Radiation Protection:
from Workplace to Environment

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What is in this talk?

- The Development of Dose Limits
- The ICRP Proposed 2005 Recommendations
- The Risks

Ionizing Radiation

The kind of radiation discussed in this presentation is called ionizing radiation because it can produce charged particles (ions) in matter.

Radiation (Ionizing Radiation)

means Electromagnetic radiation (gamma rays, X-rays) or
Corpuscular radiation (alpha particles, beta particles, neutrons, electrons, protons and other particles) capable of producing ions
Emitted by radioactive substances or from a machine in which electrons are accelerated by a voltage of not less than 5 kV.

Radiation Ordinance Cap. 303, Laws of Hong Kong

X-rays

Is generated when high speed electrons being stopped.
Cathode Ray tube in TV is an example of X-ray generator although the amount of X-ray emitted is small.

Radioactive materials

-naturally occurred radioactive nuclides such as K-40, C-14, U-238 etc. in our food and living environment
-man-made radioactive nuclides: generated by reactors, accelerators.

Irradiation

- Irradiation is exposure to penetrating radiation.

  Irradiation occurs when all or part of the body is exposed to radiation from an unshielded source.

- *External irradiation does not make a person radioactive.*

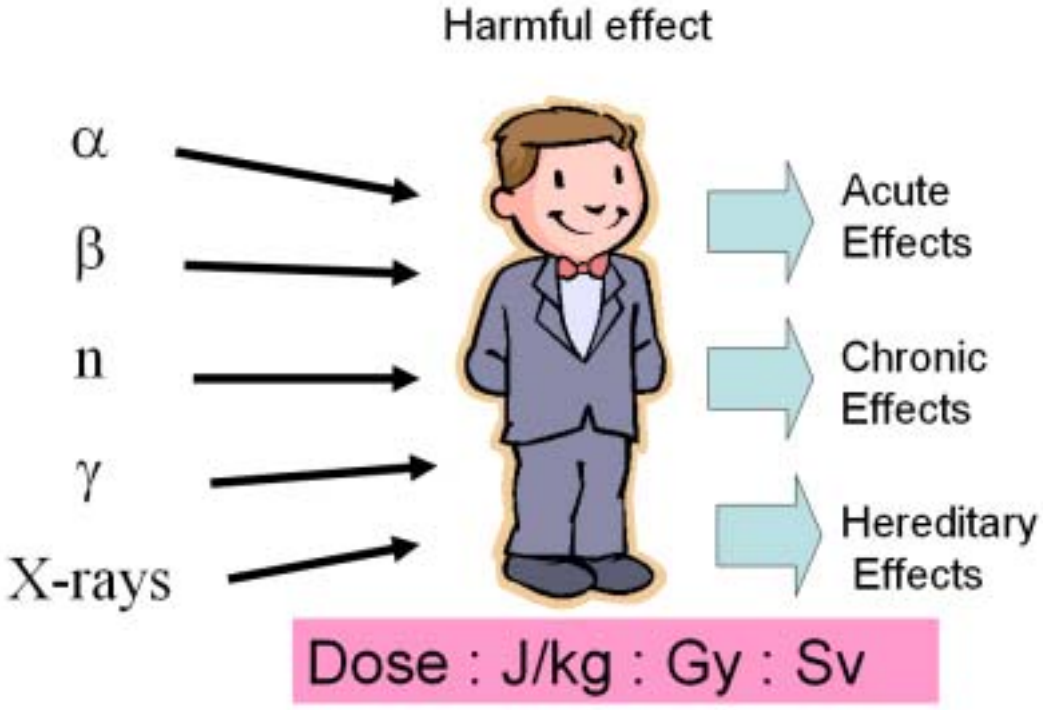
Radioactive Contamination

- The *environment* is contaminated if radioactive material is spread about or uncontained.
- A person is *externally* contaminated if radioactive material is on skin or clothing.
- A person is *internally* contaminated if radioactive material is breathed in, swallowed, or absorbed through wounds.

Radiation Protection

The Beauty of

- Physics
- Chemistry
- Biology
- Medical Science
- Social Science
- Politics ….



Unified the effects of all sources of radiation of different energy.

Recommendations of

the International Commission

on Radiation Protection ICRP in 1990

- Justification:
  - Net benefit
- Optimization:
  - As low as reasonably achievable
  - With economical and social considerations
- Dose limits

Dose Limits

- The values are chosen so that any continued exposure just above the dose limits would result in additional risk from the defined practices that could reasonably be described as “unacceptable” in normal circumstances.
- For Occupational OEL, TLV
- For Public Environmental Objectives

ICRP 60 (1990)

Annual Limits of Intake for contamination

Annual Dose limits for worker

- Annual limits of intake of a radionuclide
- Derived Air Concentration
  - similar to TLV-TWA
  - based on a reference man (ICRP)

Sources of Ionizing Radiations

- Nature Sources:
  - The Sun and the Universe- Cosmic Rays
  - Our Earth: sources of Radioactive elements
- Man-made Sources
  - X-rays machines and accelerators
  - Radioactive nuclides generated by reactors, and accelerators

Radiation Protection began when we had man made sources.

Roentgen

- On 8 Nov, 1895, he accidentally discovered an image cast from his cathode ray generator.

Harmful effects of X-rays

Skin erythema, epilation and desquamation reported in 1896.
Edison's assistant, Dally died in 1904 as a result of excess exposures and Edison stopped his research in X-ray tubes.

Dose limit of X-rays

- 0.01 of an erythema dose in 30 days.
  - [Mutscheller, USA, 1922]
- 0.1 erythema dose in a year
  - [Sievert, Sweden, 1922]

- In 1925, ICRU defined "Roentgen"
  0.2 R/day = 0.01 of erythema dose in 30 days
- In 1931, 0.1 R/day
  (It was set as no observable effects on two technicians after a survey on the X-ray technicians.)

Becquerel

- In 1896, he discovered the phenomenon of natural radioactivity of Uranium.

Harmful effects of Radioactive substances

- In 1902, Becqueral received a deep burn on his chest because he placed a radioactive sample (a gift from Curie) in his pocket for less than 6 hours.
- Marie Curie died of leukemia at the age of 67 but her husband died in an accident at age of 47.
- The Radium girls in radium dial factory in mid-1920s. A New York dentist noted osteomyelitis in the jaw of a girl. In 1925, most of the dial painting intake stopped.

Radiation Protection in 1941

- Body burden limit on internally deposited of Radium = 0.1 ug
  - "We would feel perfectly confident if our wife or daughter were the subject"
- External exposure limit = 0.1 R/day

This protected most of the people took part in the atomic bomb researches in 1940s.

Data on Health effects of Radiation

Are human data from the studies on the early X-ray radiologists and the victims of the atomic bombs.

Radiation Sub cellular Effects

Ions generated by radiation damages

- enzymes, membranes, etc
- chromosomes (DNA)
  - single-strand breaks
  - double-strand breaks

Consequeces:

- Impaired metabolism
- Repaired
- Cell death

Deterministic Effects

Total Body Irradiation

- 10-30 Gy
  - fatal.
- 3.5 Gy
  - Nausea and vomiting initially, followed by a period of apparent wellness. At 3-4 weeks, there is a potential for deficiency of white blood cells and platelets.
- 1 Gy
  - May cause nausea and vomiting for 1-2 days and temporary drop in production of new blood cells
- 50 mGy
  - No detectable injury or symptoms

Acute radiation doses may cause:

a) erythema at 2 Gy;
b) cataract at 2 Gy;
c) permanent epilation at 7 Gy;
d) delayed skin necrosis at 12 Gy.

ICRP Publication 85

Other Local Effects

- Very high doses to gonads causes sterility.
- Genetic damages (but not conclusive in human studies)

Dose Rate Effects on deterministic health effects

- Acute exposure: e.g. Atomic Bomb
- Chronic Exposure: e.g. Natural Background Radiation
- Fractionated Exposure: e.g. work situation, Medical treatment.

Stochastic Effects

- Acute leukemia and Tumors
  - skin, breast, lung, brain thyroid, bone, non-Hodgkin's lymphoma
- Linear, no threshold Hypothesis:
  - The probability of manifestation increases with the dose but there is no threshold.
- Risk of fatal cancer by radiation:
  - 0.05 per Sv [ICRP 60]
  - 50 per mSv in one million population
  - Note: natural death from cancer: 1/4 of population

Dose Limits are set for no additional risk:

– No Deterministic Effects

– Acceptable Probability of Stochastic Effects

Occupational Exposure Worker will not be at higher fatal risk than those in "safe" industries.

Public will be at an acceptable risk with consideration of natural background.

Dose Limits for Radiation Workers

ICRP 1990

- 20 mSv/a averaged over 5 years
- 150 mSv/a lens
- 500 mSv/a skin
- 500 mSv/a hands & feet.
- 2 mSv to her lower trunk and 1/20 ALI after the pregnancy declared

Radiation Regulations

- 20 mSv/a whole body
- 150 mSv/a lens
- 500 mSv/a skin
- 5 mSv/3 months: woman with reproductive capacity
- 1 mSv to the fetus

Dose Limits for Public

ICRP 1990

- 1 mSv/a whole body
- 15 mSv/a lens
- 50 mSv/a skin

Radiation Regulations

- 1 mSv/a whole body

Natural background radiation dose per year to Hong Kong residents varies from 1.8 to 3.6 mSv approx. The doses in the China high background areas are 6.4 mSv/a

ICRP 2005 Recommendations on dose constraints

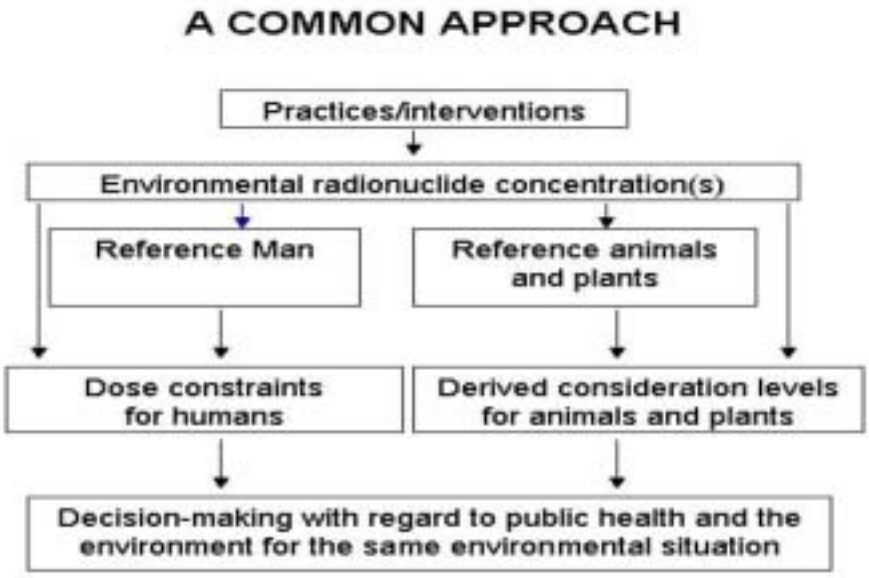
- 100 mSv in a year
  - In emergency, for workers
  - For high levels of controllable existing exposures
  - Above it, there is no individual nor societal benefit
- 20 mSv in a year
  - For situations where there is benefit for exposed individuals, who receive information and training and monitoring or assessment.
- 1 mSv in a year
  - For situation having societal benefit, no individual direct benefit, and there is no information, no training and no individual assessment for the exposed individuals in normal situations.
- 0.01 mSv a year: Minimum value of any constraint.

Protection of the Environment

In 1990 ICRP:

- "The Commission believes that the standards of environmental control needed to protect man to the degree currently though desirable will ensure that other species are not put in risk…."

ICRP 2005 recommendation



- Human as well as fauna and flora are part of the same ecosystem.

Reference Animals & Plants

Draft 2/2004

Rat	Flatfish
Frog	Bee
Duck	Crab
Pine Tree	Wild Grass
Brown seaweed	Marine Snail
Salmonid Fish	Earthworm

How Risky is my workplace?

Comparison of cancer risk from radiation and chemical exposures

Risk Coefficient for workers [ICRP 60]

Stochastic effect	Detriment per sievert[b]
Fatal cancer[c]	4.0 E-2
Non-fatal cancer	0.8 E-2
Severe hereditary effects	0.8 E-2
Total	5.6 E-2

Lifetime risk

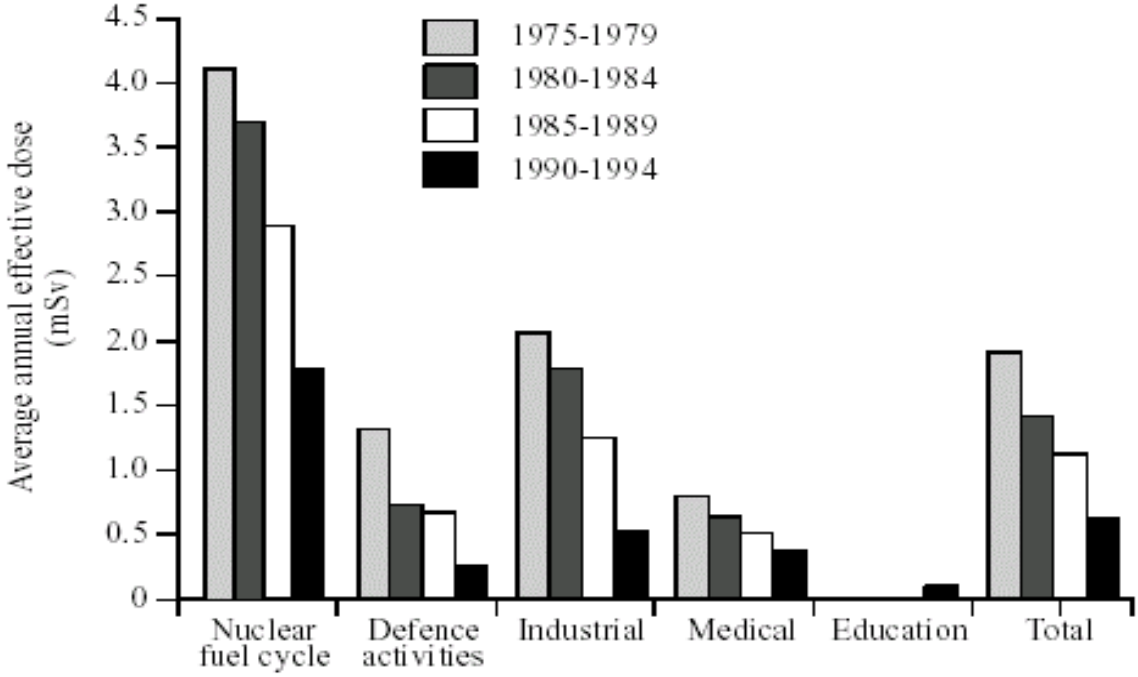
for occupational exposure over 35 years

[Pan, Protecting Workers Against Exposure To Ionizing Radiation, IAEA, 2003]

Substance	Effect	TLV	Lifetime risk** for occupational exposure over 35 years
Nickel compounds	Lung Cancer	200 µg·m^{-3} /8 h	0.9 E-2
Arsenic	Lung Cancer	10 µg·m^{-3} /8 h	0.2 E-2
Ionizing radiation	Fatal Cancer	20 mSv/a	2.8 E-2
Benzene	Leukemia	16 000 µg·m^{-3}/8 h	1 E-2
Asbestos	Lung Cancer, mesothelioma	0.1 fibre·cm^{-3} /8 h	0.2 E-2

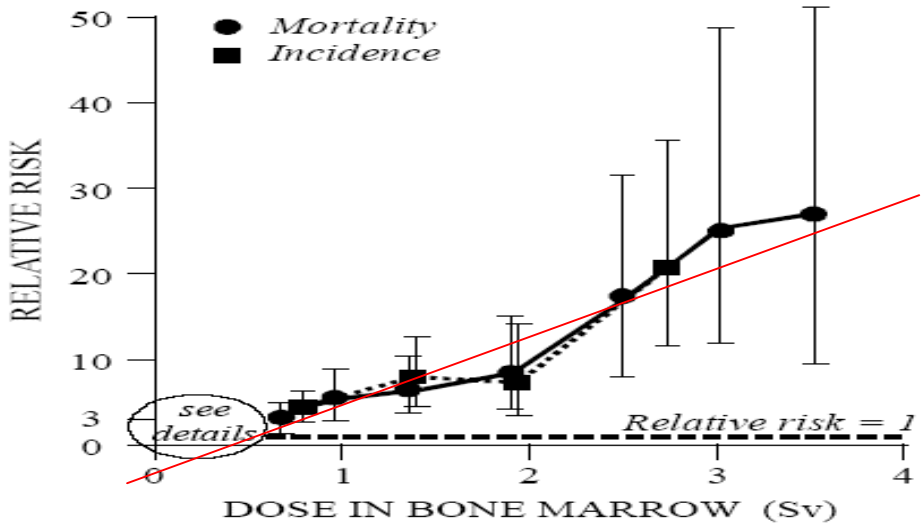
Note that the averaged dose of workers were less than the 20 mSv/a dose limits.

Trends in worldwide average annual number of monitored workers and doses to workers from man-made sources of radiation. [UNSCEAR 2000]



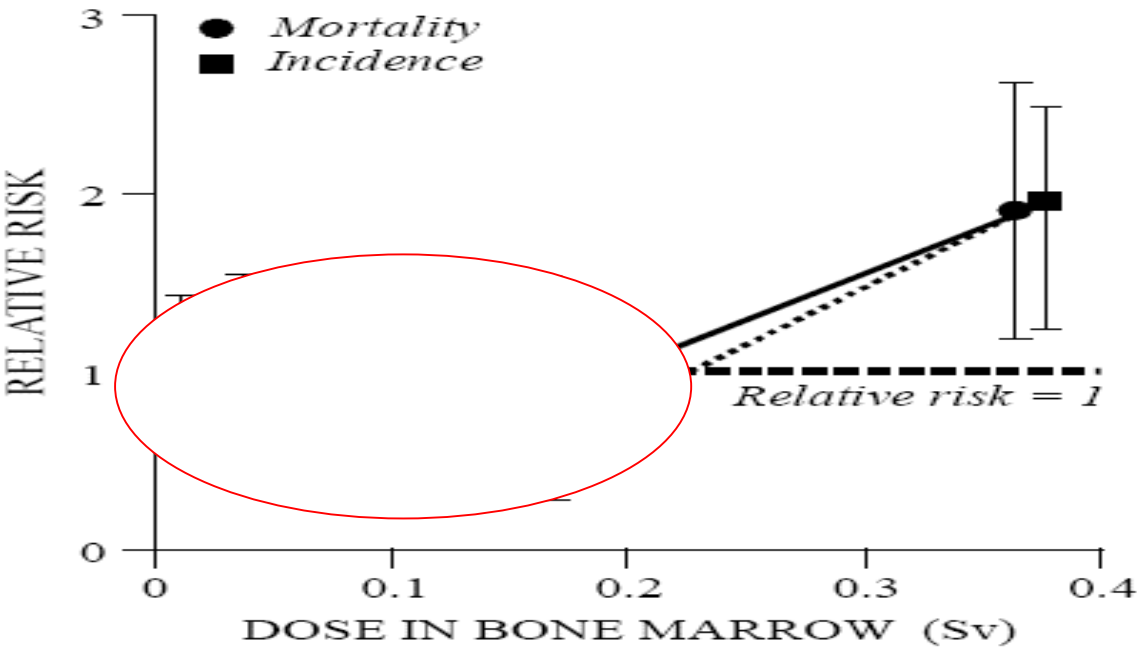
Discussion on Health effects of low dose radiation.

Linear No threshold Hypothesis



Relative risk of leukaemia in survivors of the atomic bombings

Linear No threshold Hypothesis for low dose?



- **Relative risk of leukaemia in survivors of the atomic bombings**
- **UNSCEAR 2000**

Summary

- There is a health risk in exposure to radiation.
- There is an “acceptable” level, Dose Limits.
- However, the exposures must be kept as far as reasonably practical.

Sources of Information

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