy Electrons

DNA precursors labeled with tritium
Auger emitters incorporated into DNA

Very short range →

Much higher dose in nuclei than mean dose to the tissue

However, $w_R = 1$ for **all** low LET radiations.

- The ICRP is not proposing a specific scheme for the treatment of doses and risks.
- This simplification is sufficient only for the intended application for limitation and controlling of doses.

Radiation Weighting Factor for Neutrons (1)

Neutron energy ↑

- The production of secondary photons ↓
- The energy of recoil protons ↑
- The release of heavier charged particles ↑

Therefore,

- Radiation field in the body varies between different tissues due to the production of secondary radiations of **different** radiation quality in the body.
- The biological effectiveness of neutrons is strongly **dependent on** the neutron energy.

Radiation Weighting Factor for Neutrons (2)

- A continuous function
  not because of availability of more precise data
  but because of **practical** considerations

- $E < 1$ MeV

$$RBE_{av} = RBE_{high\text{-}LET}(1-f_{low\text{-}LET}) + RBE_{low\text{-}LET} \cdot f_{low\text{-}LET}$$

$RBE_{high\text{-}LET} = 25$
$RBE_{low\text{-}LET} = 1$
$f_{low\text{-}LET}$: the absorbed dose contribution from secondary photons calculated with anthropomorphic phantoms

Radiation Weighting Factor for Neutrons (3)

◆ 1 MeV < E < 50 MeV

It is appropriate to **stay** with the values in Publ. 60

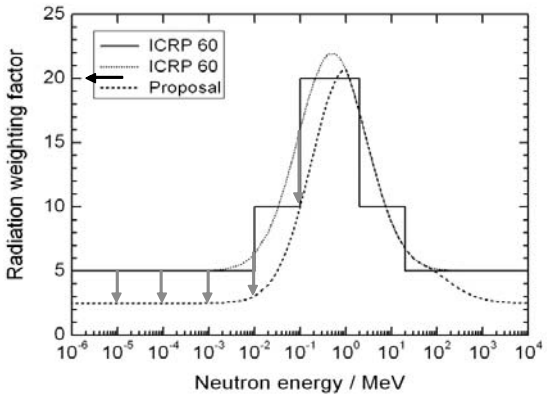
- no new experimental data
- general uncertainty of RBE in this region

◆ 50 MeV < E

The value is decreasing from 5.5 at 50 MeV to 2.5 at 10 GeV

Calculations of
- Pellicioni (1998; 2004)
- Yoshizawa *et al.* (1998)
- Sato *et al.* (2003)

Radiation Weighting Factor for Neutrons (4)



Radiation Weighting Factor for Protons

◆ External exposure of **high** energy protons is relevant to the assessment of effective dose.

4 MeV : 0.25 mm
10 MeV : 1.2 mm
} Mostly absorbed in the skin

◆ Animal experiments : 1～2
Q(L) function applied to 100 MeV : less than 1.2
Secondary charged particles at 1 GeV : 1.8

The w_R value adopted is **2** rather than 5 as in Publ. 60.

Radiation Weighting Factor for Alpha Particles

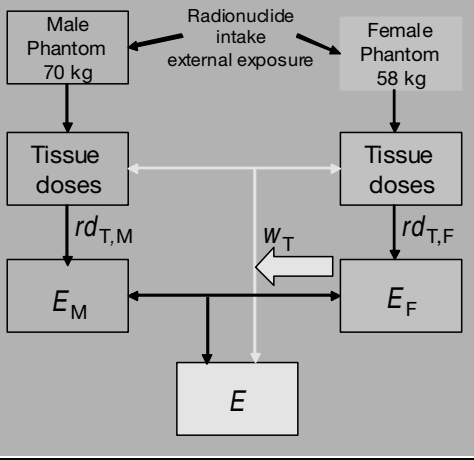
- Limited human data : **10 – 20** for lung and liver
  lower for bone cancer and leukaemia
- Animal and *in vitro* studies : **10** or greater
  Complexity in distributions of radionuclides
  Strong model dependence
  Valuable guidance but not the only basis
- Q(L) function applied to 6 MeV : **20**
- Recent data: not support the change of w_R value

The w_R value of **20** is retained.

Tissue Weighting Factor

Organ/Tissue	Tissue weighting factor, w_T		
	New	ICRP 1991	ICRP 1977
Oesophagus	0.04	0.05	–
Stomach	0.12	0.12	–
Colon	0.12	0.12	–
Liver	0.04	0.05	–
Lung	0.12	0.12	0.12
Bone surface	0.01	0.01	0.03
Skin	0.01	0.01	–
Breast	**0.12**	0.05	0.15
Bladder	0.04	0.05	–
Thyroid	0.04	0.05	0.03
Bone marrow	0.12	0.12	0.12
Brain	**0.01**	–	–
Salivary glands	**0.01**	–	–
Remainder	**0.12**	0.05	0.30
Gonads	**0.08**	0.20	0.25

Gender Averaging – Effective Dose



RVM and RVF

Zankl氏より提供のスライドより

Gender-averaged Effective Dose

$$E = \sum w_T \left[\frac{H_T^M + H_T^F}{2} \right]$$

$$H_{rem}^M = \frac{1}{13} \sum_T^{13} H_T^M \quad , \quad H_{rem}^F = \frac{1}{13} \sum_T^{13} H_T^F$$

E : Gender-averaged effective dose

W_T : Gender-averaged tissue weighting factors

H_T^M : Equivalent dose of tissue T for males

H_T^F : Equivalent dose of tissue T for females

Treatment of Remainder Tissues

	New Recommendations	ICRP 1991
Organs/tissue	Adrenals, Extrathoracic tissue, Gall bladder, Heart wall, Kidneys, Lymph nodes, Muscle, Oral mucosa, Pancreas, Small intestine, Spleen, Thymus Prostate (male) Uterus/cervix (female)	Adrenals, Brain, Upper large intestine, Small intestine, Kidneys, Muscle, Pancreas, Spleen, Thymus, Uterus
W_T	0.12	0.05
Averaging of the equivalent dose	Simple arithmetic dose averaging	Mass-weighted dose averaging
"Splitting rule"	No splitting rule	●0.025 to the tisue receiving a dose in excess of the highest dose ●0.025 to the other 'remainder' tissues

Operational Quantities

The protection quantities : **not** measurable in practice

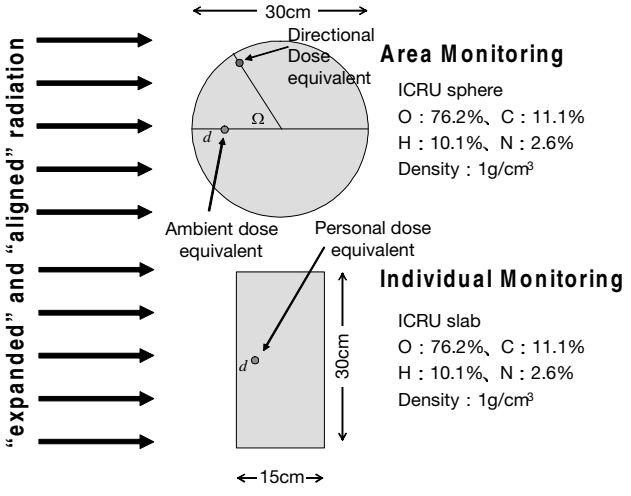
Operational quantities

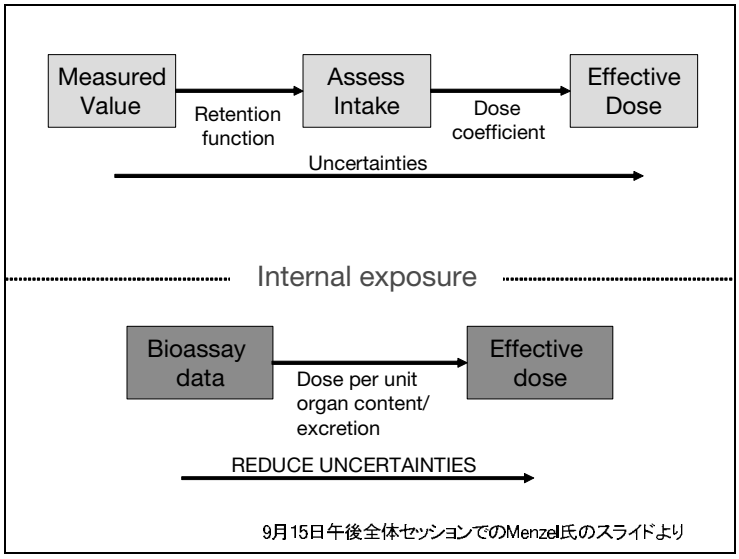
- Upper limit for the value of the protection quantities
- For practical regulations or guidance
- Different types of quantities for internal and external exposures

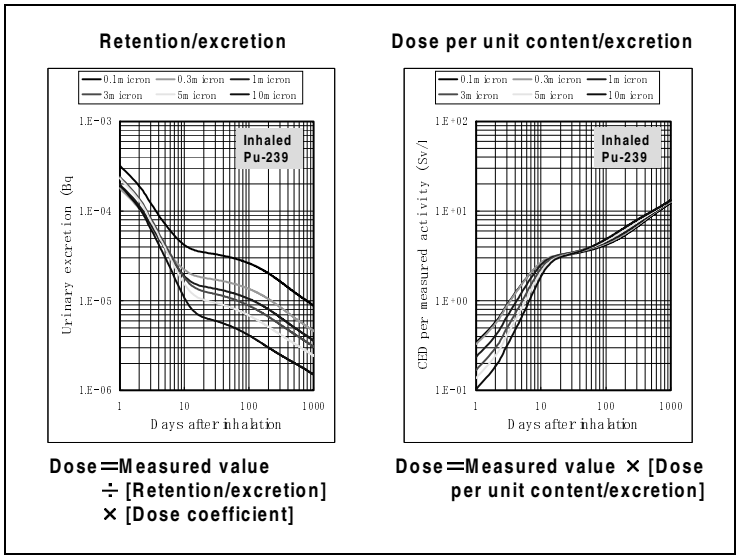
External Exposure

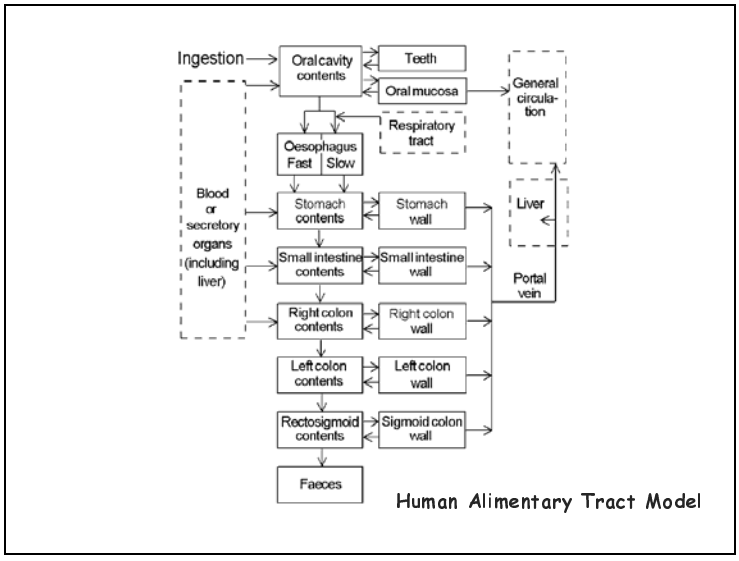
Operational quantities are defined by ICRU
(ICRU REPORT 39, 43, 51,66)

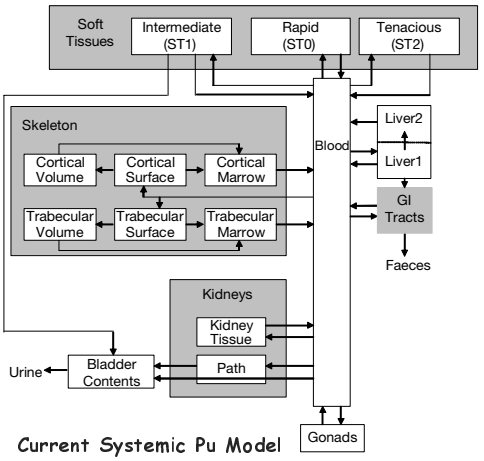
Task	Operational quantities for	
	Area monitoring	Individual monitoring
Control of effective dose	Ambient dose equivalent $H^*(10)$	Personal dose equivalent $H_p(10)$
Control of doses to the skin, the extremities and the lens of the eye	Directional dose equivalent $H'(0.07, \Omega)$	Personal dose equivalent $H_p(0.07)$




Measured Value
Retention function
Assess Intake
Dose coefficient
Effective Dose
Uncertainties
Internal exposure
Bioassay data
Dose per unit organ content/ excretion
Effective dose
REDUCE UNCERTAINTIES
9月15日午後全体セッションでのMenzel氏のスライドより


Retention/excretion
Dose per unit content/excretion
Inhaled Pu-239
Urinary excretion (Bq
CED per measured activity (Sv/
Days after inhalation
Dose＝Measured value ÷ [Retention/excretion] × [Dose coefficient]
Dose＝Measured value × [Dose per unit content/excretion]


Ingestion
Oral cavity contents
Teeth
Oral mucosa
General circulation
Respiratory tract
Oesophagus Fast Slow
Blood or secretory organs (including liver)
Stomach contents
Stomach wall
Liver
Small intestine contents
Small intestine wall
Portal vein
Right colon contents
Right colon wall
Left colon contents
Left colon wall
Rectosigmoid contents
Sigmoid colon wall
Faeces
Human Alimentary Tract Model



Uncertainties and Judgements

Effective dose : not measurable

⇒ Models and parameter values are necessary

- Best estimate
- Periodical re-evaluation
- Large uncertainties

varies for various parameters and the circumstances

ICRP takes the position that:

- It is impossible to give **general values** of uncertainties.
- The models have been developed primarily for use in **prospective** radiological protection purposes
- The models and the data should be taken as **references fixed by convention** and **not** subject to uncertainty.

System of Quantities for Radiological Protection

Absorbed dose, D

Dose quantities (protection quantities) defined in the body

Equivalent dose, H_T, in an organ or tissue T

Effective dose, E

Committed doses, $H_T(\tau)$, $E(\tau)$
Collective effective dose, S

Operational quantities defined for measurements and assessment of doses in the body

For external exposure

Dose quantities for area monitoring Dose quantities for individual monit. H_T, in an organ or tissue T

For internal exposure

Activity quantities in combination with models and computations

VIEWS ON THE NEW ICRP RECOMMENDATIONS FOCUSING ON THE OPTIMISATION OF PROTECTION AND INDIVIDUAL DOSE LIMITS

Toshiso KOSAKO
The University of Tokyo

Representative Individual

Critical group to representative individuals

1. Deterministic, probabilistic approach.
2. Retrospective & prospective.
3. Normal, existing, emergency.
4. Age dependence (three categorisation).
5. Environment.
6. Habits.
7. Distribution and uncertainty.

Optimisation (1)

Selection of the best option

characteristics of population, exposure social (equity, social benefit, etc.), environmental, non-radiation hazards, technical & economical, political, regulatory conditions

Optimisation (2)

Stakeholder involvement
in the procedure of decision making

1. Lessons learned and examples.
2. Detail structure of stakeholder involvement.
3. Generic and specific.
4. Culture difference.

Optimisation (3)

Exposure distribution and collective dose

1. Exposure distribution in time and space.
2. How to apply a multi-attribute expression to a real world?
3. Applicability of a new idea like a group weighting factor.

Optimisation (4)

Example of Cost-benefit Analysis

1. Question of an applicability or validity of cost-benefit analysis.
2. Monetary value.
3. Relationship to the former publication.

Dose Constraint >> Definition, Examples

1. Source upper bound
   > allocation of dose limitation.
2. Source related value.
3. Individual dose > target zone.
4. Relationship between dose limitation.

Practice and Intervention

Intervention

1. Emergency situation.
2. Existing exposure situation.

Use of the Intervention concept

1. Other field, ex. economics, etc.

VIEWS ON THE NEW ICRP RECOMMENDATIONS FOCUSING ON DOSE CONSTRAINTS AND DOSE LIMITS

Michiaki KAI
Oita University of Nursing and Health

Background for the Change

- Radiation protection in emergency, after accidents
- Radiation protection in NORM

↓

Practice and intervention in ICRP Publ.60

(9)‥‥All these categotisations created a complexity…

New Recommendations

Three exposure situations:

- ***Planned*** **exposure situation**
- ***Existing*** **exposure situation**
- ***Emergency*** **exposure situation**

ICRP Recommendations cover exposure to both natural and man-made regardless of its size and origin.
i.e. Controllable dose

Dose Limits

- In planned exposure situations, ICRP continues to use the same concepts and values as Publ. 60.
- The dose limits are borderlines between unacceptable and tolerable.

The optimised level under the constraints is acceptable.

Dose Constraints

- The most fundamental level of protection.
- Used for optimisation
- Source-related restriction.
- Applied only for prospective purpose.

Applied in all three types of exposure situations.

Focus on Planned Exposure

■ Dose constraints	■ Dose limits
-Single-related	-Individual-related
- Prospective	- Retrospective
- National level	- International
- Protective	- Confirmative

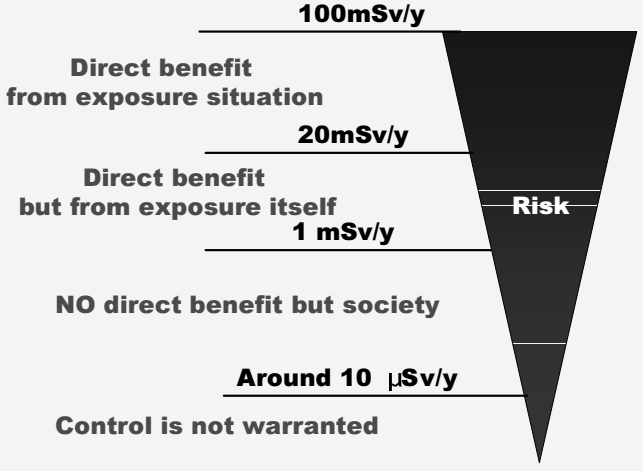
Key Points of the Dose Band

- Rationales of numerical values.
- Promoting understanding of dose constraints in the community.
- Promotion of educating what is radiation risk.

ICRP MUST carry out risk communication !

Rationales for Numerical Values

- 100 mSv
  - Significant risk of cancer
  - lowest for tissue injuries.
- 20 mSv/y
  - Lower bound of unacceptable risk.
- 1 mSv/y
  - Variation of natural background dose in the world.



Nominal Risk Coefficients

- Comparison with ICRP 60
  - No practical significant.
- Useless and misleading
  - Nominal population, gender-average, no age effects
  - NOT applied to the case in radiation protection.
- Useful to get risk coefficients depend on race, sex and age-at-exposure.

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