The International Framework for Radiation Safety

HISTORY, SCIENCE, PHILOSOPHY AND PRACTICE

DUBLIN, 2009 AUGUST 18

Chris Clement
Scientific Secretary
International Commission on Radiological Protection
Overview

THE EVOLUTION OF THE SYSTEM OF RADIOLOGICAL PROTECTION

INTERNATIONAL ORGANIZATIONS CENTRAL TO RADIOLOGICAL PROTECTION

ICRP & ITS CURRENT ACTIVITIES
The Evolution of the System of Radiological Protection

HISTORY

SCIENCE

PHILOSOPHY / ETHICS

&

THE SYSTEM OF RADIOLOGICAL PROTECTION
# Radiological Protection

## AS WE TRACE THE HISTORY OF RADIOPHICAL PROTECTION

<table>
<thead>
<tr>
<th>Circumstances of exposure considered</th>
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<tr>
<td>Who / what is being protected</td>
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<tr>
<td>Known effects of radiation exposure</td>
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<tr>
<td>The ethical basis of protection</td>
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<tr>
<td>Protection methods</td>
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</table>
The Discovery of Ionizing Radiation

X-rays were discovered by Wilhelm Roentgen in 1895, for which he received the first Nobel prize in physics in 1901.

X-ray of the hand of Bertha Roentgen (1895)
1985: Röntgen Demonstrates X-rays
Early Radiation Safety Concerns

- X-ray dermatitis of the hands was observed in the U.S. by Grubbe.

- Drury described radiation damage to the skin of the hands and fingers of early experimental investigators in the UK.
In December 1896 Wolfram Fuchs gave the first protection advice:

- make the exposure as short as possible
- do not stand within 12 inches (30 cm) of the x-ray tube
- coat the skin with Vaseline and leave an extra layer on the area most exposed
Escalating Radiation Safety Concerns

In the first decades of the 20th century ignorance about the risks of exposure to radiation caused numerous injuries despite the many papers published on tissue damage caused by radiation.
Radiation: Useful but Dangerous

tube

70,000 volts

stopwatch

ICRP

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION
Other Early Developments

- 1898 – Curie describes radium
- c. 1900 – Radiotherapy
- 1902 – Mobile x-ray units demanded for South African war

Early radiotherapy equipment and results of epilation treatment by x-ray
Encouraged by growing radiation safety concerns, the first International Congress of Radiology was held in London in 1925.

The most pressing issue was that of quantifying measurements of radiation, so the International Commission on Radiation Units and Measurements (ICRU) was created.
The second International Congress of Radiology was held in Stockholm in 1928.

The International X-Ray and Radium Protection Committee, precursor to the International Commission on Radiological Protection (ICRP), was established, and Rolf Sievert named chairman.
Radiological Protection: 1928

Effects / Science

- Concerned with occupational exposure in medicine
- Concerns are threshold (deterministic) effects
- “The effects to be guarded against are (a) injuries to superficial tissues, (b) derangements of internal organs and changes in the blood”

Protection

- “An X-ray operator should on no account expose himself unnecessarily to a direct beam of X-rays”
- “An operator should place himself as remote as practicable from the X-ray tube. It should not be possible for a well rested eye of normal acuity to detect in the dark appreciable fluorescence of a screen placed in the permanent position of the operator.”
Deterministic Effects

There are no effects below a threshold dose.

Above the threshold, the severity of the effect increases with dose.
Radiological Protection: 1930’s – early 1950’s

**Effects / Science**
- Concern expands to all occupational exposures
- Focus continues to be on threshold (deterministic) effects
- Increasing knowledge of dose thresholds for adverse effects

**Protection**
- 1934: daily tolerance dose introduced ~2 R / day
- 1951: weekly permissible dose introduced at 0.3 R / week (~150 mSv/a) because earlier value “seems very close to the probable threshold for adverse effects”
- 1951: “every effort be made to reduce exposures to all types of ionizing radiations to the lowest possible level”
The mid-1950’s: Everything Changed

- March 1, 1954: The Lucky Dragon (Japanese tuna fishing boat) contaminated by nuclear fallout from the US Castle Bravo thermonuclear device test on Bikini Atoll
- Crew of 14 diagnosed with acute radiation syndrome
Radiological Protection: 1950’s

<table>
<thead>
<tr>
<th>Effects / Science</th>
<th>Protection</th>
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<tbody>
<tr>
<td>Concerned with all occupational exposures</td>
<td>“In view of the incomplete evidence ... it is strongly recommended that every effort be made to reduce exposure to all types of ionising radiation to the lowest possible level”</td>
</tr>
<tr>
<td>Emerging science on:</td>
<td>Doses to the public are considered distinct from occupational and medical doses</td>
</tr>
<tr>
<td>- Superficial injuries</td>
<td>Occupational “dose” limit ~50 mSv/a</td>
</tr>
<tr>
<td>- General effects on the body, particularly blood and blood-forming organs, e.g. anaemia and leukaemia</td>
<td>Public dose limit 5 mSv/a</td>
</tr>
<tr>
<td>- Malignant tumour induction</td>
<td></td>
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<tr>
<td>- Other deleterious effects including cataracts</td>
<td></td>
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<tr>
<td>- Genetic effects</td>
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By 1955 excess leukaemia is observed in survivors of Hiroshima and Nagasaki
Stochastic Effects & LNT

The linear no-threshold (LNT) model assumes:

- The **probability** of an effect increases linearly with dose.
- There is no **threshold** dose below which there is no risk.
Radiological Protection: 1960’s

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<td>• It is clear that some effects (e.g. cancer induction) are stochastic in nature, rather than deterministic</td>
<td>• “for the purposes of radiological protection ... [assume] a linear relationship between dose and effect, and that doses act cumulatively”</td>
</tr>
<tr>
<td>• The probability of a stochastic effect increases with dose (without threshold)</td>
<td>• This LNT assumption “may be incorrect, but ... unlikely to lead to the underestimation of risks”</td>
</tr>
<tr>
<td>• The severity of a deterministic effect increases with dose (with threshold)</td>
<td>• “any exposure may involve some degree of risk”</td>
</tr>
<tr>
<td></td>
<td>• “any unnecessary exposure be avoided and that all doses be kept as low as is readily achievable, economic and social consequences being taken into account”</td>
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</table>
Radiological Protection: 1970’s – 1990’s

Philosophy / Ethics

- “Radiation protection is concerned with the protection of individuals, their progeny and mankind as a whole, while still allowing necessary activities from which radiation exposure might result”

- Control the risk from stochastic effects, and avoid deterministic effects

- “if man is adequately protected then other living things are also likely to be sufficiently protected”

Protection

- Justification: “no practice shall be adopted unless its introduction produces a positive net benefit”

- Optimization: “all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account” (ALARA)

- Individual Dose Limitation: “doses to individuals shall not exceed the limits”
Moral Philosophy (Ethics)

The study of the moral value of human conduct

**Normative Ethics:** Figuring out what is right and what is wrong behaviour

**Consequence**
- **Utilitarian Ethics**
  Actions are judged by their consequences

**Duty**
- **Deontological Ethics**
  Actions are judged based on duty or obligation

**Virtue**
- **Virtue Ethics**
  Focus on habits of character of a person
Utilitarian Ethics

Originate ~300 BC in the work of the ancient Greek philosopher Epicurus

Further developed in 19c England by Jeremy Bentham and John Stuart Mill

- **Actions are judged by their consequences**

- **Consequentialism**: An action is morally right if the consequences of that action are more favourable than unfavourable

- **Utilitarianism**: An action is morally right if the consequences of that action are more favourable than unfavourable to everyone

- Maximize net benefit to society

“The needs of the many outweigh the needs of the few”
Deontological Ethics

Immanuel Kant, an 18th century German philosopher, the father of modern deontological ethics

• Actions are based on duty or obligation
• Focus on the moral rightness, or intrinsic goodness, of an action
• Some actions are right (or wrong), irrespective of the consequences that might follow
• Kant argued there is a single self-evident principle of duty, the “categorical imperative”
• Act according to rules that you would apply universally

“the needs of the one... outweigh the needs of the many”
## Value Judgements in Radiological Protection

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<tr>
<th><strong>Utilitarian ethics</strong></th>
<th><strong>Deontological ethics</strong></th>
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<td>Actions are judged by their consequences</td>
<td>Actions are based on duty or obligation</td>
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<tr>
<td><strong>Justification</strong></td>
<td><strong>Dose Limitation</strong></td>
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<tr>
<td>- Do more good than harm</td>
<td>- No individual is unduly harmed</td>
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<tr>
<td><strong>Optimization</strong></td>
<td></td>
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<tr>
<td>- Maximize good vs. harm</td>
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### Radiological Protection Today

**Philosophy / Ethics**

- “an appropriate level of protection for people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure”
  - Increased focus on deontological ethics i.e. concern for the individual
  - Increased focus on protection of the environment

**Protection**

- *Justification, Optimization* and *Individual Dose Limitation* remain cornerstones of the system of protection
  - Dose constraints aid in optimization while effectively increasing dose equity
  - The environment seems to be adequately protected, but there is a greater need to demonstrate this
Value Judgements in Radiological Protection

**Utilitarian ethics**
- Actions are judged by their consequences

  - Justification
    - Do more good than harm

  - Optimization
    - Maximize good vs. harm

**Deontological ethics**
- Actions are based on duty or obligation

  - Dose Limitation
    - No individual is unduly harmed

  - Dose Constraints
    - Aid optimization & increase equity
## Radiological Protection Then and Now

<table>
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<th>THEN</th>
<th>NOW</th>
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<tr>
<td>Occupational exposure in medicine</td>
<td>All occupational exposure</td>
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<tr>
<td>Protection of man</td>
<td>Assume protection of the environment</td>
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<tr>
<td>Deterministic effects only</td>
<td>Recognition of stochastic effects</td>
</tr>
<tr>
<td>Avoid all harm</td>
<td>Main focus on utilitarian ethics</td>
</tr>
<tr>
<td>Practical advice</td>
<td>Dose limits</td>
</tr>
<tr>
<td></td>
<td>Optimization and limits</td>
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**THEN**
- Occupational exposure in medicine
- Protection of man
- Deterministic effects only
- Avoid all harm
- Practical advice

**NOW**
- All occupational exposure
- Assume protection of the environment
- Recognition of stochastic effects
- Main focus on utilitarian ethics
- Dose limits

**ICRP**

**INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION**
International Organizations Central to Radiological Protection

WHO THEY ARE, WHAT THEY DO, AND HOW THEY INTERACT

ICRP, UNSCEAR, IAEA
AND OTHERS
ICRP

International Commission on Radiological Protection

- Established in 1928 to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionising radiation

- Produces recommendations on radiological protection adopted world-wide, based on science and value judgements
United Nations Scientific Committee on the Effects of Atomic Radiation

- Established by the UN in 1955 to assess and report levels and effects of exposure to ionizing radiation
- Provides the scientific basis for evaluating radiation risk and for establishing protective measures
Established within the UN family in 1959 as the world’s "Atoms for Peace" organization to promote safe, secure and peaceful nuclear technologies

Wide range of programmes, including development of Safety Standards in regulatory language
Other International Organizations

- International Commission on Radiation Units and Measurement (ICRU)
- OECD Nuclear Energy Agency (NEA)
- CEC Euratom
- International Radiation Protection Association (IRPA)
- International Commission on Non-Ionizing Radiation Protection (ICNRP)
- ILO, WHO, PAHO, FAO, ISO, IEC, IARC, etc.
THE INTERNATIONAL COMMISSION ON RADIOPHYSICAL PROTECTION
ICRP

• Established in 1928 by the International Society of Radiology to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionising radiation

• Independent Registered Charity (not-for-profit organization) in the United Kingdom

• Scientific Secretariat in Canada
ICRP Recommendations: Primary Aim

To contribute to an appropriate level of protection for people and the environment without unduly limiting the desirable human activities that may be associated with radiation exposure.
Main Commission 2009-2012

- Dr. Claire Cousins (Chair)
- Dr. Abel González (Vice-Chair)
- Dr. Julian Preston (Chair, Committee 1 – Effects)
- Dr. Hans-Georg Menzel (Chair, Committee 2 – Doses)
- Professor Eliseo Vañó (Chair, Committee 3 – Medicine)
- Dr. Jacques Lochard (Chair, Committee 4 – Application)
- Professor Jan Pentreath (Chair, Committee 5 – Environment)
- Dr. John Boice
- Dr. John Cooper
- Professor Jai-Ki Lee
- Dr. Ohtsura Niwa
- Dr. Zi Qiang Pan
- Dr. Nataliya Shandala

Scientific Secretary: Christopher Clement
ICRP: Recent Publications

- **P 103**: The 2007 Recommendations of the International Commission on Radiological Protection (a major milestone, replacing previous fundamental recommendations of 1990)
- **P 104**: Scope of Radiological Protection Control Measures
- **P 105**: Radiological Protection in Medicine
- **P 106**: Radiation Dose to Patients from Radiopharmaceuticals - A third amendment to ICRP Publication 53
- **P 107**: Nuclear Decay Data for Dosimetric Calculations
ICRP: Upcoming Publications

- **P 108**: Environmental Protection: the Concept and Use of Reference Animals and Plants
- **P 109**: Application of the Commission’s Recommendations for the Protection of People in Emergency Exposure Situations
- **P 110**: Reference computational phantoms of the adult male and female (jointly with ICRU)
- Application of the Commission's Recommendations to the Protection of Individuals Living in Long Term Contaminated Areas After a Nuclear Accident or a Radiation Emergency
- Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies
ICRP: Other Initiatives (1)

- Conducting an in-depth review of recommendations with respect to radon in the home and workplace
- Assessing new information on effects of exposure to the lens of the eye
- Updating publications on solid long lived waste disposal and on occupational exposure, and developing a new publication on NORM
- Improving the understanding and use of effective dose
- Elaborating a system of radiological protection of the environment
ICRP: Other Initiatives (2)

- Providing further guidance on radiological protection in medicine:
  - Evaluation and management of secondary cancer risk in radiation therapy
  - Radiological protection in cardiology
  - Protecting children: diagnostic techniques involving ionising radiation

- Providing further guidance on doses:
  - Dose conversion coefficients
  - Radiation exposures to aircrew
  - Radiological protection dosimetry in space
  - Internal SAF values in the reference adult male and female
Christopher Clement M.Sc. CHP
Scientific Secretary
International Commission on Radiological Protection
PO Box 1046, Station B
280 Slater Street
Ottawa, Ontario K1P 5S9
CANADA

sci.sec@icrp.org

www.icrp.org