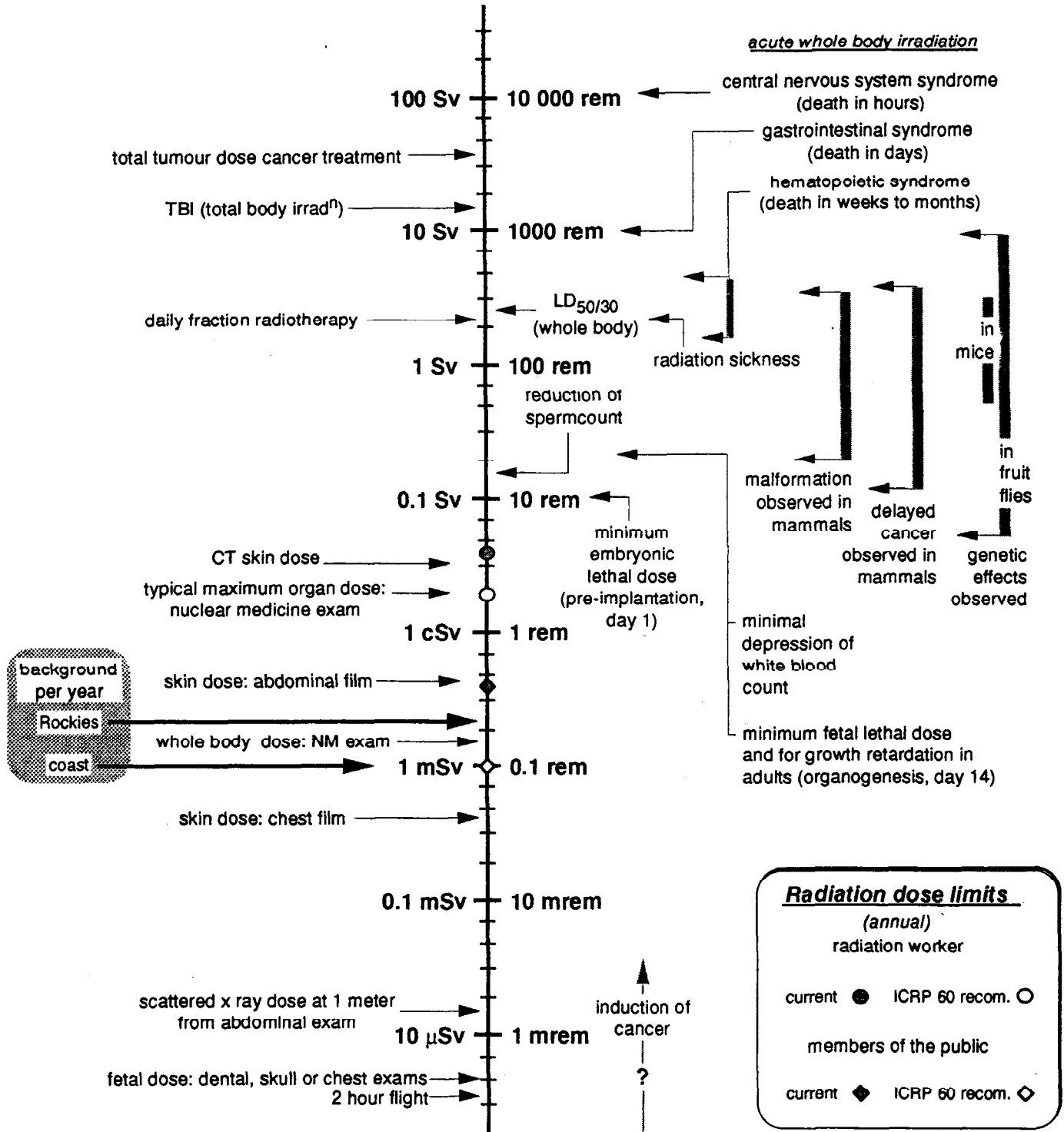


# Scale of typical radiation doses and effects.

## Typical Levels of Exposure

## Typical Levels for Effects



## **AGENCIES**

### ***Some Organizations which Set Radiation Protection Standards or Regulations:***

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#### ***International Commission on Radiological Protection: ICRP***

- responsible for providing basic guidance in matters of radiation safety
- established in 1928 by the 2<sup>nd</sup> International Congress of Radiology as the International X-ray and Radium Protection Commission
- originally its main concern was with the safety aspects of medical radiology.
- name was changed to the ICRP in 1950 when interests in radiation protection expanded with widespread use of radiation outside of medicine
- Operating philosophy:  
"The policy adopted by the Commission in preparing recommendations is to deal with the basic principles of radiation protection and to leave to the various national protection committees the responsibility of introducing the detailed technical regulations, recommendations, or codes of practice best suited to the needs of their individual countries" (ICRP Publication 6, 1964)

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#### ***International Commission on Radiological Units and Measurements: ICRU***

The International Commission on Radiation Units and Measurements (ICRU), since its inception in 1925, has had as its principal objective the development of internationally acceptable recommendations regarding:

- (1) Quantities and units of radiation and radioactivity,
- (2) Procedures suitable for the measurement and application of these quantities in clinical radiology and radiobiology,
- (3) Physical data needed in the application of these procedures, the use of which tends to assure uniformity in reporting.

The ICRU invites and welcomes constructive comments and suggestions regarding its recommendations and reports. These may be transmitted to the Chairman.

- Actual preparation of reports is carried out by ICRU report committees. Some of currently active committees are: Absolute and Relative Dosimetry at High Doses, Chemical Dosimetry, Computer Uses in Radiotherapy, Definitions of Physical Parameters to Specify Performance of Imaging Instruments, Dose Specification for Reporting Intracavitary and Interstitial Therapy, Measurement of Dose Equivalent, MTF for Screen-Film Systems, Quality Assurance in External Beam Therapy, Stopping Power...
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**Canadian Nuclear Safety Commission,  
CNSC  
(Formerly the Atomic Energy Control  
Commission AECB)**

The CNSC, is the federal agency responsible for the regulation, control and supervision of the development, application and use of atomic energy, and for participation in measures of international control of the use of atomic energy in Canada.

- The CNSC administers the control in Canada of the provisions of the Atomic Energy Control Act and Regulations
- The CNSC acts through various regulations and specific licence conditions
- The CNSC imposes requirements on licences with regard to site security, equipment maintenance and operations as well as measures to protect employees and members of the public.

**THE CNSC REGULATORY  
DOCUMENTS SYSTEM**

1. Siting, design, manufacture, construction, commissioning, operation, and decommissioning of nuclear facilities, or the production, possession, use and disposal of prescribed substances, in Canada or under Canadian control, are subject to the provisions of the Canadian Nuclear Safety Act and Regulations administered by the CNSC.
2. In addition to the Canadian Nuclear Safety Regulations, three other categories of Regulatory Document are employed by the CNSC. These are:

*Generic Licence Conditions* - standard sets of conditions that are included in particular CNSC licences of a common type, unless specific circumstances indicate otherwise;

*Regulatory Policy Statements* - firm expressions that particular "requirements" not expressed as Regulations or Licence Conditions be complied with or that any requirements be met in a particular manner but the CNSC

retains the discretion to allow deviations or to consider where alternative means of attaining the same objectives where a satisfactory case is made; and

*Regulatory Guides* - guidance or advice on any aspect of the CNSC's regulatory process that is given in a manner less rigid than that intended by Policy Statements.

3. In developing Regulatory Documents, the CNSC publishes its proposals as Consultative Documents in order to solicit comments both from the nuclear industry and from the public.
4. Comments on Consultative Documents and suggestions for new Regulatory Documents and for improvement to those that exist are encouraged and should be directed to the Regulations Development Section of the CNSC.
5. Copies of Consultative Documents, Regulatory Documents and related index lists are available in both English and French on request from the Office of Public Information. Requests for technical information on and interpretation of documents should be addressed to this office. "

- The CNSC also states

'... employees must share in the responsibility to protect employees and members of the public.. They have obligations and responsibilities pursuant to the Canadian Nuclear Safety Regulations.

According to subsection 24(2) of these regulations, "Every person employed in or in connection with a nuclear facility or a business or undertaking involving the use of prescribed substances *shall* take all reasonable and necessary precautions to ensure his own safety and the safety of fellow employees."

- **Employees found negligent or in contravention of this regulation face fines of up to \$5,000 or imprisonment for a term not exceeding two years, or both.**
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***Radiation Protection Bureau, RPB***

***Bureau of Radiation and Medical Devices, Health Protection Branch of National Health and Welfare Canada:***

- Some of the responsibilities of the Health Protection Branch of National Health and Welfare Canada, through the Environmental Health Directorate, include studying adverse effects of the chemical and physical environment on human health, and ensuring the safety, effectiveness and non-fraudulent nature of radiation emitting and medical devices.
- The Directorate also conducts research on radiation hazards and the adverse affects of environmental chemicals.
- Through the RPB the agency monitors the radiation exposures of radiation workers throughout Canada

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- **Radiation Control in Canada**

- **Federal**

- **Nuclear Safety Act**, subsequent amendments.

Canadian Nuclear Safety Commission (old Atomic Energy Control, AECB) set up under authority of N.S. Control Act. CNSC AECB has published Regulations, 1950, 1974, 1978, 1990. Regulations control "nuclear facilities" which include "particle accelerators". (see Appendices)

- CNSC in the medical field:
  - issues licences for use of radioactive materials,
  - issues licences for medical accelerators operating at about 10 MeV and above.
- **Food and Drug Act**. (Date?)
  - Medical Devices Regulations issued under this Act, but has relatively little impact in the radiation field.
- **Radiation Emitting Devices Act**, 1970 and subsequent amendments.
  - Radiation Protection Bureau (RPB) operates under this Act. RPB is part of Health Protection Branch of Health and Welfare Canada.
  - Activities of RPB:
    - Publish Regulations under the Radiation Emitting Devices Act relating to new equipment emitting ionizing radiation (X-rays) and non-ionizing radiation (microwaves, U.V., ultrasound).
    - Operates radiation monitoring service for whole of Canada
    - Produces and issues Safety Codes
    - Publishes standards for radiation equipment
    - Operates laboratories in Ottawa for testing consumer equipment (e.g. microwave ovens).

- **Provincial**

The provinces have full control over Health Services. Hence Federal Safety Codes do not apply to provincial hospitals

- but provincial codes are based on the federal model.
- In Quebec
  - Public Health Protection Act (Loi de la protection de la santé publique) 1972.
    - Regulations relating to diagnostic X-ray equipment in private radiological facilities.
    - Regulations amended 1979. Specifies standards and requirements relating to equipment, shielding, protection of personnel, protection of patients.
  - Health and Social Services Act (Loi sur les services de santé et les services sociaux).
    - Requires hospitals to carry out periodic inspection of all equipment emitting radiation.
  - Occupational Health and Security Act (Loi sur la santé et sécurité au travail) 1982.
    - Concerned with maintenance of X-ray equipment and with health of pregnant technicians.
    - Formerly applied only to private offices but since 1984 to hospitals also.

In Ontario

- HARP (Healing Arts Radiation Protection Commission)
- X-ray Inspection Services of the Ministry of Health of Ontario

## ***RADIATION PROTECTION : OBJECTIVES AND PRINCIPLES***

### ***A) OBJECTIVES***

- No practice shall be adopted unless its introduction produces a positive net benefit **-> JUSTIFICATION**
- All exposures shall be kept ***as low as reasonably achievable***, economics and social factors being taken into account (***"ALARA" principle***). **-> OPTIMIZATION OF PROTECTION**
- The equivalent dose (old dose-equivalent) to individuals shall not exceed the limits recommended for the appropriate circumstances by the ICRP **-> DOSE LIMITS**

### ***B) BASIC PRINCIPLES***

- **DISTANCE**                      Maximize distance between operator and radiation sources
- **TIME**                              Minimize time in vicinity of sources or the time working with radiation
- **SHIELDING**                      Interpose shielding material between operator and sources

The factors of time and distance are the basic elements which should be optimized first. If it is inefficient to work with these factors alone, then shielding is introduced.

Common sense must be used when these factors are considered. E.g., it is not good practice to worry so much about the time issue that you rush the work and increase the probability of making mistakes. In the long run this may actually increase the length of exposure time.

## C) OPERATING PRINCIPLES FOR IMPLEMENTATION

### ● RULES AND REGULATIONS

- a) *Safety Codes*: - these are voluntary but non-compliance can mean serious trouble in event of accident.

Examples: - Don't pipette radioactive materials by mouth  
 - Don't handle radiation sources with bare fingers  
 - Do stand behind radiation shield when making X-ray exposure

- b) *Regulations* - these have legal binding  
 - they tend to refer to equipment rather than procedures since they are then easier to enforce  
 - e.g., can verify that required lead shielding has been installed in a wall

- Note: *a law* is usually worded in general terms. This is deliberate since changing laws is a complex political process

*the regulations* used to help enforce the law are more specific. These are legally binding and are easier to change than laws.

- e.g. - the law states: Any x-ray unit used in Canada must be adequately shielded.  
 - the enforcing regulation states that the leakage radiation must be less than a certain fraction ( $\sim 1/1000$ ) of the open beam emitted by the unit

- c) *Licensing* ensures that the use of radiation equipment and radioactive sources is restricted to suitably qualified persons.

- In Canada the CNSC licenses radiation isotopes while provincial governments license diagnostic x-ray units. Higher energy LINACs (= 10 MeV) are also licensed by CNSC since high energy photons can activate materials by photo-disintegration processes.

### ● DOSE LIMITS

System of equivalent dose limits (maximum permissible doses) for radiation workers and members of the general public. These are reviewed on the next two pages.



## ***Dose Limits and Regulations***

Dose limits and regulations were discussed previously in Chapters 1, 2, and 3. In this chapter we will review some aspects of these topics in light of some of the new information we have gained in the subsequent chapters. Some of this discussion is taken from previous notes by Dr. M. Cohen.

- ***Some notes on dose limits***

Why should the limit for a Radiation Worker be 20 times higher than for a member of the public: 20 mSv/y vs. 1 mSv/y according to the ICRP 60 recommendations ? (At present the ratio is 10, i.e. 50 mSv/y vs. 5 mSv/y.) If 20 mSv/y is "safe" why do we need a lower limit for the general public ?

- In fact, 20 mSv is below the threshold required to produce any deterministic effect such as blood changes or skin erythema. The limits are therefore based on "stochastic" or "probability" effects, i.e. induction of cancer and genetic effects. The higher limit for radiation workers does not mean that these occupations are "unsafe" but these workers do have a greater chance than members of the public of induction of cancer and genetic abnormalities. An annual whole body effective dose of 20 mSv from age 18 to 65 translates into a lifetime risk of contracting a fatal cancer of  $3.5 \times 10^{-2}$ , i.e. 1 in 28. (The "natural" risk is about: 1 in 5.) This corresponds to an average annual risk of about 1 in 1300, with a smaller annual risk below the age of ~60 and a larger annual risk above this age. For 1 mSv/y over a lifetime (~75 y) the average annual risk of a fatal cancer is about 1 in 19,000, again with a smaller risk below ~60 years of age. These numbers correspond to the risks of fatal accidents in industry and in everyday life, respectively.
- The annual risk factor applicable to radiation workers would be unacceptable if applied to the whole population. In Canada, for example, it would result in about 20,000 additional cancer deaths per year. However, when applied to the small fraction of the population (<1%) who are radiation workers, the resulting additional burden on society becomes acceptable. The same argument applies, even more strongly, to the genetic effects of radiation.
- The category "Members of the Public" includes persons under 18 years of age, who are more sensitive to radiation than are older persons.
- For radiation workers, the possibility of biological harm is an "occupational hazard" which is accepted as "part of the job," as are corresponding hazards in other occupations. That is the risks have to be evaluated in the context of acceptable limits in industry and other occupations.
- The dose limit for radiation workers does not imply that all workers will actually receive this dose (recall Table 4.2 and Fig. 4.1). On the contrary, the limit is applied in practice in conjunction with the ALARA principle: As Low As Reasonably Achievable. This means that the distribution of actual occupational doses shows a peak at less than 10 mSv/y and a long "tail" stretching up to (and slightly beyond) the present official limit of 50 mSv/y. When the limit is reduced to 20 mSv/y this will alter the tail - at considerable expense - but will make practically no difference to the main part of the distribution curve.

- **MONITORING**

- a) Personnel monitoring - measurement of doses received by radiation workers using film badges or thermoluminescent dosimeters
- b) Area monitoring - measurement of dose rates at points in a defined area e.g., in the vicinity of X-ray equipment
  - also monitoring of surface contamination in labs' using radioisotopes
- c) Procedure monitoring - measurement of doses received during particular experimental or clinical procedures e.g., reference doses in diagnostic radiology or nuclear medicine

- **RECORDS**

- Keep records of everything pertaining to radiation, safety, radiation exposures, etc.

- **MEDICAL COUNSELLING AND SURVEILLANCE**

- three groups may require counselling (from ICRP 60, 1990)
  - pregnant workers
  - individuals expected to be exposed to, or over, dose limits
  - individuals (workers) considering volunteering for deliberate exposures as part of research
- individuals exposed in great excess of dose limits or who may be involved in potentially dangerous situations may require clinical testing (e.g. examination of lymphocytes for chromosome aberrations).
- For workers at the  $1 \text{ mSv year}^{-1}$  level, medical surveillance is unnecessary

- **EDUCATION (very important)**

- Radiation workers have to be familiar with principles and practice of radiation safety.

- **PERSONAL RESPONSIBILITY** (very important)
  - Every radiation worker is responsible for working in such a way as to promote his own and other people's safety.
  
- **ORGANIZATION**
  - none of the above simply "happens". An organizational structure is needed in every institution to promote radiation safety, ensure compliance with safety rules, monitor exposures and keep records, and provide appropriate information and training.

## ***D) WHO HAS TO BE PROTECTED***

- **RADIATION WORKERS**
  
  - **OTHER STAFF OF THE SAME ESTABLISHMENT**
    - need not be monitored with badges but they must be protected
  
  - **PATIENTS (IN CASE OF MEDICAL INSTITUTION)**
    - limited scope, may also involve members of families, relatives, etc.
  
  - **MEMBERS OF THE PUBLIC**
    - The notion that one should protect people other than radiation workers has only existed for the last 20 years or so.
-