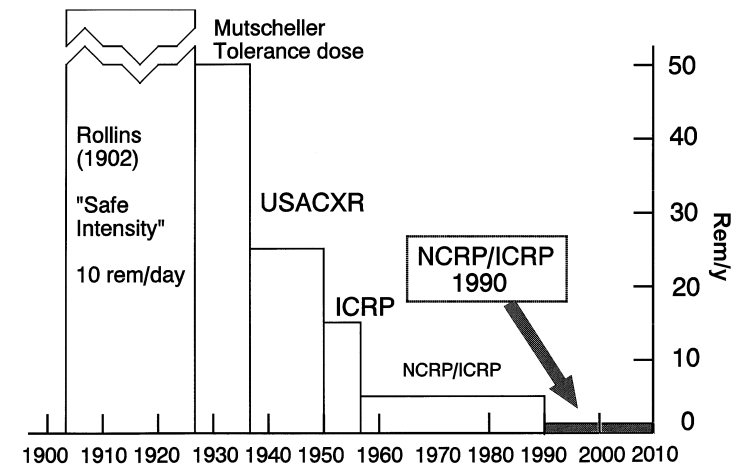
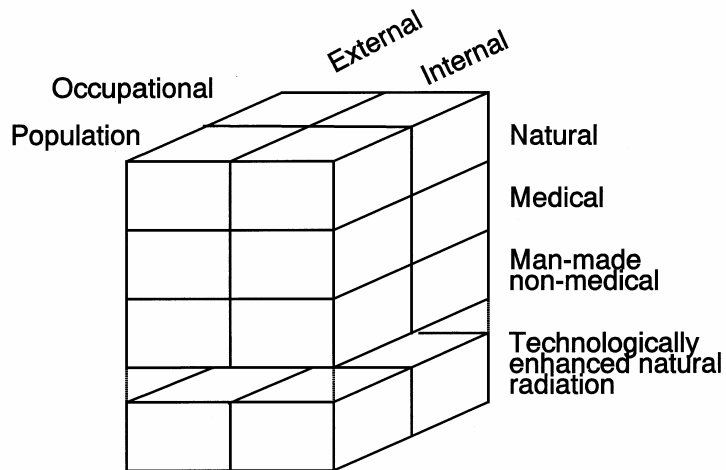


Standards and Regulations

HPHY 6605
2012

Standards Development

- Standards are based on justification, limitation and ALARA (optimization) and should strike a balance between risk and benefit (Cost Benefit Analysis)
- Standards were originally for radiation workers
- Environmental radiation standards are related to worker but came decades later
 - Radiation standards have traditionally applied only to humans -now more interest in standards for other biota



Early Standards Development

- Acute, deterministic radiation injury was noted soon after the 1896 discoveries of x rays and radioactivity
- Initial injuries were noted primarily on skin – erythema (reddening), epilation (hair loss), etc.
- Radiation energy was low
- A "safe intensity" was recommended by Rollins in 1902, equivalent to 10 R/day, and other recommendations were suggested
- These suggested limits were to prevent readily observable deterministic effects

Early Standards Development

- By mid-1930's the radium dial painter problem had surfaced and a need to protect against "internal emitters" was apparent
- In 1949 the US National Committee On Radiation Protection recommended that the dose be reduced to 0.3 R/week
- The ICRP followed suit in 1950
- Changes made to be on safe side and because higher energy radiations were being used

Early Standards Development

- By 1925 some late effects were known and drastically reduced limits were necessary
- Mutscheller in 1925 recommended a limit equivalent to 50 R/year
- The international x-ray and radium protection commission adopted Mutscheller's value in 1934
- In 1936 the US Advisory Committee on X-ray and Radium Protection cut the 50 R value in half

More Recent Standards

- By 1956 genetic effects were firmly established, and radiation use was expanding dramatically
- Occupational whole body dose was reduced to 0.1 R/week by ICRP and NCRP
 - Organ doses remained at 0.3 R/week
- 1956 also marked introduction of dose limits for the general public
- Limits were set at 1/10 of worker levels

Standards for the Public

- Reasons for a public dose limit lower than the occupational limit
 - General population less homogeneous in age and health status (healthy worker effect)
 - No personal dosimetry or regular medical exams
 - Much larger population
 - No tacit assumption of risk

Federal Radiation Council

- Also in 1959 the Federal Radiation Council was formed to provide radiation protection guidance
 - EPA has taken over functions of FRC
- FRC affirmed 0.5 rem per year as a radiation protection standard for the public but stated that an average of 1/3 that amount or 170 mrad/year was equivalent
- Guide was on the order of natural background estimates at the time

Influence of Genetic Effects on the Standard for the Public

- By 1959 the doubling dose for genetic effects had been estimated at 30-80 rad
- ICRP decided that 10 rad from birth to age 30 was a sufficiently small fraction
- The 10 rad was evenly divided between medical (5) and other (5)
- The 5 rad over 30 years is 170 mrad per year

1971 NCRP Standards

- NCRP issued basic radiation protection recommendations in 1971
- These recommendations are still the basis of the current NRC worker dose limit of 5 rem per year for the occupationally exposed
- Application of the 1/10 guideline lead to a 500 mrem/year recommendation for the public

1990 ICRP Worker Standards

- ICRP standards for workers (Report 60, 1990):
 - Effective dose of 100 mSv in 5 years and 50 mSv in one year
 - Lens: 150 msv/year
 - Skin and hands: 500 mSv/year
 - Effective dose limit assumed to cover other organs with rare exception
- ICRP fetus standards: 5 mSv after diagnosis

1993 NCRP Worker Standards

- 1993 NCRP worker standards for stochastic effects: 50 mSv/year with cap of 1 rem (10 mSv) per year of age
 - This recommendation was never adopted into regulations
- NCRP worker organ standards for deterministic effects: 150 mSv/year for lens of eye, 500 mSv/year for all other organs and tissues
- NCRP fetus standards: 5 mSv total, 0.5 mSv/month

1990 ICRP Public Dose Standards

- 1990 ICRP standards for public (Pub. 60):
 - effective dose of 1 mSv (100 mrem) per year averaged over 5 years
 - Skin and hands: 1/10 of occupational levels

1993 NCRP Public Standards

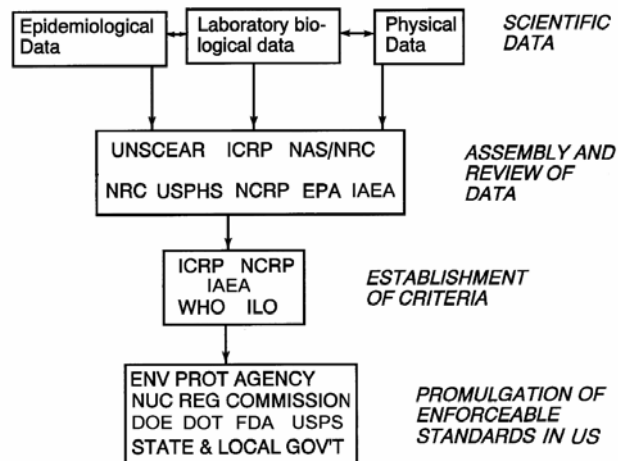
- 1993 NCRP standards for public are
 - One mSv/year equivalent dose
 - organ and tissue limits at 1/10 of worker standards

2007 ICRP Standards

- The dose limits for occupational and public exposures for practices are retained from the 1990 recommendations
 - applied to regulated sources in planned exposure situations
- Next slide reviews modern standard setting process with application to the United States

Public vs. Environmental Standards

- Kocher (1991) makes a useful distinction between a "radiation protection standard for the public" and "environmental radiation standards"
- A **radiation protection standard for the public** is usually applicable to the sum of all except natural and medical sources of radiation



Public vs. Environmental Standards

- In contrast **environmental radiation standards** are promulgated for specific practices or sources
 - include ALARA-based standards
 - may be expressed in terms of dose, concentration, total activity permitted to be released, or even site design and operation
 - often expressed as laws or regulations (rules)

AEC Regulations

- The regulatory division of AEC (now NRC) stated that power plants should not expose any member of public to more than 5 mrem per year
 - early example of ALARA or optimization of protection leading to an environmental radiation standard

EPA Environmental Regulations

- In 1990 EPA air pathway limit was reduced to 10 mrem EDE
 - EDE is “effective dose” in ICRP Publication 60 terms
- Doses from air emissions for licensees are now regulated by NRC as a “constraint”
- Dose Constraint
 - Dose constraints for specific sources or pathways are intended to ensure that the total dose from all controlled sources remains within the dose standard for the public

EPA Regulations

- In 1985 EPA regulated the dose by the air pathway through NESHAPS (National Emission Standards for Hazardous Air Pollutants), 40 CFR 61 to
- 25 mrem whole body
 - 75 mrem organ
- EPA did not want to do this, claiming that existing controls were adequate
 - Sierra Club forced EPA to regulate under the carcinogen rule

EPA Environmental Regulations

- Elemental phosphorus plants are regulated on an emission basis; standard has declined over the years from 21 to 2 Ci of polonium-210 for calciners and nodulizing kilns not to exceed 4.5 Ci per plant
- Radon emissions from mines are limited to 10 mrem/y
- Uranium mill tailings piles limited to a flux of 20 pCi/(m² s) of radon

EPA and NRC Regulations

- NRC limits public dose from licensed operations to 100 mrem/year and 2 mrem in any one hour (10 CFR 20.1301)
- For the uranium fuel cycle, EPA limits the annual dose equivalent as the result of exposures to planned discharges of radioactive materials except radon (40 CFR 190.10) to:
 - 25 mrem to the whole body,
 - 75 mrem to the thyroid, and
 - 25 mrem to any other organ
 - Emissions of some radionuclides are also limited annually to
 - < 50,000 curies of krypton-85
 - < 5 millicuries of iodine-129
 - <0.5 millicuries combined of Pu-239 and other α -emitting transuranics with half-lives >1 year

There is no international agreement about drinking water limits, e.g., tritium

Country	Tritium Limit (nCi/L)
European Union	2.7
United States	20
Canada	190
Russia	210
Switzerland	270
WHO	270
Finland	810
Australia	2060

Canadian Nuclear Safety Commission, Standards and Guidelines for Tritium in Drinking Water, INFO-0766, 2008

EPA Drinking Water Regulations

- Drinking water is protected by EPA to 4 mrem per year for beta and gamma emitters plus specific concentration limits for a few natural radionuclides (40 CFR 141)
- An attempt was made in 1991 to allow calculation of concentrations corresponding to 4 mrem/y with modern dose coefficients
 - For example, the tritium standard would have gone from 20 to 60 nCi/l
 - This was viewed by Congress as non-protective and EPA was forbidden to “weaken” the standards
- New drinking water regulations were issued in 2000, but the only significant change was the addition of a 30 $\mu\text{g/L}$ standard for total uranium

Doe Orders

- Doe orders also limit public exposure to 1 mSv/year from all pathways but DOE effectively limits dose to 0.3 mSv/year through policy
 - This policy can be thought of as a form of dose constraint

Recent EPA and NRC Regulations

- EPA has proposed rulemaking to reduce the maximum dose to the public to 1 mSv/y from 5 mSv/y but it met with resistance
- EPA also has a policy to limit the residual annual dose from remediated sites to 0.15 mSv
- NRC has a rule to limit the residual annual dose from remediated sites to 0.25 mSv and the contrast engendered much debate

De minimus or BRC

- “*De minimus risk*” refers to a very small risk from a product or practice. Also called “below regulatory concern” (BRC)
- If the risk is very small, then it is not considered worth expending public time and funds in controlling the product or practice
- Efforts to incorporate the concept of *de minimus* or BRC into regulation has met with resistance from public interest groups and have apparently been abandoned

Protecting Plants And Animals From Radiation

- ICRP 60 (1990) - The standard of environmental control needed to protect man will ensure that other species are not put at risk
- ICRP 103 (2007) reaffirms that the standards of environmental control needed to protect the general public will protect other species
- ICRP does not propose to set any form of dose limits for environmental protection
- However,
 - ICRP proposes use of reference animals and plants
 - Doses to reference organisms could be compared with doses for specific effects and with natural doses

Examples of Exposures, Guides, Standards, and Regulations

Working Level

- A unit of radon decay product concentration
- Any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 130,000 MeV of potential alpha energy
- Approximately the total alpha energy released by short-lived decay products in radioactive equilibrium with 100 pCi per liter of Rn-222 in air

Exposure Condition	Dose (mrem/y)	Type
Lowest Radon Daughter Level at which EPA Recommended Remedial Action Within Weeks (1.0 WL)	50,000	Guide
Radiation Worker Limit	5,000	Regulation
Lowest Radon Daughter Level at which EPA Recommended Remedial Action Within Several Months (0.1 WL)	5,000	Guide
Highest Radon Level for which Remediation was Recommended by EPA Within a Few Years (0.1 WL)	5,000	Guide
Radon Daughter Limit for Uranium Miners (4 WLM per year without gamma)	4,000	Regulation

Working Level Month

- A unit of accumulated human exposure to radon decay products
- 1 WLM = 1 WL exposure for 170 hours
- In U.S. underground mines, the limits are
 - 1 WL concentration
 - 4 WLM per year cumulative exposure
- In homes, the U.S. EPA recommends exposure levels not exceeding 4 pCi/L
 - equivalent to about 0.02 WL, because the decay product equilibrium indoors is about 50%

Exposure Condition	Limit (mrem/y)	Type
Lowest Radon Level for which Remediation is Recommended by EPA (0.02 WL). Action within a few years was recommended in 1986. No time is specified in 1992.	1,000	Guide
Lowest Radon Level for which EPA now recommends that homeowners consider remedial action(0.01 WL).	500	Guide
NCRP Remedial Action Threshold for natural radionuclides (including background)	500	Standard
NCRP recommended limit for infrequent exposure & EPA regulatory limit for the public	500	Standard
Average dose to U.S Citizen from all sources	360 (630)*	Exposure

*NCRP 2009

Exposure Condition	Limit (mrem/y)	Type
Average Indoor Radon (0.004 WL)	200 (220)*	Exposure
Gamma Radiation Limit for Buildings Contaminated with Uranium Mill Tailings (Above Background)	175	Standard
Typical Dose to Civilian Air Crews	160	Exposure
NCRP recommended limit & NRC limit for continuous or frequent exposure of the public	100	Standard/Regulation
U.S Average Natural Background Except Radon	100 (84)*	Exposure
Cosmic Ray Background in Idaho	58	Exposure

*NCRP Report 160, 2009

Exposure Condition	Limit (mrem/y)	Type
Drinking Water Limit for Radon (300 pCi/L, Proposed by EPA)	8	Proposed Regulation
One Transcontinental Round Trip per Year by Air	5	Exposure
Drinking Water Limit for Beta-Gamma emitters (EPA)	4	Regulation
Proposed de minimus, negligible, or below regulatory concern dose	1	Proposed Guideline
U.S Average Dose from Air Travel	1	Exposure

Exposure Condition	Limit (mrem/y)	Type
U.S. Average for Diagnostic Radiography Including Nuclear Medicine	53 (300)*	Exposure
Natural Gamma Background in Idaho	47	Exposure
U.S. Average for Internally Deposited Radioactivity	40 (28)*	Exposure
U.S Average Natural Gamma Background	28 (22)*	Exposure
U.S Average Natural Cosmic Ray Background	27 (34)*	Exposure
Maximum Individual Dose Limit from Nuclear Facilities – Air pathway	10	Regulation

*NCRP Report 160, 2009