Historical Look at Internal Dosimetry

The Radium Dial Workers and the ICRP-2 System

Learning Objectives

- Describe the radium workers as a case study in occupational internal dosimetry
- Identify the principles and parameters of the ICRP-2 system
- Explain the ICRP-2 concepts still used in regulations

A Little History

- Georgius Agricola (a.k.a. Paracelsus) published a treatise in the 1500's describing what became known as "Joachimsthaler Bergkrankheit" or Joachimstal Mountain Sickness in lead miners near what is now Jachymov, Czech Republic
- The symptoms are those of lung cancer, probably induced by exposure to Rn-222 and its progeny in the mines
- You can stay at the Hotel Radium Palace and Radon Spa in Jachymov, 6 nights for 322 euros.

Dial-painting industry

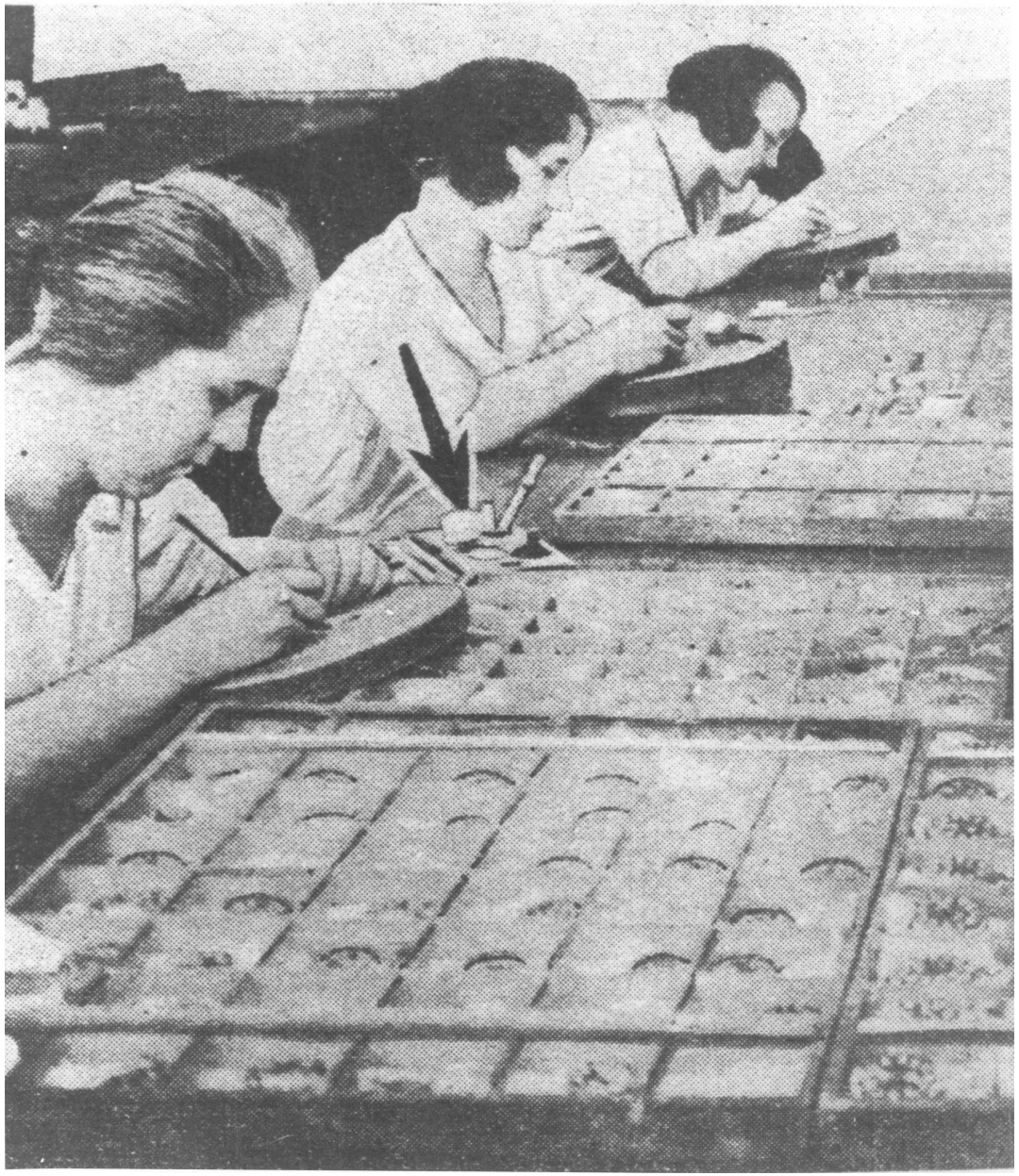
- Waterbury, CT
  - Waterbury Clock Co.
  - Studied by Evans at MIT
- East Orange, NJ
  - Radium Dial, Inc.
  - Studied by NJ State Health Dept.
- Elgin, Ottawa, Peru, LaSalle, IL
  - Elgin Watch Co. and Radium Dial, Inc.
  - Elgin State Hospital: iatrogenic cases
  - Studied by ACRH and ANL-E


Bottle of glue
Radium powder
Dial being painted

Radium health effects

- First noted by Dr. Theodore Blum, a NJ dentist in the early 1920's
- "Radium jaw" analogous to "phossy jaw"
- Quantified by Dr. Harrison Martland, pathologist in Orange NJ
- Numerous trials and stories on the "girls doomed to die" in the late 1920's

Radium Workers at Deadly Task



A simple safety standard

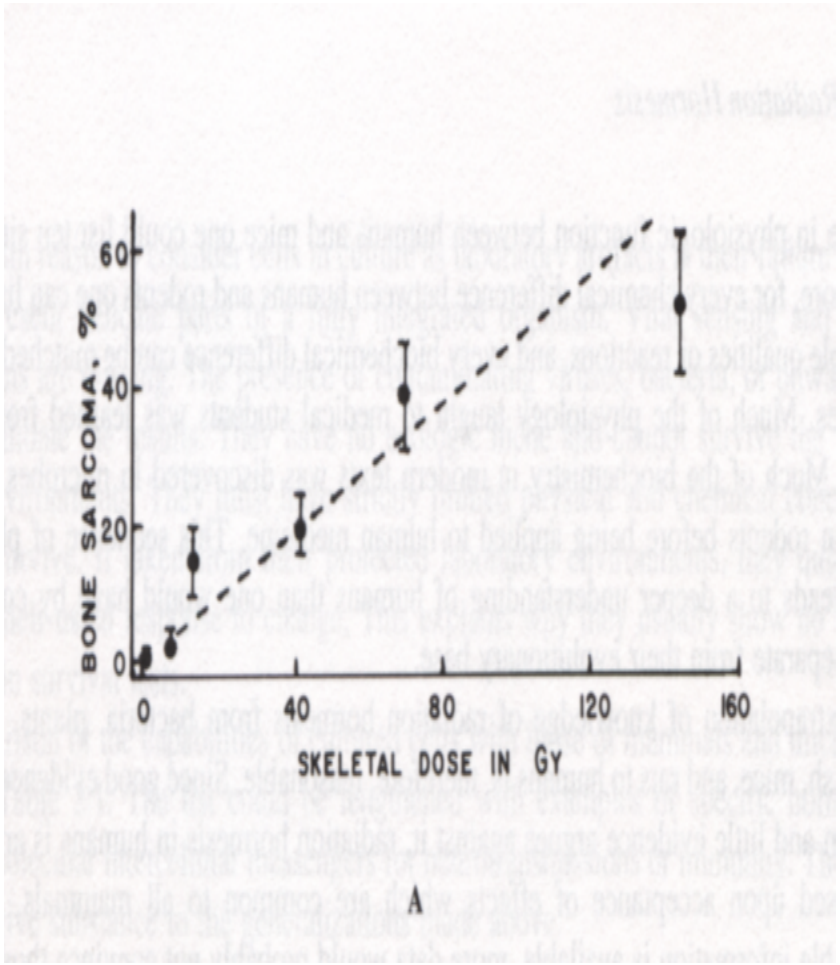
- Don’t eat the paint
- Brush-tipping was forbidden as an unsafe labor practice by the U. S. Department of Labor in 1929
- No dial workers from the 1930’s on had significant intakes of radium, but were followed up because of external gamma exposure

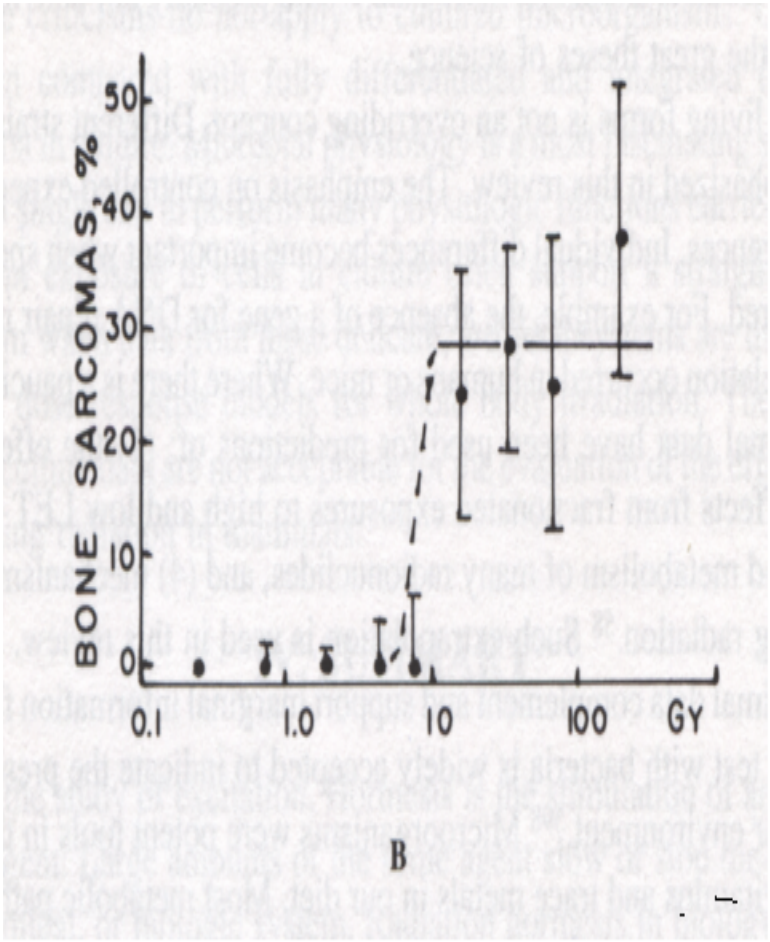
Malignancies observed

- Bone tumors:
  - Osteosarcomas
  - Chrodrosarcomas
  - Giant cell tumors
- Head Carcinomas:
  - Sinuses
  - Mastoids
- Nothing Else!
  - No excess leukemias
  - No other excess solid tumors

Bone Tumor Incidence

Ra intake, μCi	Cases	Bone tumors
More than 2500	16	4
1000 -- 2499	22	15
500 -- 999	18	8
250 -- 499	32	9
100 -- 249	27	2
Less than 100	644	0





Linear scale

Log scale

Bone sarcoma in Radium dial painters

Radium standard

- No health effects noted in radium DPs with retained Ra-226 < 1.0 µCi
- Throw in a safety factor of 10
- MPBB for Ra-226 = 0.1 µCi
- Used to establish safe level of plutonium exposure during the Manhattan Project
- MPBB for Pu-239 = 0.04 µCi

ICRP-2 (1959)

- Dose Limits:
  - 5 rem per year to red marrow, gonads, and lens of the eye, based on the 5(N-18) limit, where N = age in years
    - But no more than 3 rem per quarter, so could go to 12 rem per year if < 5(N-18)
  - 30 rem per year to thyroid and skin (0.6 rem per week, 8 rem per quarter)
  - 15 rem per year (0.3 rem per week, 4 rem per quarter) to other organs

ICRP-2 Concepts

- Critical organ: the organ receiving the largest dose from an intake of a given radionuclide, e.g., the thyroid for an intake of I-131
- Maximum Permissible Organ Burden: the activity of a given radionuclide in an organ that would produce a radiation dose equivalent equal to the limit for that organ
- Maximum Permissible Body Burden: the activity in the whole body that represents an MPOB for the critical organ

Other ICRP-2 Limits

- Dose limit for non-radiation workers = 10% of occupational dose limit
- Dose limit for general public = 1% of the occupational limit for whole-body (RM and gonads) and 3.3% for other organ doses
- Maximum Permissible Concentrations for air and water set for 40 hours and 168 hours of exposure per week

MPCs

- The MPC is that concentration of a radionuclide in air (inhalation intake) or in drinking water (ingestion intake) that would result in accumulation of the MPBB in the body AFTER 50 YEARS OF EXPOSURE.
- Usually the MPBB is reached in < 50 years because equilibrium is reached in the body (daily excretion = daily input)
- Doses from progeny included in the MPC for the parent radionuclide

MPCs con't.

- Daily (24 hr) air intake = 20 m^3, daily water intake = 2.2 L
- Worker intake in 8 hours are half the daily intakes, or 10 m^3 air and 1.1 L water
- The 168-hour MPC is therefore:

  (12 x 5 x 50) /(24 x 365) = 0.3425 x the 40-hr MPC

  or, the 40-hr MPC = 2.92 x the 168-hr MPC, except for submersion in a noble gas, where it is 4.38 times the 168-hr MPC, i.e., (24x365)/(8 x 5 x 40)

Example for Co-60

- ICRP 2 40-hr MPC for soluble forms of Co-60 in air = 4×10^{-7} µCi/ml (MPBB = 10 µCi)
- Current value for derived air concentration of soluble forms of Co-60 in air is 7×10^{-8} µCi/ml

  (10 CFR 20, Appendix B)
- The difference is due to the introduction of the concept of committed dose in ICRP 26 (1977)

MPC Sum Rule

- For a mixture of radionuclides, permissible exposure limits will not be exceeded if:

  C(1)/MPC(1) + C(2)/MPC(2) +…C(n)/MPC(n) </= 1.0

- Not generally recognized that ICRP-2 also included external dose:

  – C(1)/MPC(1) +…C(n)/MPC(n) + R/L </= 1.0

  Where R = external dose and L is the dose limit for the organ or whole body

Problems with ICRP-2

- Difficult to keep track of all components of exposure when various internal organs are not uniformly irradiated
- Consider Pu-239:
  - MPBB = 40 nCi (bone is critical organ for soluble forms)
  - MPLB = 16 nCi (for lung dose from inhalation of insoluble forms)
  - Liver also receives dose
  - Dose received for many years after single intake
  - What would the overall risk from an intake be?