ASTAR

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Current State of Human Health Standards

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History of Standards

Georg Bauer ("Agricola")

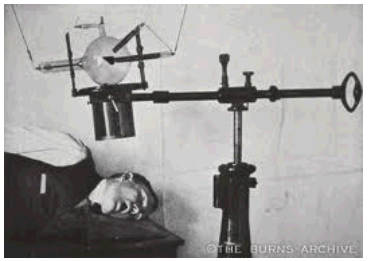
Prior to 1895:

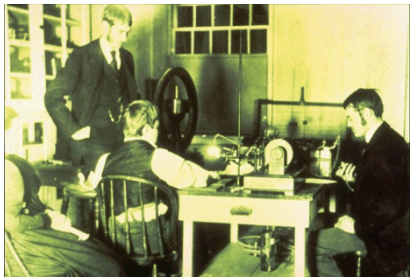
- Existence of radiation and ionizing substances unknown
- *Harmful properties* of radioactive substances well known
  - 15th century – uranium miners in Erzgebirge, Germany "cursed" with "*Bergsucht*" (current day lung cancer)
  - 16th century – first recommendations for the use of ventilation in mines and the use of hand-made inhalation filters
- No radiation protection standards for the industry

History of Standards (Cont.)

Period 1895-1914:

- Wilhelm Roentgen discovers x-rays (Nov. 1895)
- First diagnostic x-ray taken, followed quickly by first x-ray picture of a fetus in utero (Feb. 1896)
- First dental x-rays taken (Mar. 1896)
- Early ignorance of the hazards resulted in numerous unexpected injuries

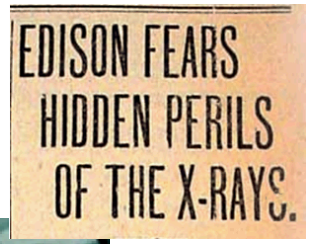


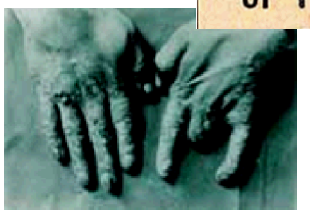


History of Standards (Cont.)

Period 1895-1914 (Cont.):

- Thomas Edison reports eye injuries from working with x-rays (Mar. 1896)
  - Experimenters cautioned *not to get too close to x-ray tubes* (June 1896)
  - Some researchers set-out to publicize the hazards and establish limits on exposure (July 1896)
- Cases of hair loss, reddened skin, skin sloughing off, and lesions reported (late 1896)
- Potential carcinogenic effect of x-ray exposure in humans reported (early 1900s)





History of Standards (Cont.)

Period 1895-1914 (Cont.):

- Dec. 1896: First recommended protective measures published
  - Make the exposure as short as possible
  - Do not place the x-ray tube closer to the body than 12 inches
  - Rub the skin carefully with Vaseline and leave a layer on the part that shall be exposed

- 1902: First dose limit recommended [10 rem (0.1 Sv) per day; 3,000 rem (30 Sv) per year]
  - Limit based upon lowest amount of x-rays that could be easily detected

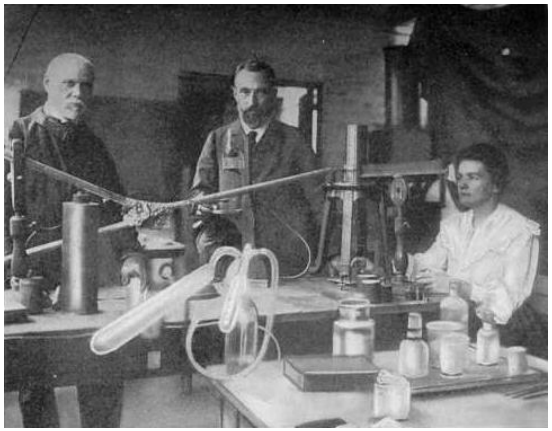
History of Standards (Cont.)

Period 1895-1914 (Cont.):

- Henri Becquerel discovers radioactivity
- Marie and Pierre Curie discover polonium and radium
- No radiation protection standards or limits for the use of radioactive substances

Henri Becquerel, 1896

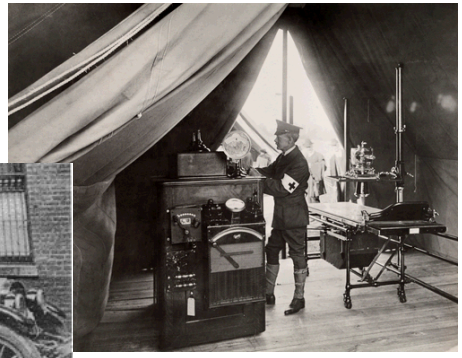
Marie & Pierre Curie, 1898



History of Standards (Cont.)

Period 1915-1940:

- Earlier recommended protective measures and dose limits ignored
  - General ignorance of hazards of diagnostic x-rays resulted in radiation injuries among doctors and nurses
- Number of radiation injuries increases as primitive equipment comes into heavy use during WWI



History of Standards (Cont.)

Period 1915-1940 (Cont.):

- American Roentgen Ray Society recommends a "*tolerance dose rate*" for radiological workers (early 1924)
  - Based upon *observations* of physicians & technicians who *worked in shielded work areas*
  - Workers received ~1/10 of an erythema dose (~60 rem, 0.6 Sv) per month without signs of radiation injury
- Tolerance dose rate "limit" set at 70 rem (0.7 Sv) per year (Sept. 1924)
  - "… *radiation dose to which the body could be subjected without production of harmful effects*"

History of Standards (Cont.)

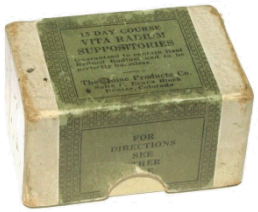
Period 1915-1940 (Cont.):

- International Commission on Radiological Protection (ICRP) founded (1928)
  - Recommends a common unit for quantifying x-rays
  - Recommends protective barriers and practices for the safe operation of x-ray installations, ***AND*** protection against radium (e.g., shielding, remote handling)

History of Standards (Cont.)

Period 1915-1940 (Cont.):

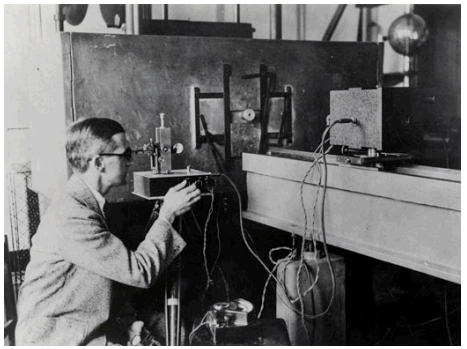
- Misuse of radium increasingly common
  - Luminous compounds containing radium used in paint
  - Radium looked upon as a source of healing
- Various dose limits proposed for radium, but concept of "dose" not mature (1920s)



History of Standards (Cont.)

Period 1915-1940 (Cont.):

- ICRP recommends its first quantitative dose limit: a “tolerance dose rate” of 0.2 rem (0.002 Sv)/day (1930)
  - Corresponds to 50 rem (0.5 Sv) per year
- U.S. Advisory Committee on X-Ray and Radium Protection proposes 1st formal standard for *protecting people from radiation sources* (Sept. 1934)
  - ~1/100 of an erythema dose (approx. 0.1 rem/day) (0.001 Sv/day)



History of Standards (Cont.)

Period 1941-1950:

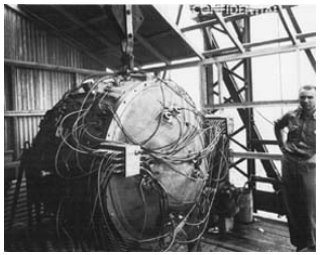
- Dose limits for radiation sources outside the body augmented by a limit on the amount of radium a person could tolerate inside the body (1941)
  - Clinical observations of 27 persons internally exposed to radium, combined with quantitative measurements of their radium body burdens, were the bases for the radium standard
  - Tolerance limit: 0.1 microgram (0.0000001 Ci) of radium

History of Standards (Cont.)

Period 1941-1950 (Cont.):

- Radium standard used as basis for setting the first tolerance limit for internal retention of plutonium (1944)
  - Working-lifetime limit of 5 micrograms (0.0000005 Ci)

- Manhattan Project reduces the plutonium limit to 0.06 microgram (0.00000006 Ci) (1945)
  - Reduction based upon animal studies on the relative toxicity of plutonium and radium, and on distribution in the body



- Hanford Site adopts a plutonium limit of 0.03 microgram (0.00000003 Ci)

History of Standards (Cont.)

Period 1941-1950 (Cont.):

- Concern for limiting/monitoring intakes of radium and plutonium inspires beginnings of the field of internal radiation dosimetry (1945)
- Atomic Energy Commission (AEC) established to oversee U.S. nuclear activities (1945)
- National Council on Radiation Protection (NCRP) established (1946)
  - Recommends reducing maximum permissible dose from 0.1 to 0.05 rem (0.0005 Sv) per day [or 12.5 rem/year]
  - Recommends maximum permissible concentrations of radioactive substances in air and water

History of Standards (Cont.)

<u>Period 1951-1956</u>:

- New concepts concerning measurement of dose developed
  - Absorbed dose, equivalent dose, relative biological effectiveness

- Experts from U.S., UK and Canada agree on:
  - External limit for *public*: 1.5 rem (0.015 Sv) per year
  - Internal exposure limit for radon in mines
  - Plutonium body-burden of 0.03 microgram (0.00000003 Ci)
  - Bone-marrow dose limit: 15 rem (0.15 Sv) per year
  - Skin dose limit: 0.6 rem (0.006 Sv) per week (1953)

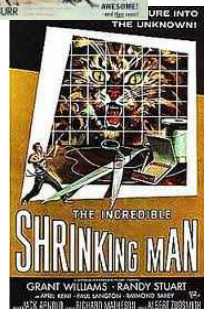
History of Standards (Cont.)

Period 1951-1956 (Cont.):

- Further reductions in external radiation exposure limits recommended as a result of:
  - Studies on survivors from Hiroshima and Nagasaki
  - Studies on survivors of high-dose medical procedures
  - Growing concerns re: potential for genetically significant doses
  - Growing concerns re: potential cancer risk (e.g., leukemia)
    - Use of x-rays to treat ankylosing spondylitis, tinea capitis, etc.
    - Use of shoe-fitting fluoroscopes and other commercial uses of x-rays (1956)

History of Standards (Cont.)

Period 1957-1965:

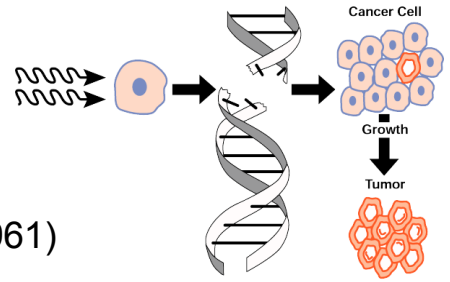


- Public fears mount re: possible genetic effects from radiation exposure
  - Leads to additional reductions in limits
- ICRP recommends an *occupational* dose limit of 5 rem (0.05 Sv) per year (1958)
- NCRP recommends a life-time occupational dose limit of D = 5 (N-18) rem (1958)
  - N = age in years
- NCRP recommends a dose limit of 0.5 rem (0.005 Sv) per year *for the public*

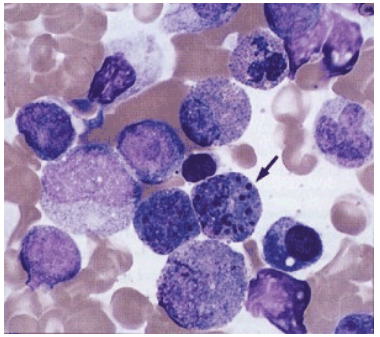
History of Standards (Cont.)

Period 1957-1965 (Cont.):

- Research indicates that risk of genetic radiation effects less than previously thought (from atomic bomb survivors) (1961)



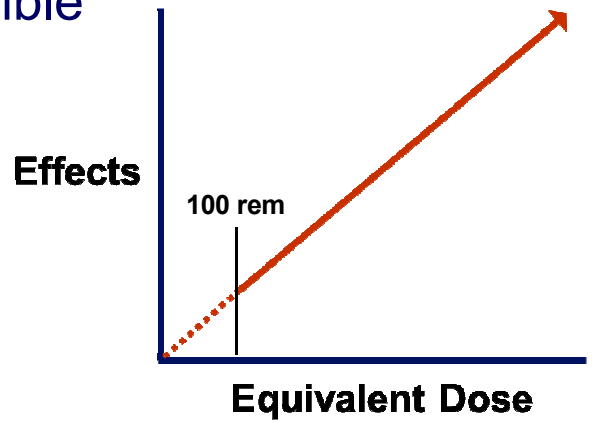
- Studies identify increased risk of cancer (leukemia) from radiation exposure
  - Elevated rates for solid tumor cancers also observed over time
  - Different cancers have different latency periods
    - Leukemia: 2 – 25 years
    - Solid tumors: 25 – 40 years



History of Standards (Cont.)

Period 1957-1965 (Cont.):

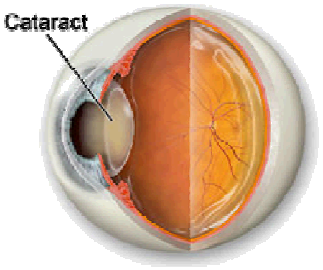
- Growing concern that even low levels of radiation exposure might induce cancer (1965)
  - No definitive data to support the concern
  - Data regarding malignancies were obtained from populations receiving large radiation doses at high dose rates
  - Risk estimates for low doses only possible by extrapolating high-dose data
    - Procedure suggests low cancer risks from low doses
  - No data to suggest the existence of a threshold dose for radiogenic cancers

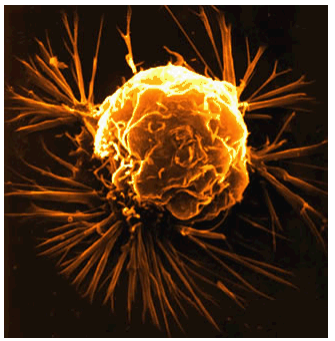


History of Standards (Cont.)

Period 1957-1965 (Cont.):

- ICRP shifts its radiation protection philosophy:
  - *OLD* focus: compliance with dose limits and avoiding "*deterministic*" effects (cataracts, permanent organ damage)
  - *NEW* focus: emphasis on reducing "*stochastic*" effects and overall cancer risks to working populations (1965)
  - Distinction between "normal operations" and accidents
  - Adopts NCRP's recommended "dose limit" of 0.5 rem (0.005 Sv) per year for *public* exposures

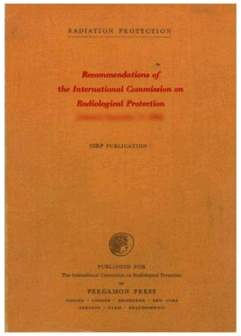




History of Standards (Cont.)

Period 1966-1978:

- Continued assumption of a linear dose-response relationship without any threshold dose
- Lung cancer risk from radon in uranium mines (and non-uranium mines) widely recognized
- ICRP publications summarize knowledge about radiation risks, both somatic and genetic (1966)
  - Probability of leukemia after a dose of 1 rem (0.01 Sv) estimated at 20 cases per million people exposed

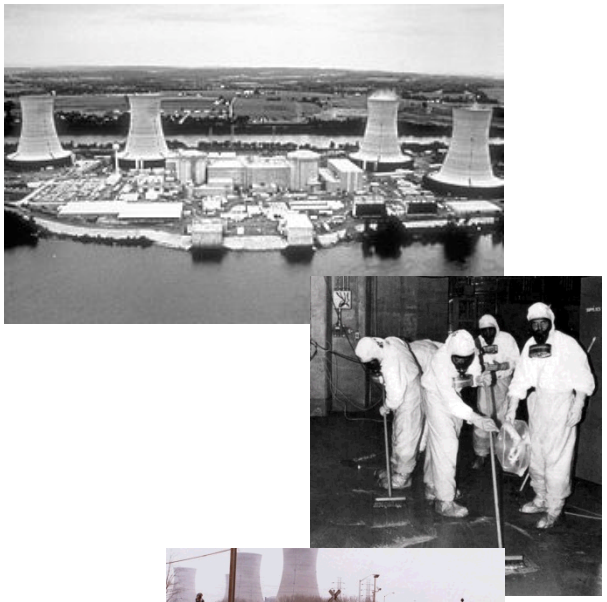


History of Standards (Cont.)

Period 1966-1978 (Cont.):

- ICRP adopts a more formal risk-based approach to setting standards (1977)
  - The average incremental risk of death from occupational radiation exposures in radiation industries should be no larger than the average incremental risk of death from traumatic injuries to workers in "safe" industries (10^{-4}/year)
- ICRP recommends a dose limit for radiological workers: 5 rem (0.05 Sv) per year
  - Recommended limit unchanged from the 1957 recommendation, but is now justified in terms of a risk-based philosophy

History of Standards (Cont.)



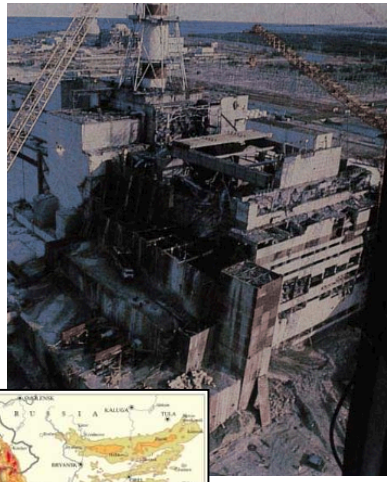
Period 1979-1990:

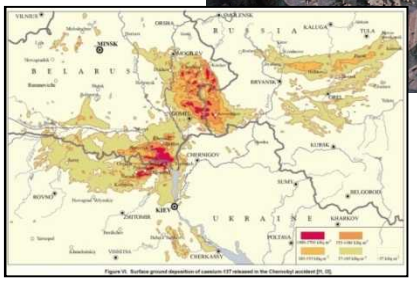
- Accident at Three-Mile Island (1979)
  - Huge impact on public acceptance of nuclear power
- Estimates of the doses received by atomic bomb survivors adjusted downward (1980)
  - New estimates of neutron-to-gamma ratios in the radiation at Hiroshima & Nagasaki
  - New data on cancer incidence/mortality among survivors indicates higher rates for some cancers than previously thought

History of Standards (Cont.)

Period 1979-1990:

- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) publishes report on indoor radon hazards and dose estimates: ~0.2 rem (0.002 Sv) per year (1982)
- Accident at Chernobyl (1986)
  - Growing suspicion regarding the safety of nuclear power
  - Increased efforts to establish a policy for avoiding accidental exposures





History of Standards (Cont.)

Period 1990-Today:

- ICRP recommends limiting occupational radiation exposures to 10 rem (0.1 Sv) over any 5-year period, and 5 rem (0.05 Sv) in any one year (1990)
  - Public limit: 0.1 rem (0.001 Sv) per year (averaged over any 5-year period)
- NCRP releases own set of national recommendations (1993)
  - Relate to both stochastic effects (e.g., cancer and genetic effects) and to deterministic effects (e.g., cataracts)
  - Consistent with ICRP recommendations

History of Standards (Cont.)

Period 1990-Today (Cont.):

- National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiation releases its BEIR V Report, "*Health Effects of Exposure to Low Levels of Ionizing Radiation*" (1990)
  - Using the linear no-threshold risk model: the average lifetime risk of death from cancer following an acute dose (to all body organs) estimated at 0.8%
  - Baseline risk of death due to cancer in the U.S. is 25%
  - A dose of 0.01 rem creates a risk of death due to cancer of approx. 1 in 1,000,000

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History of Standards (Cont.)

Period 1990-Today (Cont.):

- BEIR VI Report, "*Health Effects of Exposure to Radon*," released (1998)
  - Most extensive and thorough study to date of health effects attributed to exposure to radon and its decay products
  - Estimates 15,400 – 21,800 lung cancer deaths per year in the U.S. from radon exposure
    - Even very small exposures to radon can result in lung cancer
    - No evidence of a threshold of exposure below which radon levels are harmless

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History of Standards (Cont.)

Period 1990-Today (Cont.):

- BEIR VII Report, "*Health Risks from Exposure to Low Levels of Ionizing Radiation (Phase 2)*" released (1998)
  - Linear Non-Threshold model of cancer risk prediction validated (no evidence of a threshold for cellular damage)
  - Radiation-related cancer mortality risks for women ~37.5% higher than for men
  - Exposure in infants produces 3 - 4 times the cancer risk compared to adults
  - At low doses, the risk of cancer estimated at one excess cancer in 100 exposed persons during their lifetime

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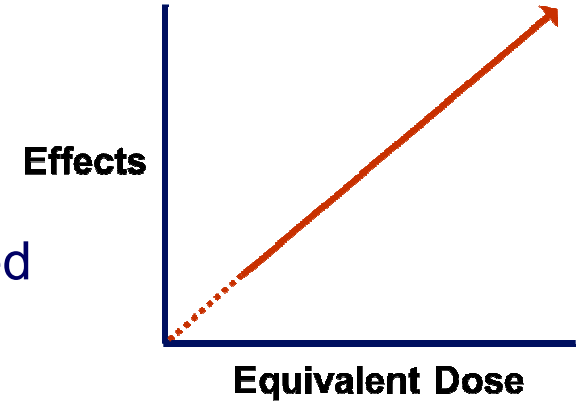
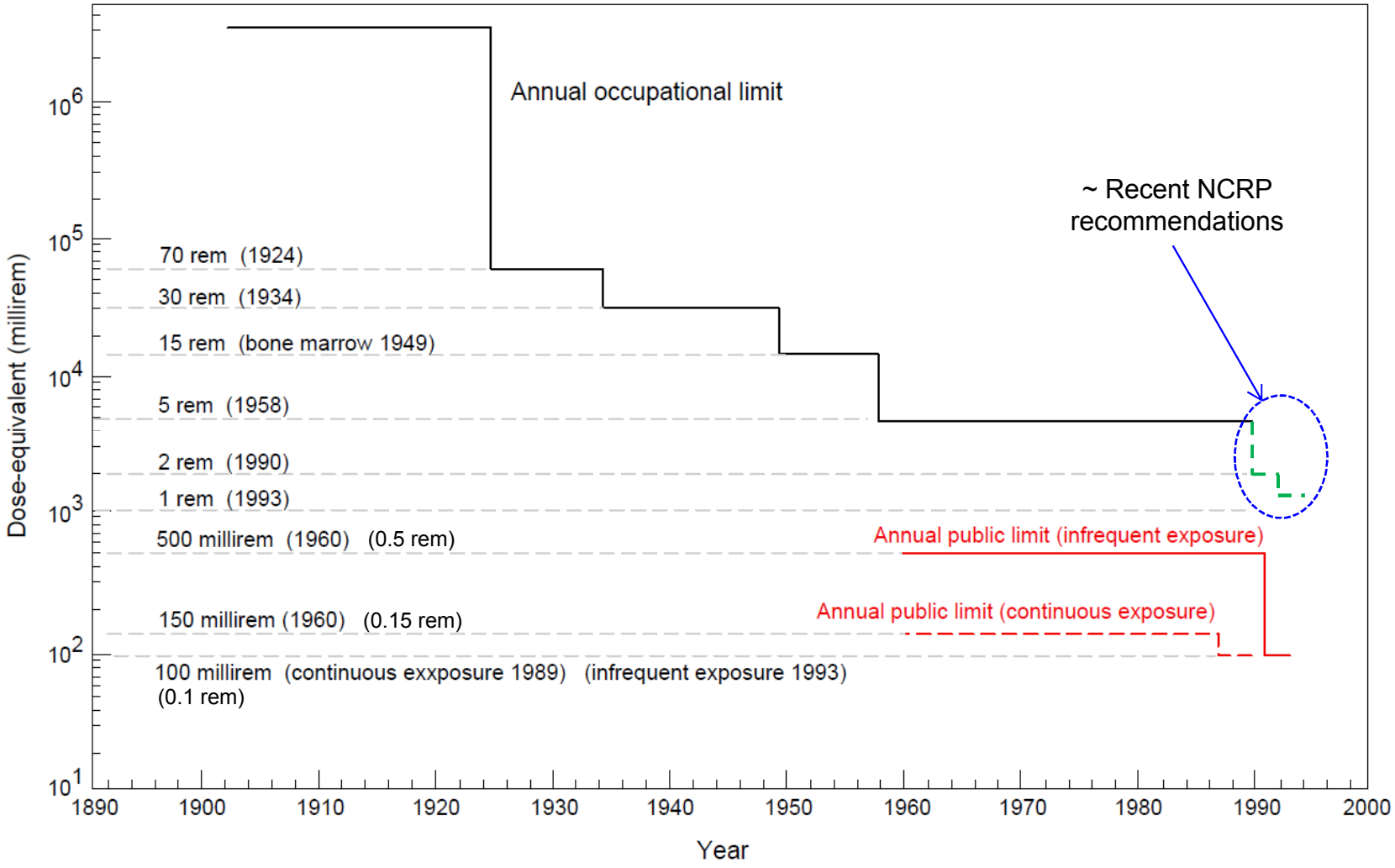


Current Standards

Consistent with the NCRP's recommendations of 1993:

- *Occupational Exposure*:
  - Limit for **whole-body**: **5 rem (0.05 Sv)/year** (stochastic)
    - Lifetime average: ≤ 1.5 rem/year (over 47-year "*working life*")
  - Limit for **lens of the eye**: **15 rem (0.15 Sv)/year** (deterministic)
  - Limit for **skin**: **50 rem (0.5 Sv)/year** (deterministic)
  - Limit for **individual organ/tissue**: **50 rem (0.5 Sv)/year** (deterministic)
- *Public Exposure* (whole-body):
  - **0.1 rem (0.001 Sv)/year** (*continuous exposure*)
  - **0.5 rem (0.005 Sv)/year** (*infrequent exposure*)

Changes to Dose Limits Over Time



Radiation Protection Standards

- Based upon the latest research findings and recommendations of national and international scientific bodies
  - Current limits represent a culmination of intensive epidemiological and radiobiological research
  - Still many questions regarding the detailed mechanisms that cause biological effects
- Used to establish acceptable policies and practices for the effective protection of radiological workers, emergency response personnel, and the public

Questions?