Perspectives on the advancement of radiation protection through ICRP 2005

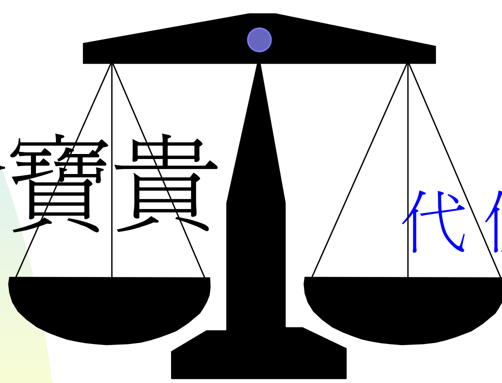
Place : Polytechnic University

Date : 18 Mar 2005

John Lam, Physicist,PYNEH

Quality of Life

生命寶貴

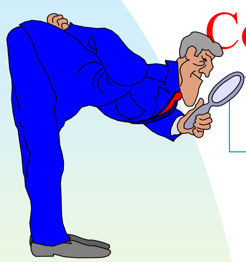


代價

Hippocratic Oath an oath of professional behavior sworn by physicians as they embark upon their medical careers; it is attributed to Hippocrates: "I swear by Apollo the physician, by Aesculapius, Hygeia, and Panacea, and I take to witness all the gods, all the goddesses, to keep according to my ability and my judgment the following Oath: To consider dear to me as my parents him who taught me this art; to live in common with him and if necessary to share my goods with him; to look upon his children as my own brothers, to teach them this art if they so desire without fee or written promise; to impart to my sons and the sons of the master who taught me and the disciples who have enrolled themselves and have agreed to the rules of the profession, but to these alone, the precepts and the instruction. I will prescribe regimen for the good of my patients according to my ability and my judgment and never do harm to anyone. To please no one will I prescribe a deadly drug, nor give advice which may cause his death. Nor will I give a woman a pessary to procure abortion. But I will preserve the purity of my life and my art. I will not cut for stone, even for patients in whom the disease is manifest; I will leave this operation to be performed by practitioners (specialists in this art). In every house where I come I will enter only for the good of my patients, keeping myself far from all intentional ill-doing and all seduction, and especially from the pleasures of love with women or with men, be they free or slaves. All that may come to my knowledge in the exercise of my profession or outside of my profession or in daily commerce with men, which ought not to be spread abroad, I will keep secret and will never reveal. If I keep this oath faithfully, may I enjoy my life and practice my art, respected by all men and in all times; but if I swerve from it or violate it, may the reverse be my lot."

Actuary : 保險精算師,保險公司精算人員

Transformation of Social & Economic values feasible ?



Controversial : Utilitarian Ethics

1 male adult Life = ? $

1 female adult Life = ? $

1 child Life = ? $

Radiation detriment to health = ? $

10 mSv Risk = ?

Decision Making and Justification

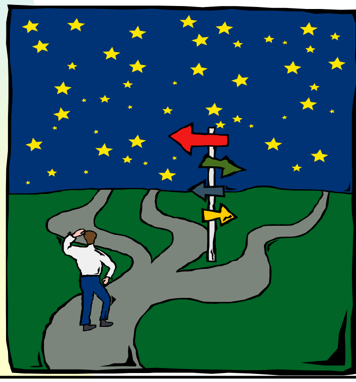
利益 風險 剩餘 正數

$$\Sigma_j [\Sigma w_{j*} Benefits(j^{th}) - \Sigma Risks(j^{th})] > 0$$

Standard value ?

Standard value ?

Sum over all j^{th} factor from {society & environment}



W_j: "Equal" factor

Who decides?

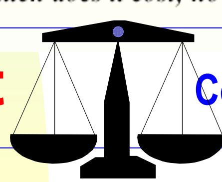
The ICRP Publication 26 System

1977

- **Prevent deterministic, minimise stochastic harm**
- **Justification *by Cost-Effectiveness Analysis***
  More good than harm to society
- **OPTIMISATION *by Cost-Benefit Analysis***
  ALARA; maximise net collective benefit
- **Dose limits**

'How much does it cost; how many lives are saved?'

Life Cost



Cost in Protection measures

Concept of sources & exposures

(16) The term *'source'* is used by the Commission to indicate the cause of an exposure, not necessarily a physical source of radiation. For example, when radioactive materials are released to the environment as waste, both the installation as a whole and the discharged material can be regarded as sources, depending on the context. The term 'exposure' is used by the Commission to mean the process of being exposed to radiation or radioactive material. Exposure can then lead to a dose to some part of the exposed individual.

- (1) patients
- (2) public
- (3) workers : classified radiation workers
- (4*) patient comforters, caregivers
- (5*) workers : non-classified workers (clerks, Minor staff, technicians etc)

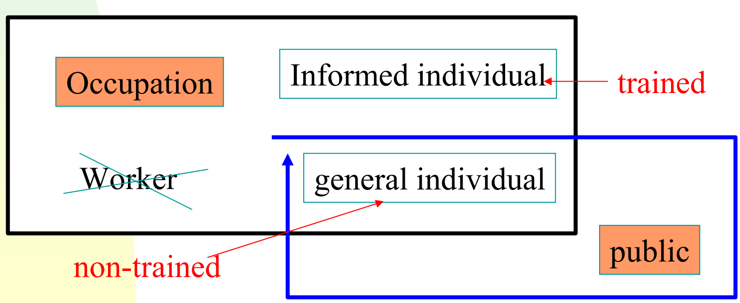
Exposed individuals : "Rights" to know

6.3.1. The identification of the exposed individuals

(168) It is necessary to deal separately with at least three types of exposed individual. These types can be called informed individuals, patients, and general individuals. They can, essentially, correspond to individuals whose exposures fall into the three classes of exposure defined in Chapter 5.3, i.e. occupational, medical and public.

Occupational exposure

(169) Workers in 'controlled areas' of workplaces are not strictly volunteers, but they are well informed and are specially trained, thereby forming a separate group of informed individuals. Other workers, such as administrative and support staff, might be included in the group of general individuals, and treated as members of the public.



Controllable & Uncontrollable sources

Uncontrollable exposure

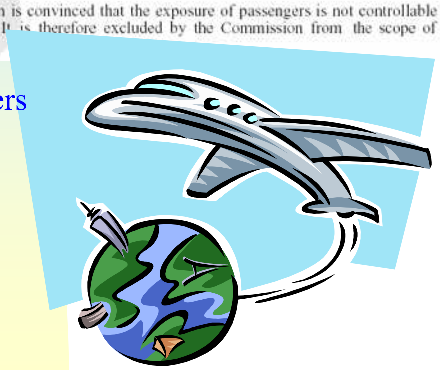
8.3. Cosmic rays

(211) Cosmic rays at ground level and the resultant exposures are not controllable. They are thus excluded from the scope of the Commission's recommendations. Limiting the time spent by passengers and crew at high altitudes would be the only practical way in which to control exposure to cosmic rays in aircraft. The average annual effective doses to most aircrew are in a narrow range, previously estimated at around 3 mSv, although this will reduce significantly with the Commission's revised radiation weighting factors for neutrons and protons (Chapter 3). The exposure of some specialist aircrew, such as security staff, and a small number of professional couriers may be twice the average value for aircrew. These exposures of aircrew and couriers in the operation of commercial jet aircraft should be dealt with as occupational exposure in the general system of protection and thus of informed individuals.

(212) The Commission is convinced that the exposure of passengers is not controllable by any reasonable action. It is therefore excluded by the Commission from the scope of its recommendations.

Air crew

Passengers



Background Dose vs "Existing Annual Dose"

eg. From natural sources , cosmic rays

[19] The term *existing annual dose* is used to mean all of the existing and persisting whole annual doses incurred by individuals in a given location. The adjectives *total*, *environmental*, *ambient*, and *background* are also sometimes used to describe this concept, but will not be used for that purpose in this report. The adjective *total* could be misunderstood to describe the sum of transitory and prolonged doses; *environmental* and *ambient* could be confused to describe a dose in the environment rather than in people (moreover, *ambient* has been used by the International Commission on Radiological Units and Measurements to denote an operational quantity); and, *background* has been commonly understood as describing exposures caused by natural radiation sources only, although a fraction of such exposure may be artificial (such as the exposure to fallout from historical nuclear weapons testing). Therefore, in order to avoid confusion, the qualifier *existing* will be used in this report. It should be noted that there is always an *existing annual dose* before the introduction of a practice or the undertaking of an intervention, and a *residual* existing annual dose after the cessation of the practice or the completion of the intervention.

Protection of the public in situations of prolonged radiation exposure

ICRP Publication 82

Approved by the Commission in September 1999

International Standards

National Standards

Local Standards

How?

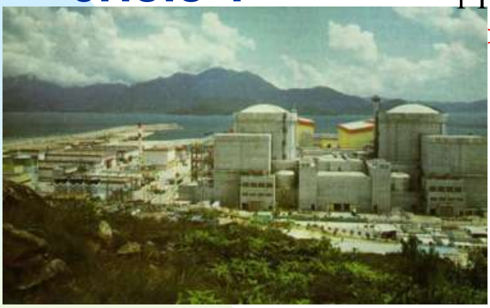
Which?

HK
CHINA

UK
NRPB
ARSAC 98
IRMED IRR
RSA 93

USA
NRC
NUREG-1556
10CFR Part 20,35

Reactor: A key to energy crisis ?



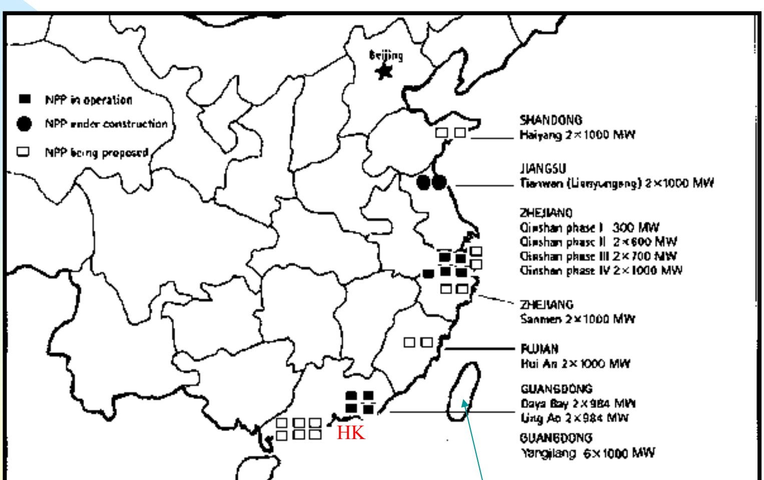
Started operations
1 Feb , 6 May 1994
> 10 years old

Who? How? Why?

Society:國計民生

- Nuclear industries eg. Nuclear Reactors
- already justified ………….
- Future installation: to be justified …………

Nuclear Reactors distribution in China



the 4th nuclear plant in this island is ……..

ICRP 2005

Justification : Controversial

(18) Judgements on whether it would be justifiable to introduce or continue a particular practice involving exposure to ionising radiation are important. Alternatives to existing practices may develop over time, which would require that those practices that do exist should be periodically re-examined to ensure that they are still justified. The responsibility for judging the justification of a practice usually falls on governments or government agencies to ensure an overall benefit in the broadest sense to society and thus not to each individual. Governments make these decisions for strategic, economic, defence and other reasons and radiological protection considerations are recognised as being only one input that could influence the justification decisions. Therefore, while justification is a prerequisite of the complete system of radiological protection, the methods of ensuring justification are largely outside the scope of these Recommendations.

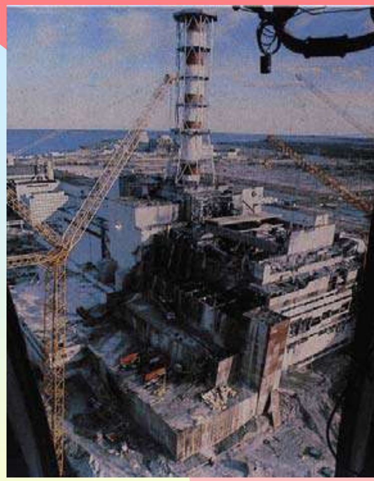
What are the other inputs?
And by whom?
What methods?

The Current and Coming Recommendation from ICRP

- **International Commission on Radiological Protection**
  ICRP: Who, why, what?
- **Sources, doses, dose response**
  Linear, no threshold – the best current approximation
- **ICRP 60**
  Justification – optimisation – limits
  Emphasis shifting from society to individual
- **The next, 2005, Recommendations**
  Justification (political) – limits & constraints – optimisation
  Include non-human species

Chernobyl Accident: 25,26 Apr 1986 at Reactor 4, Ukraine, USSR

前蘇聯



Justification:
Running ? Closure ?

Energy ? Health ?

In the early 1990s some US$400 million was spent on improvements to the remaining reactors at Chernobyl, considerably enhancing their safety. Energy shortages necessitated the continued operation of one of them (unit 3) until December 2000.
(Unit 2 was shut down after a turbine hall fire in 1991, and unit 1 at the end of 1997.)

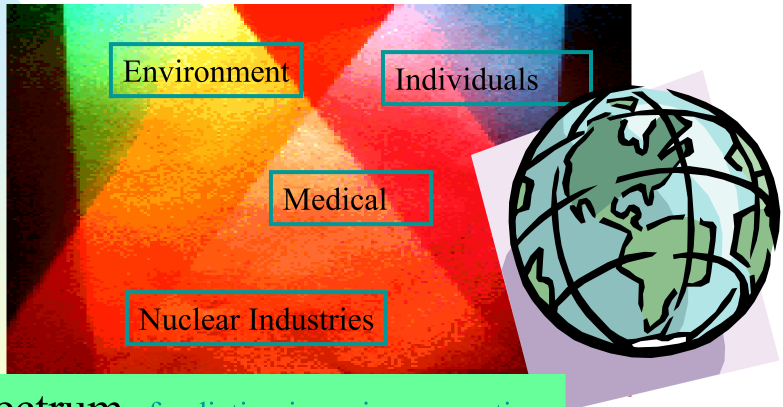
Radioecology study 放射生態學 (研究放射性物質與生物的關係)

In 1998 an agreement with the US provided for the establishment of an international radioecology laboratory inside the exclusion zone (Chernobyl).

"Anthropocentric and Ecocentric Principles of Environmental Protection", containing a new relevant conceptual rule of radiation protection of humans and the environment.

- "Radiobiological Effects in Environment Components. Radioecological Significance of Exclusion Zone Facilities";
- "Distribution and Migration of Radionuclides in Environment Components";
- "Rehabilitation of Contaminated Territories. Methods and Instrumentation for Radioecological Research".

Concerned parties in the operations

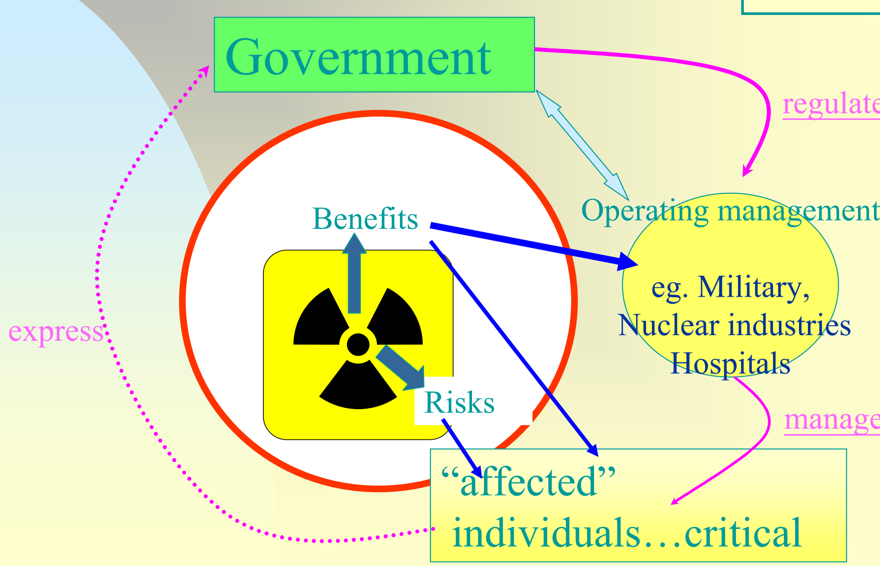


Spectrum of radiation in various operations

Laws

Standard “Values”?

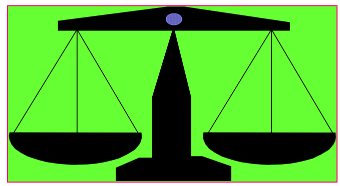
Ethics



2005 Recommendations

- Aim : Control of radiation hazards

  appropriate standard, without unduly limiting the beneficial actions giving rise to exposure
- Basis : Not scientific concepts alone
- including *value* judgements about kinds of risks and the balance of
- benefits and risks



Numerical Problem ?

Not simple !!

Safety Culture

BASIC PRINCIPLES

The principles of radiation protection and safety on which the Standards are based are those developed by the ICRP and by INSAG. The detailed formulation of these principles can be found in the publications of these bodies and they cannot easily be paraphrased without losing their essence. However, a brief — although simplified — summary of the principles is as follows: a practice that entails or that could entail exposure to radiation should only be adopted if it yields sufficient benefit to the exposed individuals or to society to outweigh the radiation detriment it causes or could cause (i.e. the practice must be justified)[1]*; individual doses due to the combination of exposures from all relevant practices should not exceed specified dose limits; radiation sources and installations should be provided with the best available protection and safety measures under the prevailing circumstances, so that the magnitudes and likelihood of exposures and the numbers of individuals exposed be as low as reasonably achievable, economic and social factors being taken into account, and the doses they deliver and the risk they entail be constrained (i.e. protection and safety should be optimized); radiation exposure due to sources of radiation that are not part of a practice should be reduced by intervention when this is justified, and the intervention measures should be optimized; the legal person authorized to engage in a practice involving a source of radiation should bear the primary responsibility for protection and safety; a safety culture should be inculcated that governs the attitudes and behaviour in relation to protection and safety of all individuals and organizations dealing with sources of radiation; in-depth defensive measures should be incorporated into the design and operating procedures for radiation sources to compensate for potential failures in protection or safety measures;and protection and safety should be ensured by sound management and good engineering, quality assurance, training and qualification of personnel, comprehensive safety assessments and attention to lessons learned from experience and research.*

?

(153) Regulatory authorities should encourage the operational managements to develop a 'safety culture' within their organisations. Safety culture has been defined internationally by the inter-agency Basic Safety Standards (FAO et al.. 1996) as

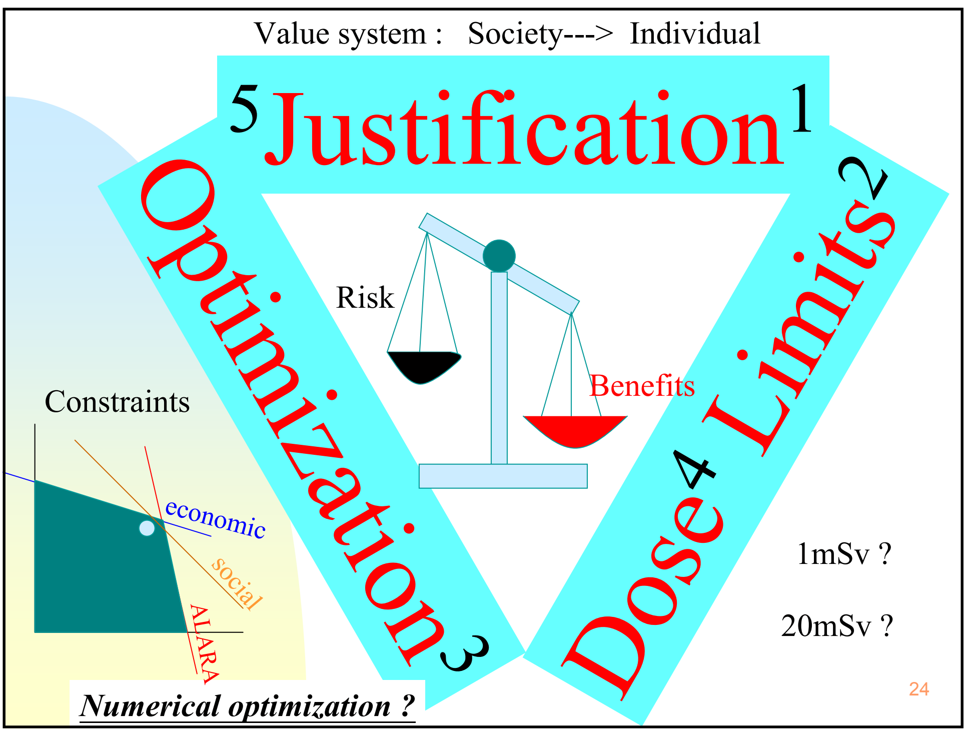
Justification in principle : How

- Benefits to patients : Clinical efficacy or effectiveness
- Harms (deterministic / Stochastic)
- Cost in RP (economic)
- Cost in RP (social : lives : individual or society)
- Radiation biology : health risk analysis
- ALARA

Cost effective analysis

Optimization of protection ALARA

Benefits > Risk : Value judgement



Level of Protection increases

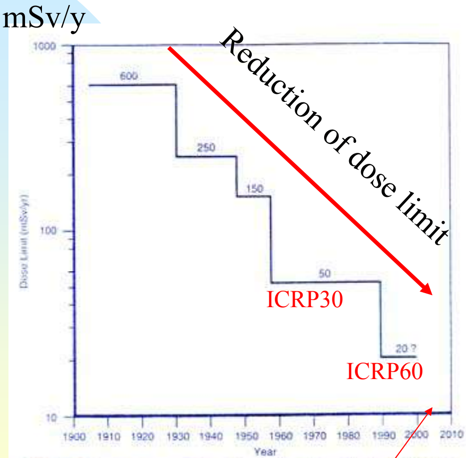


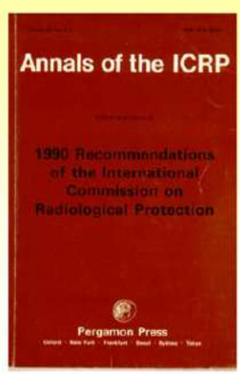
FIGURE 1-2. Trends in the annual whole body dose limit. [From Edwards, M. (1991). Development of radiation protection standards. *Radiographics, 11,* 699–705. Reproduced by permission.]

ICRP 2005?

Our current reference still in use

The ICRP Publication 60 System

- **Prevent deterministic, minimise stochastic harm**
- **Justification**
- **Optimisation:** ***CBA & other means***
  'Constrained by restrictions on the doses to individuals (Dose Constraints) … so as to limit the inequity likely to result from the inherent economic and social judgements'
- **Dose and risk limits**



Ethics倫理觀

義務論;道義學

Ethical Basis for the ICRP System

Utilitarian ethics *Judge actions by the consequences*	Deontological ethics *Some duties are imperative*
Justification *Do more good than harm*	
Optimisation *Maximise good > harm*	
	Limitation *No individual unduly harmed*

緊急事態;不可迴避的義務

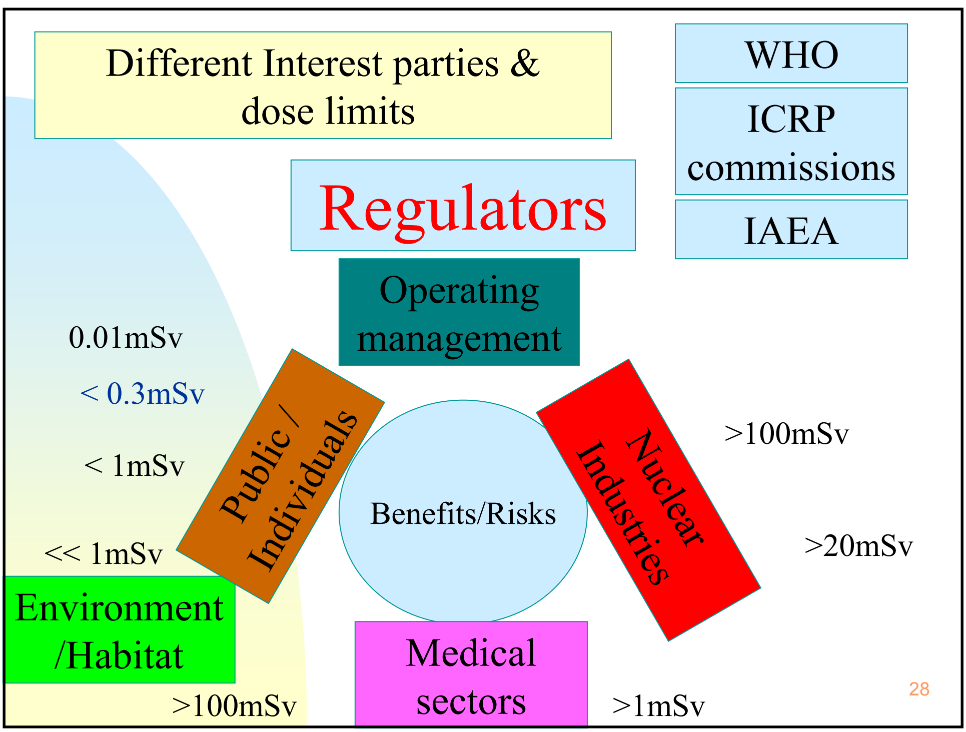
功利主義

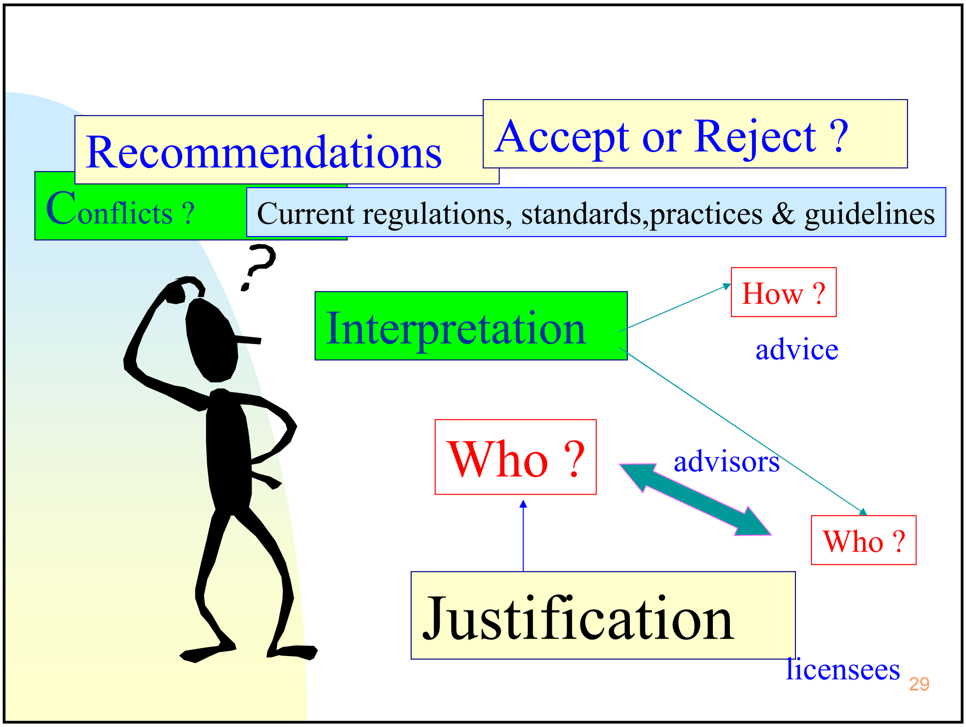
不適當地;不正當地;有違道德標準地

Capitalism資本主義

Stakeholders

[5] The term *stakeholder* is used in the report to mean those parties who have interests in and concern on the prolonged exposure situation.





(2) Regulations make under this section may provide that contravention of specified provisions of such regulations shall be an offence and may provide penalties therefor;

Provided that no penalty so provided shall exceed a fine of $50,000 and imprisonment for 2 years. *(46 of 1990, s.4)*

Recommendations for protection from radiation hazards.

14. (1) The Board may from time to time issue free of charge in such manner as it thinks fit recommendations for protection from radiation hazards for the guidance of licensees and persons engaged in radiation work.

(2) Failure on the part of any person to observe the provisions of any such recommendations shall not of itself render that person liable to criminal proceedings of any kind, but any such failure may in any proceedings under this Ordinance be relied upon by any party to the proceedings as tending to establish or to negative any liability which is in question in those proceedings. *(Added, 6 of 1961, s.4)*

Power to exempt from provisions of Ordinance or regulations.

15. (1) The Board may grant subject to such conditions or restrictions as it may consider expedient, exemption from any of the provisions of this Ordinance to any specified person, group or class of persons "or in respect of a specified radioactive substance or radiating apparatus or class thereof" where, having regard to the public interest to be served and the degree of risk, if any, to human health involved by the granting of such exemption, the Board is of opinion that it is expedient and safe so to do. *(46 of 1990, s.8)*

Examples of Radiation protection in Hospital services

check sources Co57

Tc99m, I131, F18,C11, O15, N13

Transmission sources Gd153,Ge68, Cs137

Nuclear Medicine

{*Patients}

Radiation sources

{*Wastes}

Radioactive substances

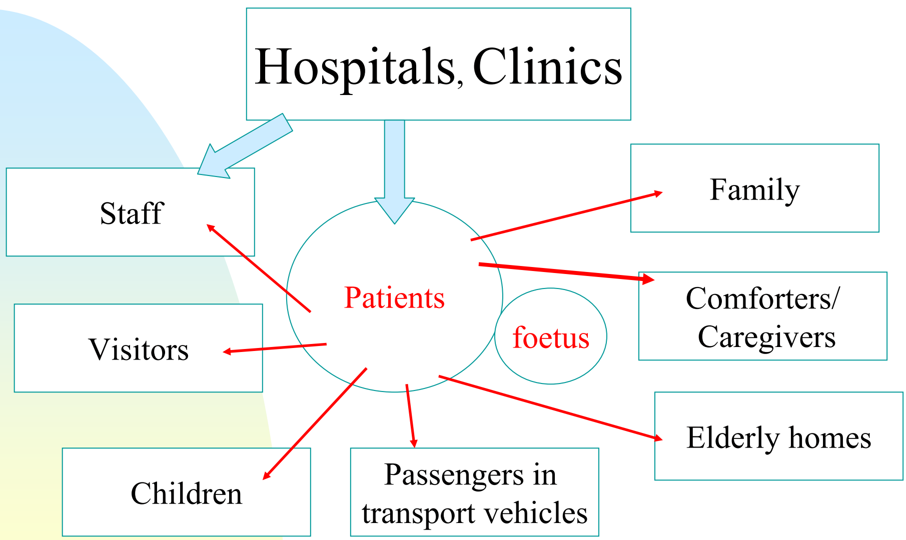
Irradiating apparatus

Sealed radioactive sources

CT-PET

Cyclotron

Unsealed radioactive sources



External dose rates from radioactive sources used in NM

Γ

Isotopes	Half-life	Specific gamma ray constant : $R*cm^2*mCi*hr^{-1}$
Co-57	270.9 d	1.007
Tc-99m	6.02 h	0.772
Tl-201	3.04 d	6.625
Ga-67	3.26 d	0.767
In-111	2.83 d	3.288
Cr-51	27.7 d	0.177
I-131	8.04	2.2
C-11	20.4 m	5.906
N-13	9.97 m	5.909
O-15	122 s	5.914
F-18	110 m	5.725

~ 2 uSv/hr at 1m from a 1mCi point source

Guidance Levels of Activity for Procedures in Nuclear Medicine for a Typical Adult Patient (Cont.)

Test	Radionuclide	Chemical form[a]	Maximum usual activity per test[b] (MBq)
Stomach, gastrointestinal tract			
Stomach/salivary gland imaging	$^{99}Tc^m$	TcO_4^-	40
Meckel's diverticulum imaging	$^{99}Tc^m$	TcO_4^-	400
Gastrointestinal bleeding	$^{99}Tc^m$	Labelled colloid	400
	$^{99}Tc^m$	Labelled normal red blood cell	400
Oesophageal transit and reflux	$^{99}Tc^m$	Labelled colloid	40
	$^{99}Tc^m$	Non-absorbable compounds	40
Gastric emptying	$^{99}Tc^m$	Non-absorbable compounds	12
	^{111}In	Non-absorbable compounds	12
	$^{113}In^m$	Non-absorbable compounds	12
Kidney, urinary system and adrenals			
Renal imaging	$^{99}Tc^m$	Dimercaptosuccinic acid	160
Renal imaging/renography	$^{99}Tc^m$	DTPA, gluconate and glucoheptonate	350
	$^{99}Tc^m$	Macroaggregated globulin 3	100
	^{123}I	O-iodohippurate	20
Adrenal imaging	^{75}Se	Selenorcholesterol	8
Miscellaneous			
Tumour or abscess imaging	^{67}Ga	Citrate	300
	^{201}Tl	Chloride	100
Tumour imaging	$^{99}Tc^m$	Dimercaptosuccinic acid	400
Neuroectodermal tumour imaging	^{123}I	Meta-iodo-benzyl guanidine	400
	^{131}I	Meta-iodo-benzyl guanidine	20
Lymph node imaging	$^{99}Tc^m$	Labelled colloid	80
Abscess imaging	$^{99}Tc^m$	Exametazime labelled white cells	400
	^{111}In	Labelled white cells	20
Thrombus imaging	^{111}In	Labelled platelets	20

Table VII Guidance Levels for Maximum activity for Patients in Therapy on Discharge from Hospital

~ 11mCi

Radionuclide	Activity (MBq)
Iodine-131	400

Close contact dose ~ 2mSv per hour

Pregnancy and Medical Radiation (ICRP 84)

Protection on pregnant patients ICRP 84

Breast-feeding

Notes for Guidance on the Clinical Administration of Radiopharmaceuticals and Use of Sealed Radioactive Sources

Administration of Radioactive Substances Advisory Committee

December 1998

* This relates to all females who are breast feeding. In most cases this will be the mother but the guidance also applies to those circumstances where 'wet-nursing' is undertaken, or where milk is being donated to a milk bank.

Radiopharmaceutical	Activity administered to mother (MBq)	Feeding interruption time[a] (hours)
^{32}P-phosphate	Any	STOP
^{51}Cr-EDTA	3	0
^{67}Ga-Ga^{3+}	Any	STOP
^{81m}Kr-gas	6000	0
^{99m}Tc-pertechnetate	80	24
-pertechnetate	800	48
-macro-aggregates	80	12
-macro-aggregates + ^{99m}Tc-technegas	100+20	14
-mercaptoacetyl	100	18
-normal erythrocytes[b]	800	18
-DTPA	800	0
-DMSA	80	0
-microspheres	450	0
-exametazime	500	0
-MAG3	200	0
-sestamibi	1000	0
-colloid	80	0
-phosphate compounds	800	0
^{111}In-leucocytes	10[c]	0
^{123}I-iodide	20	27
-o-iodohippurate	20	11
-m-iodobenzylguanidine (MIBG)	400	21
^{125}I-fibrinogen	Any	STOP
^{125}I-human albumin	Any	STOP
^{131}I-iodide	Any	STOP
^{201}Tl-Tl^{+}	80	0

a Feeding may be restarted immediately after the stated time has elapsed since administration of the radionuclide. The interruption time advised is based on the guideline that the dose to the infant should be less than 1 mSv. In many cases the time is ZERO, ie no interruption of feeding is strictly necessary.
The principle of ALARP, however, indicates that it is usually appropriate to discard one feed. For some radiopharmaceuticals the necessary 'interruption time' would be so long that the mother should be advised to STOP feeding altogether. Breast feeding can be undertaken following subsequent pregnancies. These figures do not apply during the period of early lactation when colostrum is being secreted. During that period feeding should be interrupted until measurements on milk samples prove that it is safe to recommence.
b For labelled normal erythrocytes the figures will be sensitive to changes in the labelling efficiency which can vary substantially.
c It is recommended that the activity of ^{111}In-leucocytes administered to a nursing mother should not exceed 10 MBq (see paragraph 7.21).
d ^{123}I should not be administered to breast feeding females unless it is pure (containing no ^{124}I or ^{125}I).

Prevention of Accidental Exposures to Patients Undergoing Radiation Therapy

ICRP 86

List of Recommendations for prevention (ICRP 86)

- Overall preventive measure: a Quality Assurance Programme, involving
  - Organisation
  - Education and training
  - Acceptance testing and commissioning
  - Follow-up of equipment faults
  - Communication
  - Patient identification and patient charts
  - Specific recommendations for teletherapy
  - Specific recommendations for brachytherapy

New levels of protection

> 20mSv

Occupational

public

< 1mSv

Maximum Constraints

Effective Dose in a year (mSv)

ICRP 2005

mSv	
100	• Emergencies: work; evacuation; relocation • High levels of existing controllable exposures • Information, training, monitoring • No individual / societal benefit above this constraint
20	• Emergencies: Sheltering; stable iodine • Normal: Occupational exposure • Existing controllable exposures, e.g. radon • Comforters and carers to patients • Information, training, monitoring or assessment • Direct or indirect benefit to the individual
1	• Normal situations • No information or training, no individual dose assessment • Societal, but no individual direct benefit
0.01	• Minimum value of any constraint — exclusion

ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Protection measures in 30mCi Tc99m SPECT QA setup

Before safety design

After safety design : Optimization of Protection

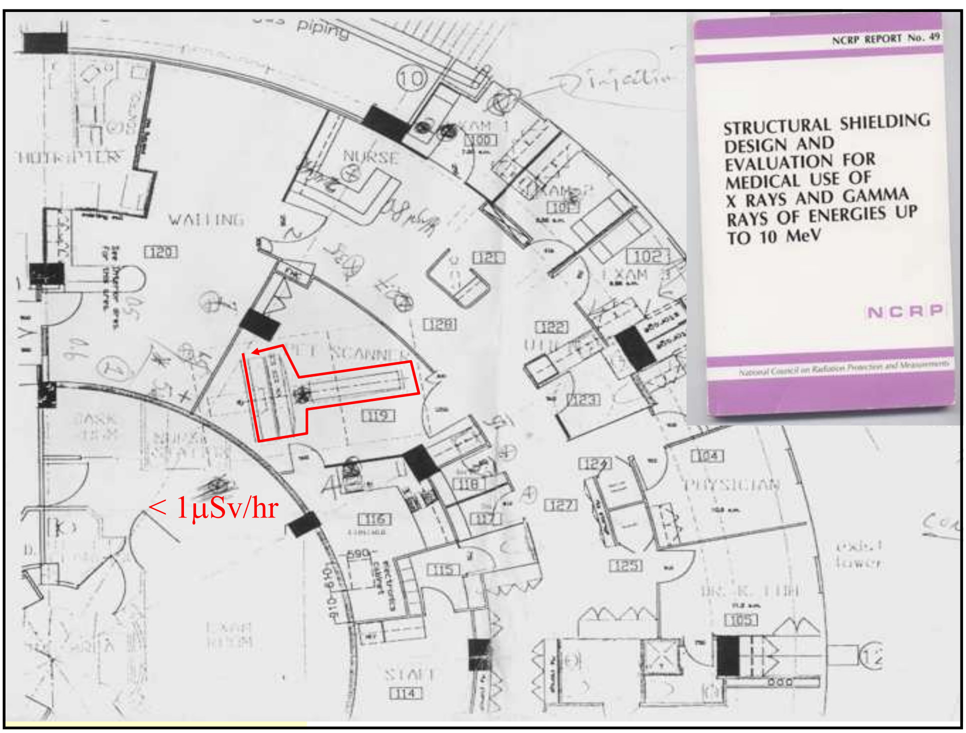
Advancements in the 21st century

- New regulations needed ?
- new structure of responsibilities ?
- new guidelines written : eg. NM, critical groups, pregnancy, breastfeeding ,CT/PET ?
- new protection levels adopted ?

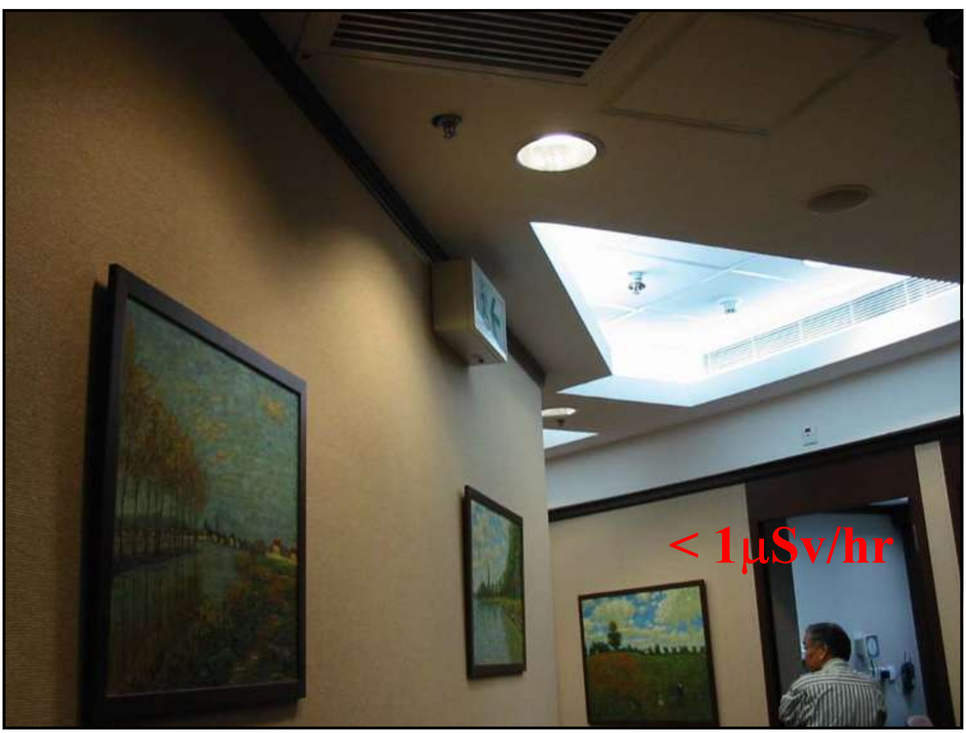
Justification (Medical)

- Valid clinical indication
- Benefits to patients : Clinical efficacy or effectiveness
- necessary result (diagnosis, therapy) cannot be achieved with other lower risks methods
- Medical practitioner takes overall clinical responsibility for an exam

Life saving cost > operation costs

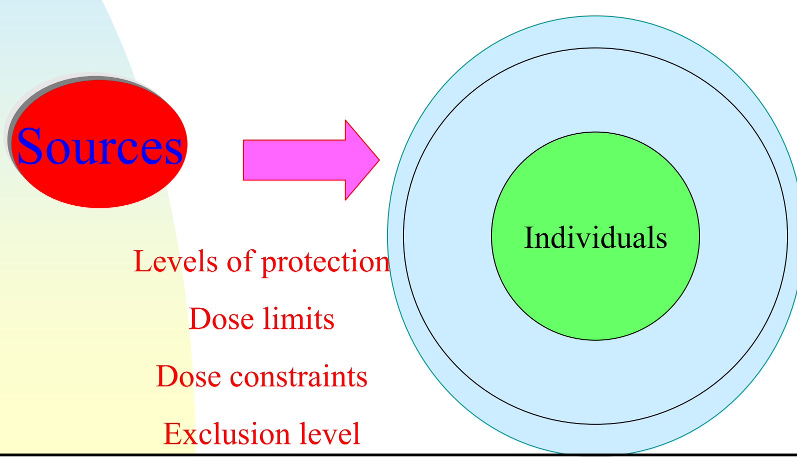


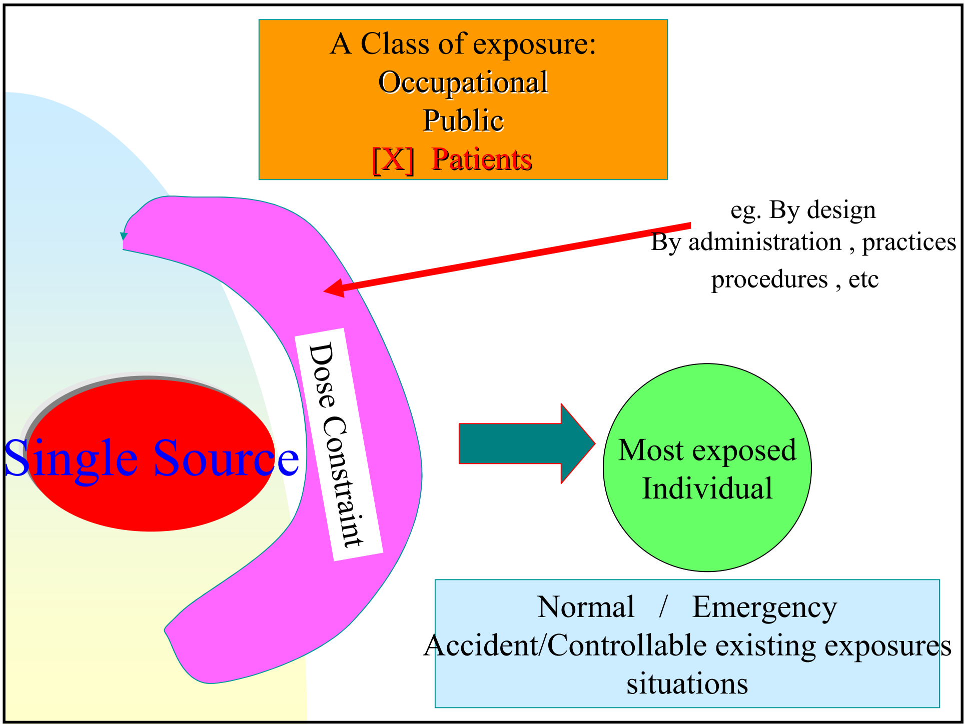
< 1μSv/hr
NURSE
PHYSICIAN
STAFF
NCRP REPORT No. 49
STRUCTURAL SHIELDING DESIGN AND EVALUATION FOR MEDICAL USE OF X RAYS AND GAMMA RAYS OF ENERGIES UP TO 10 MeV
NCRP
National Council on Radiation Protection and Measurements


< 1μSv/hr

Situations: Normal/Emergency

Classes of exposures:
Medical
Occupational
Public





A Class of exposure:
Occupational
Public
[X] Patients
eg. By design
By administration , practices
procedures , etc
Single Source
Dose Constraint
Most exposed Individual
Normal / Emergency
Accident/Controllable existing exposures
situations

The public is protected -
Nuclear power
Mining
Radiology
Wastes
Transport
Industry
From a single source in normal, emergency, and controllable exposure situations, by
The dose constraints
From all regulated sources, only in normal situations, by
The dose limits
The worker is protected -
From a single source in normal, emergency, and controllable exposure situations by
The dose constraints
From all regulated sources only in normal situations by
The dose limits
52

Dose Limit for the Public

- Sum of contribution from many sources
- Can only be regulated at source
- Does not include the dominant natural background
- Does not apply to interventions
- Does not apply in emergencies

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Dose Limits For Practices

PUBLIC	WORKERS	
1 mSv in a year	20 mSv per y averaged over 5 y -100 mSv in 5 years and less than 50 mSv in one year	ICRP 30
	20 mSv in any year	ICRP 60

Organ or tissue	Radiation weighted dose (mSv/yr)	
	Occupational	Public
Lens of the eye	150	15
The skin	500	50
Hands and feet	500	-

Exposures

Medical

Occupational

Public

Chapter: 303B Title: RADIATION (CONTROL OF IRRADIATING APPARATUS) REGULATIONS Gazette Number:
Regulation: 14 Heading: Dose limit Version Date: 30/06/1997

PART V

CONTROL OF EXPOSURE TO RADIATION

(1) Except in the case of a patient who is required to be exposed to radiation in furtherance of medical treatment or investigation prescribed by a medical practitioner or dental practitioner, no person shall cause or permit any other person to be exposed to a dose of radiation to any part of the body in excess of-
(a) in the case of a person employed in radiation work, the dose limit; or
(L.N. 225 of 1990; L.N. 154 of 1995)
(b) in the case of any other person, 1 millisievert, (L.N. 154 of 1995)
in any calendar year.
(2) Any person who contravenes any of the provisions of subregulation (1) shall be guilty of an offence and be liable on conviction to a fine of $15000.
(L.N. 97 of 1970; L.N. 225 of 1990)

Interpretation : Any flexibility? Average in 5 years?

New levels of protection

> 20mSv

Occupational

public

< 1mSv

Maximum Constraints

Effective Dose in a year (mSv)

ICRP 2005

mSv	
100	• Emergencies: work; evacuation; relocation • High levels of existing controllable exposures • Information, training, monitoring • No individual/societal benefit above this constraint
20	• Emergencies: Sheltering; stable iodine • Normal: Occupational exposure • Existing controllable exposures, e.g. radon • Comforters and carers to patients • Information, training, monitoring or assessment • Direct or indirect benefit to the individual
1	• Normal situations • No information or training, no individual dose assessment • Societal, but no individual direct benefit
0.01	• Minimum value of any constraint exclusion

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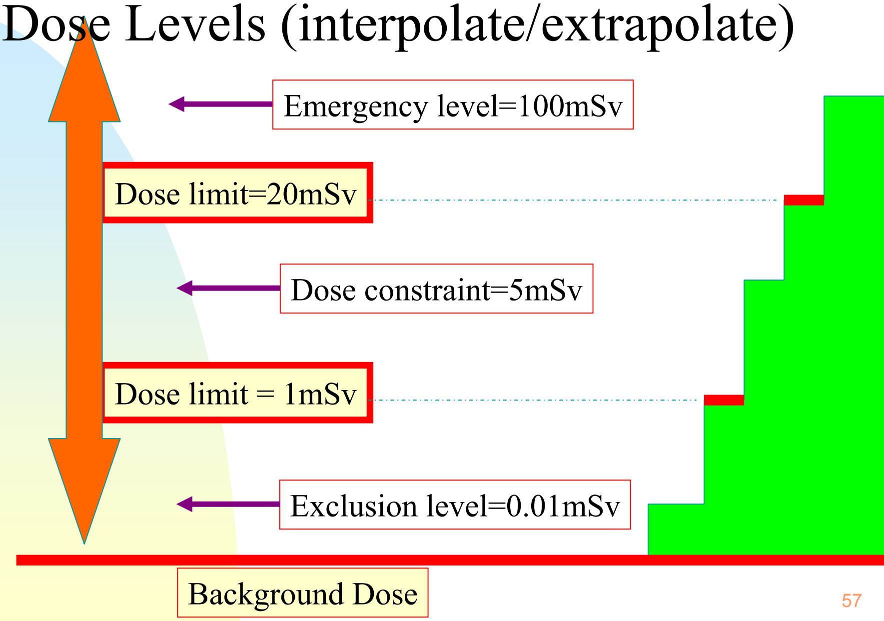
Full Range
Dose Levels (interpolate/extrapolate)



Public

5.3.2. Public exposure

(145) Public exposure is incurred as a result of a range of controllable sources. Dose limits for public exposure can be used only as a basis for national policy. Dose limits cannot in principle be applied to operational control, because neither the operator nor the regulator has the information about the totality of sources contributing to the dose to be limited in normal situations. The only feasible approach is to select a single source, or a small group of sources, and to estimate the exposure to the most exposed individual or the most highly exposed group of individuals (the critical group). For normal situations, it is unlikely that the total exposure from the defined controlled sources can be judged against the dose limit. This is because the selected sources are only a part of the whole group of likely sources. Therefore, an individual dose from single source during normal situations has to be judged against the constraint.

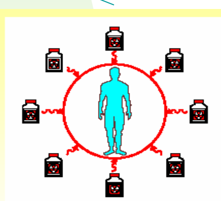
$\Sigma_i (<1mSv)_i$ for individual dose is still less than 1mSv/y ?

para164 background). It would be the maximum public constraint in normal situations while in case of multiple dominant sources a figure of 0.3 mSv/year would be appropriate (*Publication 77*).

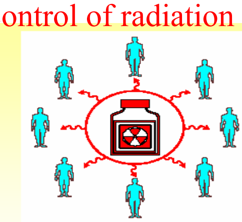
(ICRP 2005)

Individual related < **Source related**

Control of radiation source



INDIVIDUALS are protected from ALL regulated sources by the DOSE LIMITS



INDIVIDUALS are protected from a SINGLE source by the DOSE CONSTRAINT

Optimization of protection(1)

- 'In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should be kept ALARA, economic and social factors being taken into account' ICRP 60

Issue of TLD dosemeter to staff?

ICRP 2005

(190) The optimisation of protection is a forward-looking iterative process aimed at preventing exposures before they occur. It is continuous, taking into account both technical and socio-economic developments and requires both qualitative and quantitative judgements. This process must be systematic and carefully structured to ensure that all relevant aspects are taken into account. Optimisation is a frame of mind, always questioning whether the best has been done in the prevailing circumstances. It also requires the commitment from all levels of all concerned organisations as well as adequate procedures and resources. Both the operators and the appropriate national authority have responsibilities for optimisation. Operators design, propose and implement optimisation, and then use experience to further improve it. Authorities require and promote optimisation and may verify that it has been effectively implemented.

Other parties involved in optimization of protection ? Yes !

Optimization of Protection (2)

(153) Regulatory authorities should encourage the operational managements to develop a 'safety culture' within their organisations. Safety culture has been defined internationally by the inter-agency Basic Safety Standards (FAO et al., 1996) as

> 'The assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance'.

(154) Although it is not the task of the Commission to provide suitable texts for either standards or operational instructions, some quantitative features can be usefully recommended for international use. The components of the definitions of some dosimetric quantities are best adopted internationally. The Commission recommends values for such quantities. In the past, the Commission has recommended values for regulatory quantities such as the dose limit for individuals. Recommendations for dose limits have been useful in avoiding inconsistency between national systems. They are not without problems because it is also necessary to define the conditions in which the limit applies.

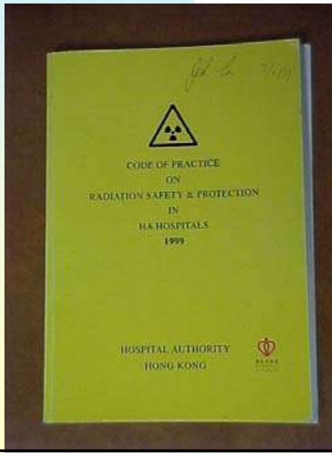
(195) The basic role of the optimisation of protection is to foster a 'safety culture' as discussed in paragraph 153 and thereby to engender a state of thinking in everyone involved in the control of radiation exposures, such that they are continuously asking themselves the question, 'Have I done all that I reasonably can to reduce these doses?'. Clearly, the answer to this question is a matter of judgement and necessitates co-operation between all concerned parties and, as a minimum, the operating management and the regulatory agencies.

Operating Management

Hospital Authority

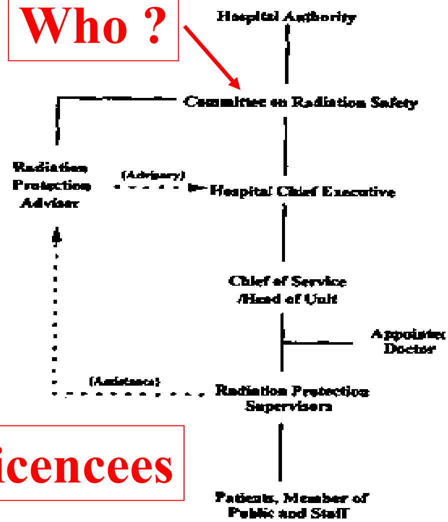
How ?

Code of Practice



APPENDIX 1
Administrative organisation for radiological safety

Who ?



Licencees

Compliances (HK)

in order of priorities within HA

- (1) Hong Kong Cap 303 (IA, RS)
- (2) Licence requirements & "Basic Safety Standards"(IAEA Safety Series115)
- (3) RB/RHU code of practices & guidances
- (4) HA 1999 Code of practice & HAHO documents
- (5) International reports / guidances eg. ICRP, NRPB etc

Comforters and Caregivers

9.4. Helpers and carers, and the public

(225) The exposure, other than occupational, of informed and consenting individuals helping to support and comfort patients, is a part of medical exposure. This definition includes the exposures of families and friends of patients discharged from hospital after diagnostic or therapeutic nuclear medicine procedures. Their exposure is different from that for public exposure, since the constraints on their exposures are not restricted by the dose limits. In *Publication 73* the Commission specified that dose in the region of a few millisieverts per episode is likely to be reasonable. This constraint is not to be used rigidly. For example, higher doses may well be appropriate for the parents of very sick children, if they are properly informed of the risks.

Publication Number	Title	*Annals of the ICRP* Vol.
60	1990 Recommendations of the International Commission on Radiological Protection	21 (1-3)
-	Risks Associated with Ionising Radiations	22 (1)
61	Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations	21 (4)
62	Radiological Protection in Biomedical Research	22 (3)
63	Principles for Intervention for Protection of the Public in a Radiological Emergency	22 (4)
64	Protection from Potential Exposure	23 (1)
65	Protection Against Radon-222 at Home and at Work	23 (2)
66	Human Respiratory Tract Model for Radiological Protection	24 (1-3)
67	Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 2. Ingestion Dose Coefficients	23 (3-4)
68	Dose Coefficients for Intakes of Radionuclides by Workers	24 (4)
69	Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 3. Ingestion Dose Coefficients	25 (1)
70	Basic Anatomical and Physiological Data for use in Radiological Protection: The Skeleton	25 (2)
71	Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 4. Inhalation Dose Coefficients	25 (3-4)
72	Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients	26 (1)
73	Radiological Protection and Safety in Medicine	26 (2)
74	Conversion Coefficients for use in Radiological Protection against External Radiation	26 (3-4)
75	General Principles for the Radiation Protection of Workers	27 (1)
76	Protection from Potential Exposures: Application to Selected Radiation Sources	27 (2)
77	Radiological Protection Policy for the Disposal of Radioactive Waste	27 (Supplement)
78	Individual Monitoring for Intakes of Radionuclides by Workers: Replacement of ICRP Publication 54	27 (3-4)
79	Genetic Susceptibility to Cancer	28 (in press)
80	Radiation Dose to Patients from Radiopharmaceuticals: Addendum 2 to ICRP Publication 53	28 (in press)

Age effects

DRL

Collective dose

Σ (number of exposed individual)*(exposure)
Limit < 1 man* Sv /y

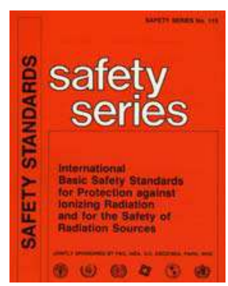
Risk values are age dependent

Dose Matrix

(202) Key matrix elements of such a matrix include the characteristics of exposed individuals, and the dose distribution in time and space. Aspects to be considered when establishing the importance of each matrix element in the decision-making process may include: -

- Number of exposed individuals
- Magnitude of individual doses
- Dose distribution in time
- Age and gender dependent risks as modifiers to dose distributions
- Equity considerations (achieving a balanced dose distribution)
- Real or potential exposure

Exclusion & Exemption



I-2. The general principles for exemption[35] are that:

(a) the radiation risks to individuals caused by the exempted practice or source be sufficiently low as to be of no regulatory concern;

(b) the collective radiological impact of the exempted practice or source be sufficiently low as not to warrant regulatory control under the prevailing circumstances; and

(c) the exempted practices and sources be inherently safe, with no appreciable likelihood of scenarios that could lead to a failure to meet the criteria in (a) and (b).

I-3. A practice or a source within a practice may be exempted without further consideration provided that the following criteria are met in all feasible situations:

(a) the effective dose expected to be incurred by any member of the public due to the exempted practice or source is of the order of 10 μSv or less in a year, and

(b) either the collective effective dose committed by one year of performance of the practice is no more than about 1 man.Sv or an assessment for the optimization of protection shows that exemption is the optimum option.

- Effective dose < 10 μSv/year for an individual
- Ease & accuracy of measurement ?
- But Recording of dose >167μSv/month

HK : 75Bq/g

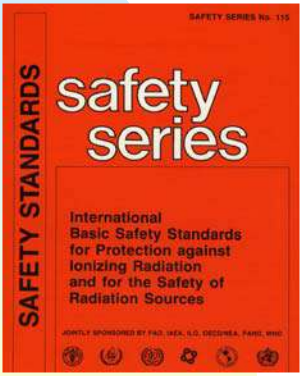


TABLE I-I. EXEMPTION LEVELS: EXEMPT ACTIVITY CONCENTRATIONS AND EXEMPT ACTIVITIES OF RADIONUCLIDES (ROUNDED) *(see footnote 36)*

Nuclide	Activity concentration (Bq/g)	Activity (Bq)	Nuclide	Activity concentration (Bq/g)	Activity (Bq)
H-3	1×10^6	1×10^9	Fe-52	1×10^1	1×10^6
Be-7	1×10^3	1×10^7	Fe-55	1×10^4	1×10^6
C-14	1×10^4	1×10^7	Fe-59	1×10^1	1×10^6
O-15	1×10^2	1×10^9	Co-55	1×10^1	1×10^6
F-18	1×10^1	1×10^6	Co-56	1×10^1	1×10^5
Na-22	1×10^1	1×10^6	Co-57	1×10^2	1×10^6
Na-24	1×10^1	1×10^5	Co-58	1×10^1	1×10^6
Si-31	1×10^3	1×10^6	Co-58m	1×10^4	1×10^7
P-32	1×10^3	1×10^5	Co-60	1×10^1	1×10^5
P-33	1×10^5	1×10^8	Co-60m	1×10^3	1×10^6
S-35	1×10^5	1×10^8	Co-61	1×10^2	1×10^6
Cl-36	1×10^4	1×10^6	Co-62m	1×10^1	1×10^5
Cl-38	1×10^1	1×10^5	Ni-59	1×10^4	1×10^8
Ar-37	1×10^6	1×10^8	Ni-63	1×10^5	1×10^8
Ar-41	1×10^2	1×10^9	Ni-65	1×10^1	1×10^6
K-40	1×10^2	1×10^6	Cu-64	1×10^2	1×10^6
K-42	1×10^2	1×10^6	Zn-65	1×10^1	1×10^6
K-43	1×10^1	1×10^6	Zn-69	1×10^4	1×10^6
Ca-45	1×10^4	1×10^7	Zn-69m	1×10^2	1×10^6
Ca-47	1×10^1	1×10^6	Ga-72	1×10^1	1×10^5
Sc-46	1×10^1	1×10^6	Ge-71	1×10^4	1×10^8
Sc-47	1×10^2	1×10^6	As-73	1×10^3	1×10^7
Sc-48	1×10^1	1×10^5	As-74	1×10^1	1×10^6
V-48	1×10^1	1×10^5	As-76	1×10^2	1×10^5
Cr-51	1×10^3	1×10^7	As-77	1×10^3	1×10^6
Mn-51	1×10^1	1×10^5	Se-75	1×10^2	1×10^6
Mn-52	1×10^1	1×10^5	Br-82	1×10^1	1×10^6
Mn-52m	1×10^1	1×10^5	Kr-74	1×10^2	1×10^9
Mn-53	1×10^4	1×10^9	Kr-76	1×10^2	1×10^9
Mn-54	1×10^1	1×10^6	Kr-77	1×10^2	1×10^9
Mn-56	1×10^1	1×10^5	Kr-79	1×10^3	1×10^5

Schedule

Table I

Dose Limits[1]

Tissue or Organ	Dose Limit[3]	Time Period
Workers, aged 18 or above		
(1) Whole body	20 mSv	In any calendar year
(2) Individual organ or tissue, extremity, skin averaged over any 1 cm^2	500 mSv	In any calendar year
(3) Lens of the eye	150 mSv	In any calendar year
(4) Abdomen of female worker of reproductive capacity	5 mSv	In any consecutive 3 months interval
(5) Foetus of pregnant female worker	1 mSv	During the pregnancy
Members of the public[2]		
Whole body	1 mSv	In any calendar year

1 The dose limits apply to exposures attributable to practices, with the exception of medical exposures and of exposures from natural sources that cannot reasonably be regarded as being under the responsibility of an employer or licensee.

2 The dose limit set out in this part shall not apply to adult comforters of patients, i.e., to adult individuals knowingly exposed while voluntarily helping (other than in their employment or occupation) in the care, support and comfort of patients undergoing medical diagnosis or treatment, or to adult visitors of such patients. However, the dose of any such comforter or visitor of patients shall be constrained so that it is unlikely that his or her dose will exceed 5 mSv during the period of a patient's diagnostic examination or treatment. The dose to children visiting patients, including those who have ingested radioactive materials, should be similarly constrained to less than 1 mSv.

3 The dose limits apply to the sum of the relevant doses from external exposure in the specified period and the relevant committed doses from intakes in the same period. The period for calculating the committed dose shall normally be 50 years for intakes by adults and to age 70 years for intakes by children. For the purpose of demonstrating compliance with dose limits, the sum of the personal dose equivalent from external exposure to penetrating radiation in the specified period and the committed equivalent dose or committed effective dose, as appropriate, from intakes of radioactive substances in the same period shall be used.

Dose limit vs Dose Constraint in Public exposure

5.3.2. Public exposure

(145) Public exposure is incurred as a result of a range of controllable sources. Dose limits for public exposure can be used only as a basis for national policy. Dose limits cannot in principle be applied to operational control, because neither the operator nor the regulator has the information about the totality of sources contributing to the dose to be limitedin normal situations. The only feasible approach is to select a single source, or a small group of sources, and to estimate the exposure to the most exposed individual or the most highly exposed group of individuals (the critical group). For normal situations, it is unlikely that the total exposure from the defined controlled sources can be judged against the dose limit. This is because the selected sources are only a part of the whole group of likely sources. Therefore, an individual dose from single source during normal situations has to be judged against the constraint.

Dose limits : (Local Rules PET center, QEH)

Table 1. Dose Limits

Tissue or Organ	**Dose Limit**	**Time Period**
Worker, aged 18 or above		
1. Whole body	20 mSv	In any calendar year
2. Individual organ or tissue, extremity, skin averaged over any 1 cm^2	500 mSv	In any calendar year
3. Lens of the eye	150 mSv	In any calendar year
4. Abdomen of female worker of reproductive capacity	5 mSv	In any consecutive 3 mont interval
5. Foetus of pregnant female worker	1 mSv	During pregnancy
Members of the public Whole body	1 mSv	In any calendar year
Adult comforters/visitors of patients (knowingly exposed)	5 mSv	During the period of patie diagnostic examination or treatment

1.1 Every individual using ionizing radiation has a duty to protect himself and others (including patients) from any radiation hazards arising from his work.

Control of radioactive wastes

Type	Disposal Route	Limits
Excreta from Patients	Toilet drain	Nil
Liquid	Sewer	S <1 per day, where S is the sum of the ratios of the disposed activities to the respective Annual Limits on Intake.
Solid	As ordinary refuse	<400 kBq per 0.1 m^3 and <4 kBq per article.
	Direct to landfill	<40 MBq per 0.1 m^3 for NM radionuclides with half life less than 1 year.
Inert gas	To atmosphere	Diagnostic quantities only subject to S < 1 per day.

Dose constraint : released patient as a single source

Released I131 patient

- Release limit of I-131 (400Mbq ~ 10mCi)
- Dose rate @1m <20μSv/hr
- Dose rate @ 0.2m <0.5mSv/hr : at proximity
- Dose(2 hours for travelling) <1mSv/2hr

This report by Committee 3 gives valuable guidance regarding whether to hospitalise or release patients. Hospitalisation will reduce exposure to the public and relatives, but will increase exposure of hospital staff and can also result in significant monetary costs that need to be analysed and justified. Patients travelling after radioiodine therapy rarely present a hazard to other passengers if travel times are limited to a few hours, and restrictions following release of patients should focus on infants and children. The Commission now recommends that the public dose limit of 1 mSv/year should apply to infants, children, and casual visitors, rather than the dose constraint of 5 mSv/episode.

ICRP 94

Only for this subgroup

Public transport & Waiting Area

(227) Some public exposure may result from wastes discharged by nuclear medicine departments. The implications of such discharges to sewers and of airborne effluents should be assessed to ensure the relevant national constraints for public exposure are met. The adventitious exposure of members of the public in waiting rooms and on public transport is not high enough to require special restrictions on nuclear medicine patients, except for those being treated with radioiodine for thyroid cancer (*Publications 73* and *94*; ICRP, 1996a, 2004).

5mSv/ episode

ICRP dose constraints

- From ICRP Publication 94
- 1mSv/y : public®
- 5mSv/episode : relatives, visitors & caregivers (ICRP 1991 ,1996)
- 1mSv/y applied also to infants, children and casual visitors
- * Licence (there will normally be no need to place restriction on visitors : patient at home)

®
*HK: in Table I :Dose Limits of Basic Safety Standards(RB)

International recommendations

- ICRP 30 (1982)
- ICRP 52 : Radiation protection to patients
- ICRP 53 : (1987) addenum ICRP 80
  Radiation Dose to Patients from Radiopharmaceuticals
- ICRP 60 (1991)
- ICRP 68 (1994)
- ICRP 73 (1996) : eg. (DRL)
- ICRP 84 Pregnancy and Medical radiation
- ICRP 2005

IAEA/EC/PAHO/WHO Conference (IAEA, 2001)

Table VI. Guidance Levels of Activity for Procedures in Nuclear Medicine for a Typical Adult Patient

Test	Radionuclide	Chemical form[a]	Maximum usual activity per test[b] (MBq)
Bone			
Bone imaging	$^{99}Tc^m$	Phosphonate and Phosphate compound	600
Bone imaging by single photon emission computerized tomography (SPECT)	$^{99}Tc^m$	Phosphonate and Phosphate compound	800
Bone marrow imaging	$^{99}Tc^m$	Labelled colloid	400
Brain			
Brain imaging (static)	$^{99}Tc^m$	TcO_4^-	500
	$^{99}Tc^m$	Diethylenetriamine-penta-acetic acid (DTPA), gluconate and glucoheptonate	500
Brain imaging (SPECT)	$^{99}Tc^m$	TcO_4^-	800
	$^{99}Tc^m$	DTPA, gluconate and glucoheptonate	800
	$^{99}Tc^m$	Exametazime	500
Cerebral blood flow	^{133}Xe	In isotonic sodium chloride solution	400
	$^{99}Tc^m$	Hexamethyl propylene amine oxime (HM-PAO)	500
Cisternography	^{111}In	DTPA	40
Lacrimal			
Lacrimal drainage	$^{99}Tc^m$	TcO_4^-	4
	$^{99}Tc^m$	Labelled colloid	4
Thyroid			
Thyroid imaging	$^{99}Tc^m$	TcO_4^-	200
	^{123}I	I^-	20
Thyroid metastases (after ablation)	^{131}I	I^-	400
Parathyroid imaging	^{201}Tl	Tl^+, chloride	80
Liver and spleen			
Liver and spleen imaging	$^{99}Tc^m$	Labelled colloid	80
Functional biliary system imaging	$^{99}Tc^m$	Iminodiacetates and equivalent agents	150
Spleen imaging	$^{99}Tc^m$	Labelled denatured red blood cells	100
Liver imaging (SPECT)	$^{99}Tc^m$	Labelled colloid	200

Guidance Levels of Activity for Procedures in Nuclear Medicine for a Typical Adult Patient (Cont.)

Test	Radionuclide	Chemical form[a]	Maximum usual activity per test[b] (MBq)
Cardiovascular			
First pass blood flow studies	$^{99}Tc^m$	TcO_4^-	800
	$^{99}Tc^m$	DTPA	800
	$^{99}Tc^m$	Macroaggregated globulin 3	400
Blood pool imaging	$^{99}Tc^m$	Human albumin complex	40
Cardiac and vascular imaging/probe studies	$^{99}Tc^m$	Human albumin complex	800
Myocardial imaging/probe studies	$^{99}Tc^m$	Labelled normal red blood cells	800
Myocardial imaging	$^{99}Tc^m$	Phosphonate and phosphate compounds	600
Myocardial imaging (SPECT)	$^{99}Tc^m$	Isonitriles	300
	^{201}Tl	Tl^+ chloride	100
	$^{99}Tc^m$	Phosphonate and phosphate compounds	800
	$^{99}Tc^m$	Isonitriles	600
Lung			
Lung ventilation imaging	$^{81}Kr^m$	Gas	6000
	$^{99}Tc^m$	DTPA-aerosol	80
Lung ventilation study	^{133}Xe	Gas	400
	^{127}Xe	Gas	200
Lung perfusion imaging	$^{81}Kr^m$	Aqueous solution	6000
	$^{99}Tc^m$	Human albumin (macroaggregates or microspheres)	100
Lung perfusion imaging (with venography)	$^{99}Tc^m$	Human albumin (macroaggregates or microspheres)	160
Lung perfusion studies	^{133}Xe	Isotonic solution	200
	^{127}Xe	Isotonic chloride solution	200
Lung imaging (SPECT)	^{99}Tc	Macroaggregated albumin (MAA)	200

DRL

DIAGNOSTIC REFERENCE LEVELS IN MEDICAL IMAGING: REVIEW AND ADDITIONAL ADVICE

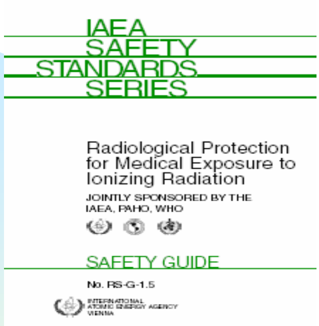
A web module produced by Committee 3 of the International Commission on Radiological Protection (ICRP

Key Points

- Diagnostic reference levels (DRLs) should be used by regional, national and local authorized bodies. The numerical values of DRLs are advisory, however, implementation of the DRL concept may be required by an authorized body.
- The concept of DRLs allows flexibility in their selection and implementation.
- The Committee 3 advice does not specify quantities, numerical values or details of implementation for DRLs. This is the task of the regional, national and local authorized bodies, each of which should meet the needs in its respective area.
- The Committee 3 rationale for its advice is that any reasonable and practical approach, consistent with the advice, will improve the management of patient doses in medical imaging.

Reference : ICRP 73 : 1996

International Standards



Year 2002

http://www-pub.iaea.org/MTCD/publications/PDF/SS-115-Web/Pub996_web-1b.pdf

Dose constraints for RS (HK)

in terms of hourly rate

- Outside storage area
- [Public area]
- 1μSv/hr (unconditional ?)
- 2 mSv/y (if 2000 hrs)
- 9 mSv/y (using 365 days)
- HK Bkg dose ~ 2.2mSv/y

- Inside storage room
- [Occupational area]
- 10μSv/hr
- 20 mSv/y (2000 hrs)

maximum constraint acceptable ?

A need to reduce to 10% RS activity * time max.storage limit

ICRP 2005

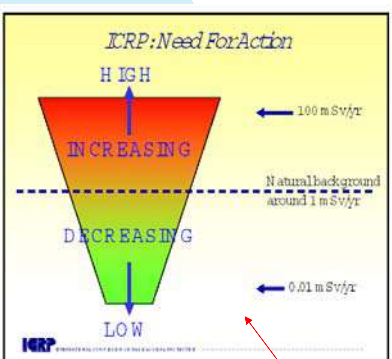


Table 1. Levels of concern and individual effective dose as a function of the natural background, excluding radon exposures.

LEVEL OF CONCERN	EFFECTIVE DOSE
HIGH	> 100x
RAISED	> 10x
NORMAL	AVERAGE NATURAL BACKGROUND
LOW	< 0.1x
NONE	< 0.01x

exclusion

HK: 2mSv

ICRP COMMITTEE 5

Protection of the environment

Development and use of Reference Animals and Plants

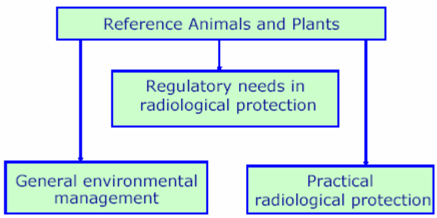
Ensure compatibility of approach with:
- human radiological protection and
- with other forms of environmental protection

Purposes

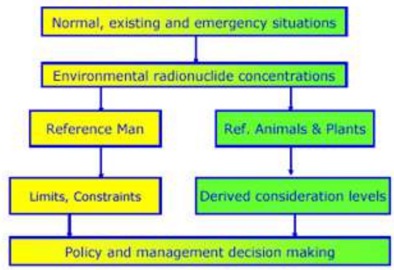
ICRP's decision has not been driven by any particular concern over environmental radiation hazards, but by the need to fill a conceptual gap in radiological protection.

Any other reasons ?

USES AND CHOICES



COMBINED APPROACH



A good preparation for Nuclear "Emergencies/Accidents/Disasters"

Conclusions

- "Value"system for justification & optimization
- Need common concepts & approaches in RP
- Guidance, recommendations & regulations require continuous reviews and update
- Need "specified" responsibilities and "specified" committees
- Task group for reviews ,discussions, interpretations and advices for the above points


STOP
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