“The Biological Basis of Radiation Protection Standards”

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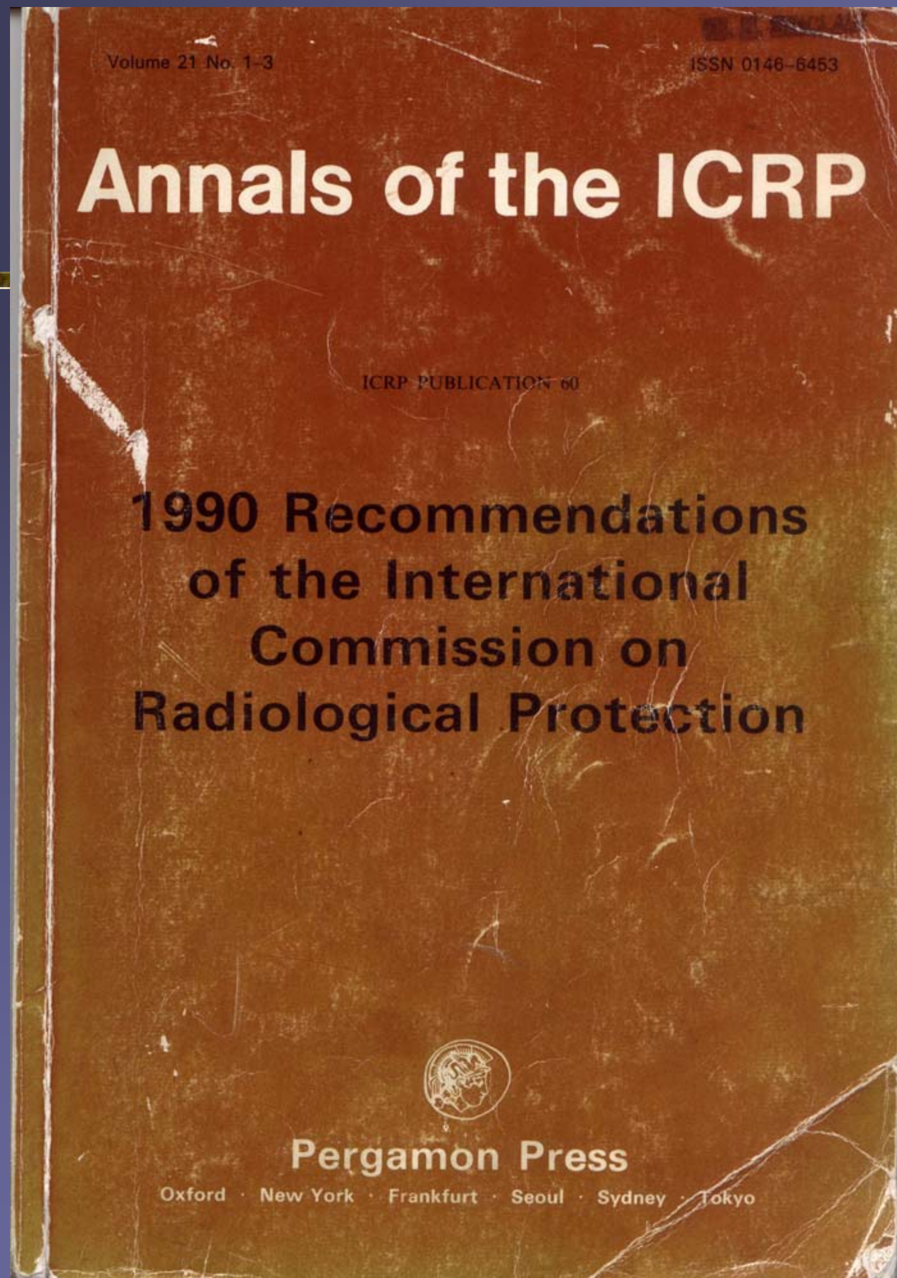
Member of ICRU, ICRP, UNSCEAR and Beir VI

NCI Radioepidemiology Course, May 13, 2004


Volume 21 No. 1-3
ISSN 0146-6453
Annals of the ICRP
ICRP PUBLICATION 60
1990 Recommendations of the International Commission on Radiological Protection
Pergamon Press
Oxford · New York · Frankfurt · Seoul · Sydney · Tokyo

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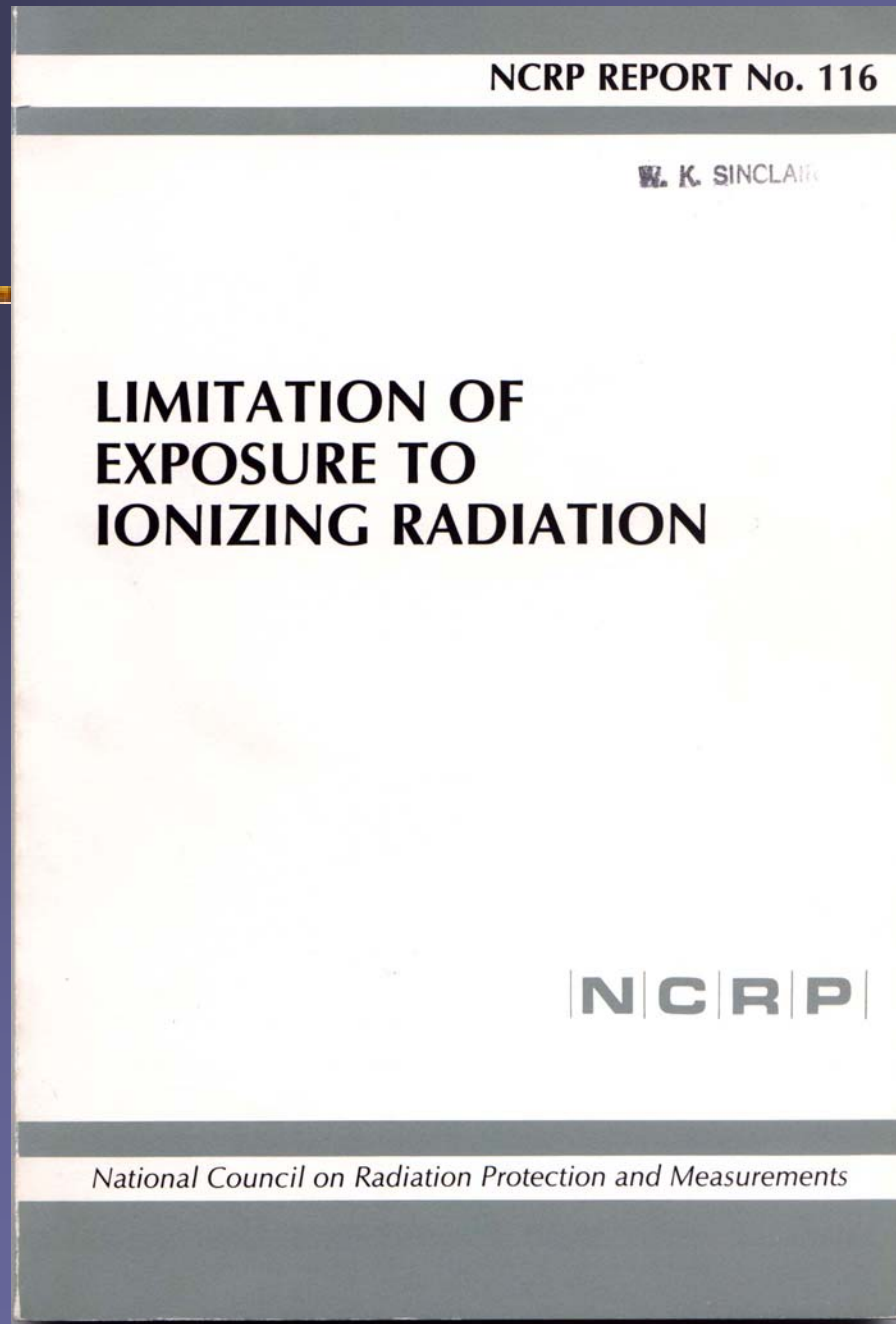
NCRP REPORT No. 116
W. K. SINCLAI
LIMITATION OF EXPOSURE TO IONIZING RADIATION
NCRP
National Council on Radiation Protection and Measurements

Membership of NCRP (NCRP 116)

- Council of 75 members (under age 65) from many disciplines and all parts of the USA, each elected for a six year term.
- 11 are Board Members
- All members must approve Council Reports and Statements
- Disagreement of 3 or more voting members requires resolution by the Board

Honorary Membership NCRP (NCRP 116)

- Elected by membership for individual contributions to NCRP during service as member.
- In 1993 there were 37 Honorary members with
- Lauriston S. Taylor, Honorary President
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Operating Principles of Radiation Protection (NCRP 116)

- **Justification:** In activities involving radiation exposure the societal benefits should exceed the societal cost.
- **'ALARA':** All radiation exposures should be kept As Low As Reasonably Achievable.
- **Limitation:** Individuals or groups of individuals should not exceed levels of acceptable risk by the application of dose limits.

Objectives of Radiation Protection (NCRP 116)

- To prevent the occurrence of clinically significant deterministic effects by adhering to dose limits below threshold levels.
- To limit the risk of stochastic effects, to a reasonable level in relation to other risks consistent with societal needs, values, benefits and economic factors.

Deterministic Effects

- Dose Threshold
- Severity increases with dose above threshold
- All exposed persons suffer, although threshold may vary
- Examples – erythema, cataract, impaired fertility, blood changes, radiation sickness, death
- Thresholds mostly ~ 1 Sv and greater

Deterministic Effects - Limits

- Severity minor until about 1 Sv
- Protracted exposures less effective than acute exposures
- For a recent discussion read; ICRP 60 or NCRP 132, “Radiation Protection Guidance for activities in Low-Earth Orbit”
- Can dismiss for doses less than ~ 1 Sv

Stochastic Effects

- Probability of effect increases with dose
- Magnitude of effect essentially same at all doses
- Only some of those exposed (or their offspring) get the effect
- Examples – Cancer induction - Genetic effects

Stochastic Effects Cancer and Genetic

Era of more and more precise quantitation of these effects 1970s to 1990s. Cancer induction – once thought to be ~ 1%/Sv (1977) was established, by 1988 (UNSCEAR) and 1990 (BEIR V) to be about 10%/Sv for *acute* exposure, (from the LSS of the A bomb survivors).

ICRP 1991 decided that for *protracted* exposure a DDREF of 2 should be applied (see their reasoning in Para B67 of Pub. 60) so a nominal risk for a population of all ages is 5%/Sv (4%/Sv for adult workers).

ICRP DOSE LIMITS

Occupational

Should not exceed an average of 20 mSv per year over 5 years

Should not exceed 50 mSv in any one year

Individual deterministic limits for certain organs – eye, skin, hands and feet

Public

Not greater than 1mSv per year. Individual deterministic limits 1/10 of occupational

Dose Limits – Occupational
(NCRP 116)

- Workers Lifetime Effective Dose limited to his or her age (over 18) x 10 mSv, no more than 50 mSv in any one year
- Under 18, avoid – training, less than 5 mSv in a year
- Limits are for man-made sources, do not include exposure from natural background and medical exposure

Dose Limits – Public (NCRP)

- 1 mSv per year
  (not more than 0.25 mSv from any one source)
- (5 mSv in a year infrequent)
- Negligible Individual Dose 0.01 mSv (per source or practice)

Dose Limits, Flexibility, Design
(NCRP 116)

- Dose Limits are upper bounds and define the edge of unacceptability.
- The 50 mSv annual limit is for flexibility in existing facilities and practices.
- The 10 mSv (annual average for the cumulative limit is still a limit). New facilities and practices should be designed to fractions of this limit using ALARA considerations.
- Reference levels should be site specific and based on ‘ALARA’.

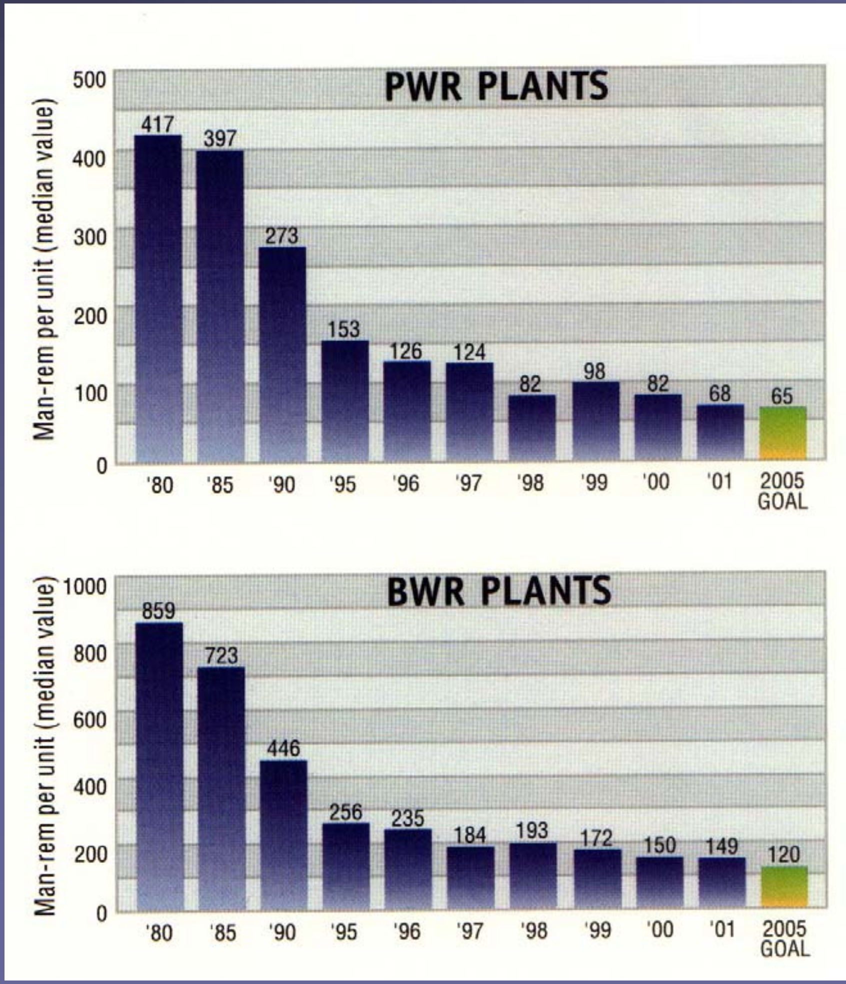
Occupational Exposure (USA)

	1985 Workers (1000s)		Mean dose (exposed) (mSv)	
Category	Monitored	Exposed	1980	1985
Medicine	735	267	1.5	1.1
Industry	274	101	2.4	1.5
government	229	117	1.2	1.3
Nuclear Fuel Cycle	206	107	6	4.2
Air Transport	114	114	0	3.5
Miscellaneous	182	56	1.6	0.6
All Workers	1,739	762	2.3	1.9

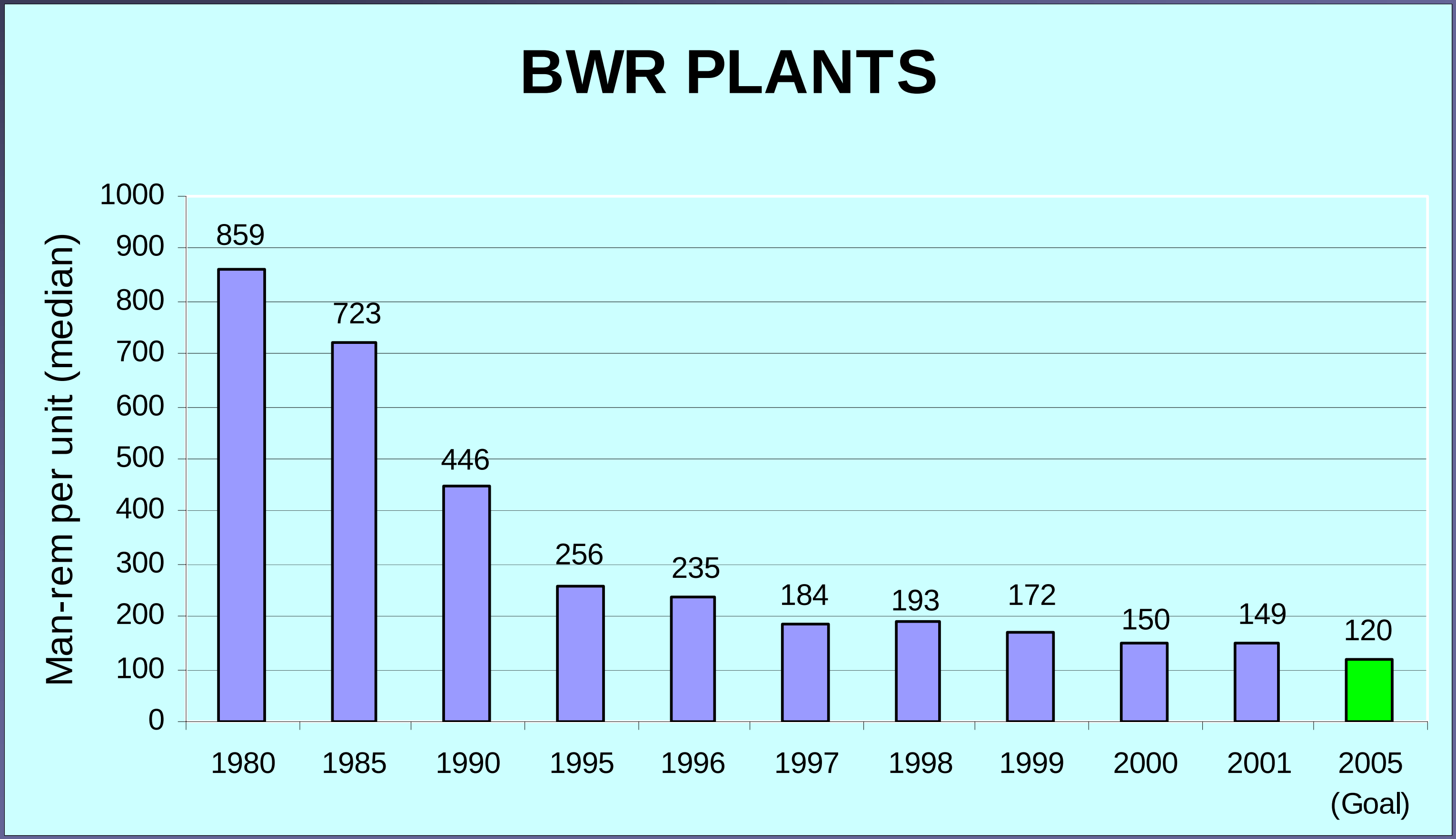
Exposures of workers in Nuclear Power Industry

Year	Average Exposure, mSv
1980	6.0
1985	4.2
1990	2.4
1992	1.8
2001	0.6 (est)

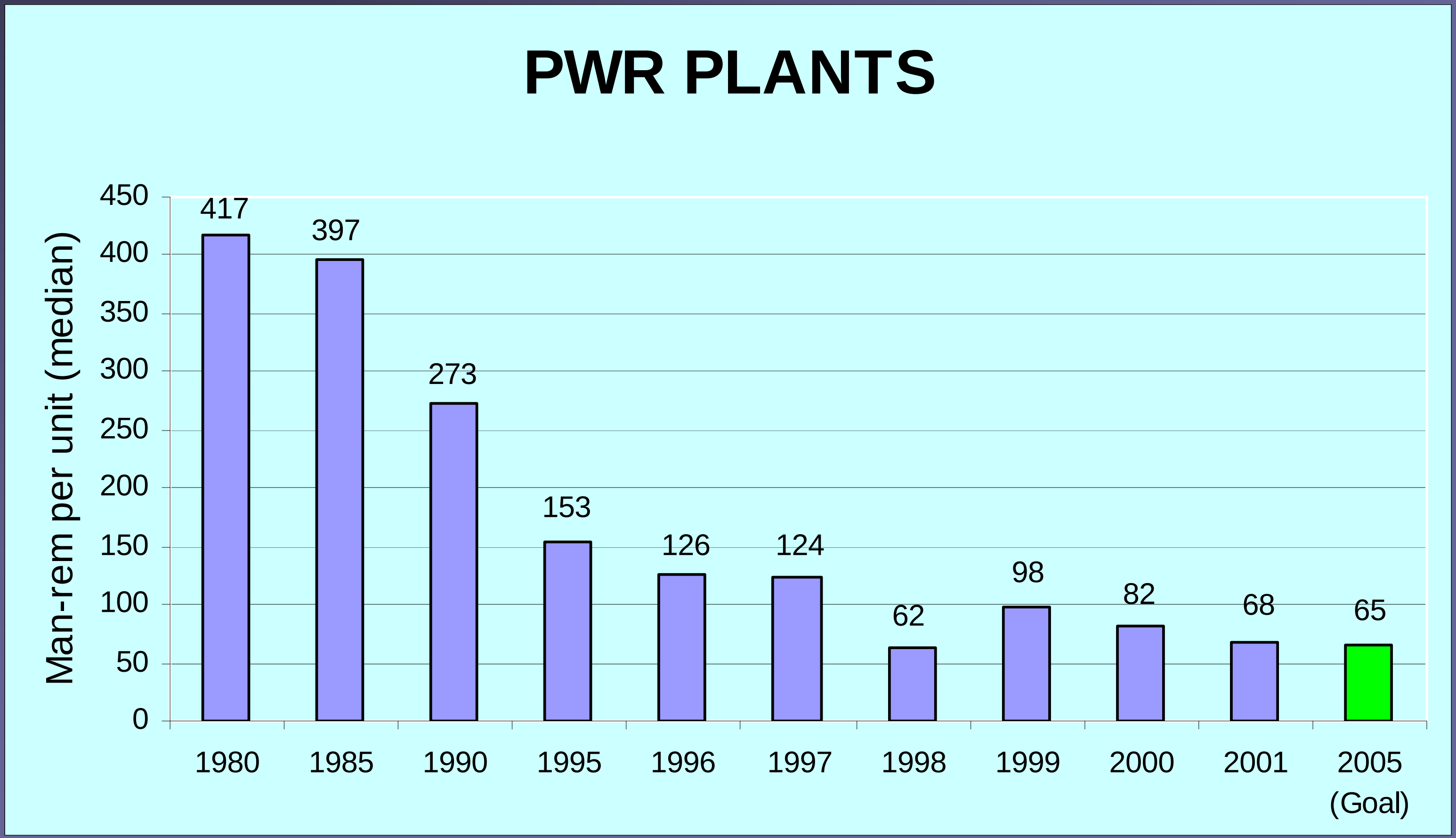
Collective Radiation Exposure



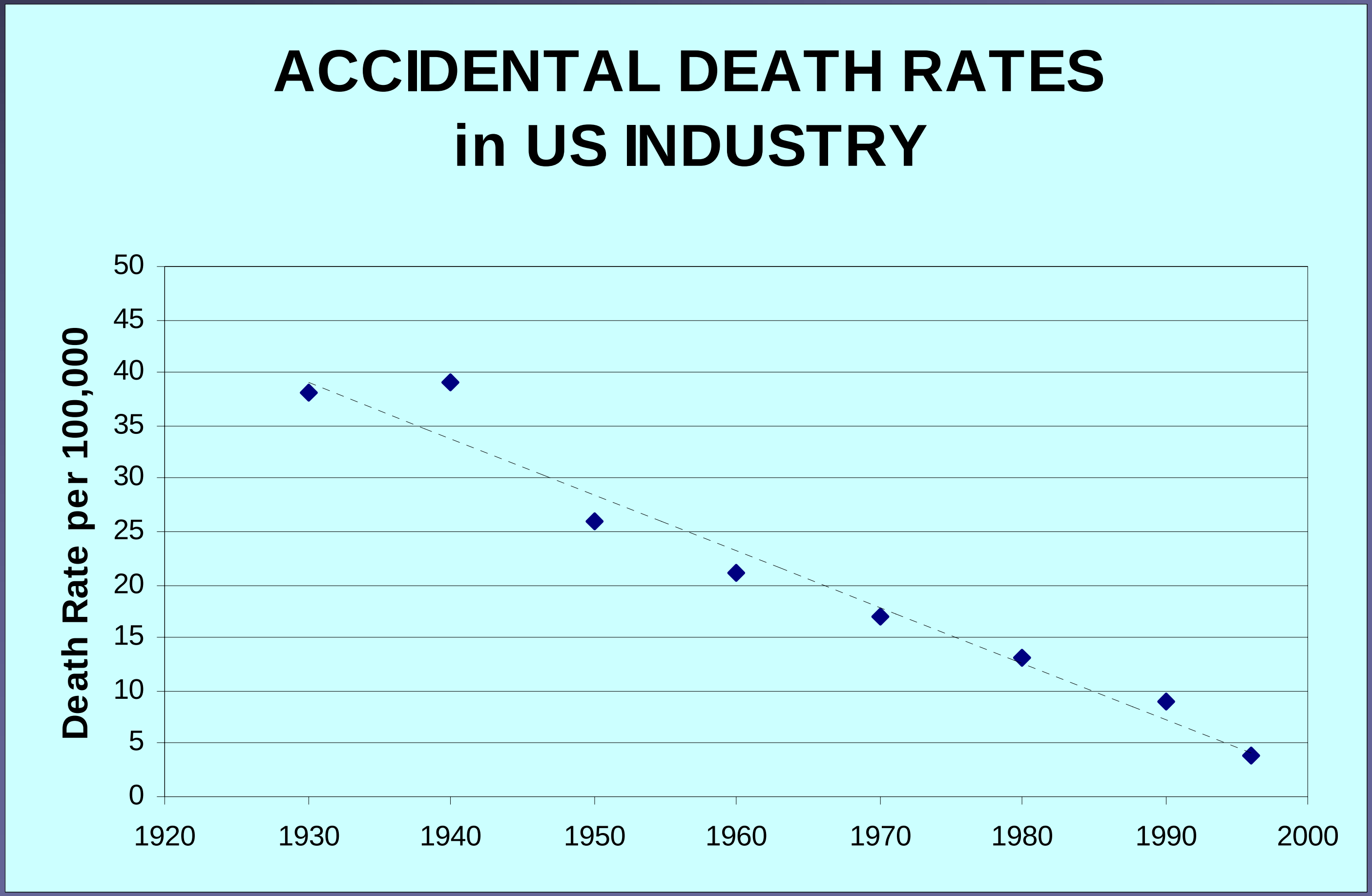
Collective Radiation Exposure



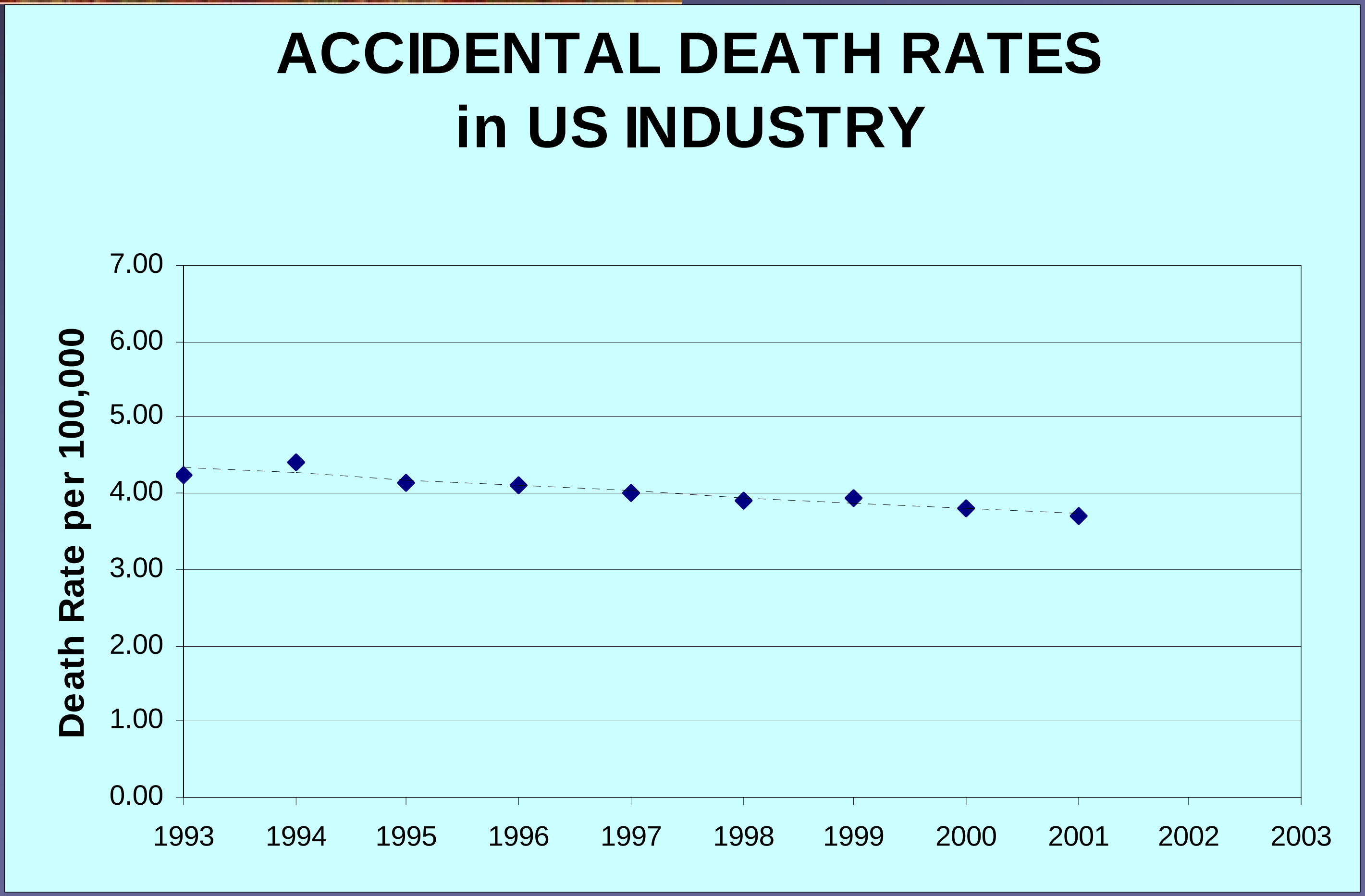
Collective Radiation Exposure



Accidental Fatalities in Industry



Fatal Accidents



Chernobyl Accident

April 26, 1986

30 acute deaths due to radiation and burns

Acute radiation sickness in 134 others, doses ~ 2-6 Gy

116,000 people evacuated (Pripyat, etc.)

220,000 relocated (Belarus, Russian Fed. & Ukraine)

600,000 “liquidators” 170 mSv 1986; 130 mSv 1987, 33 mSv 1988; 15 mSv 1989 (average doses, big range)

Chernobyl Accident

2000 UNSCEAR Report.

Except for thyroid, NO adverse late medical effects clearly established in contaminated versus control areas.

Thyroid doses I-131 0.1 – 2 Gy infants. Increases of thyroid cancer in children in Belarus, Russian Federation and Ukraine.

Genetic Effects

Once the predominant concern of early UNSCEAR committees, the risk of genetic effects were now estimated to be ~1.3%/Sv (whole population) 0.8%/Sv (for adult workers) less than the risk of induced cancer (5%/Sv).

HEALTH DETRIMENT

ICRP considered the Health Detriment to include:

	Whole population	Workers
Fatal cancer	5%/Sv	4%/Sv
Non fatal cancer	1.0%/Sv	0.8%/Sv
Genetic effects	1.3%/Sv	0.8%/Sv
Total	7.3%/Sv	5.6%/Sv

$$\text{Risk of cancer} = \frac{\text{No. of excess cancers}}{\text{dose causing them}}$$

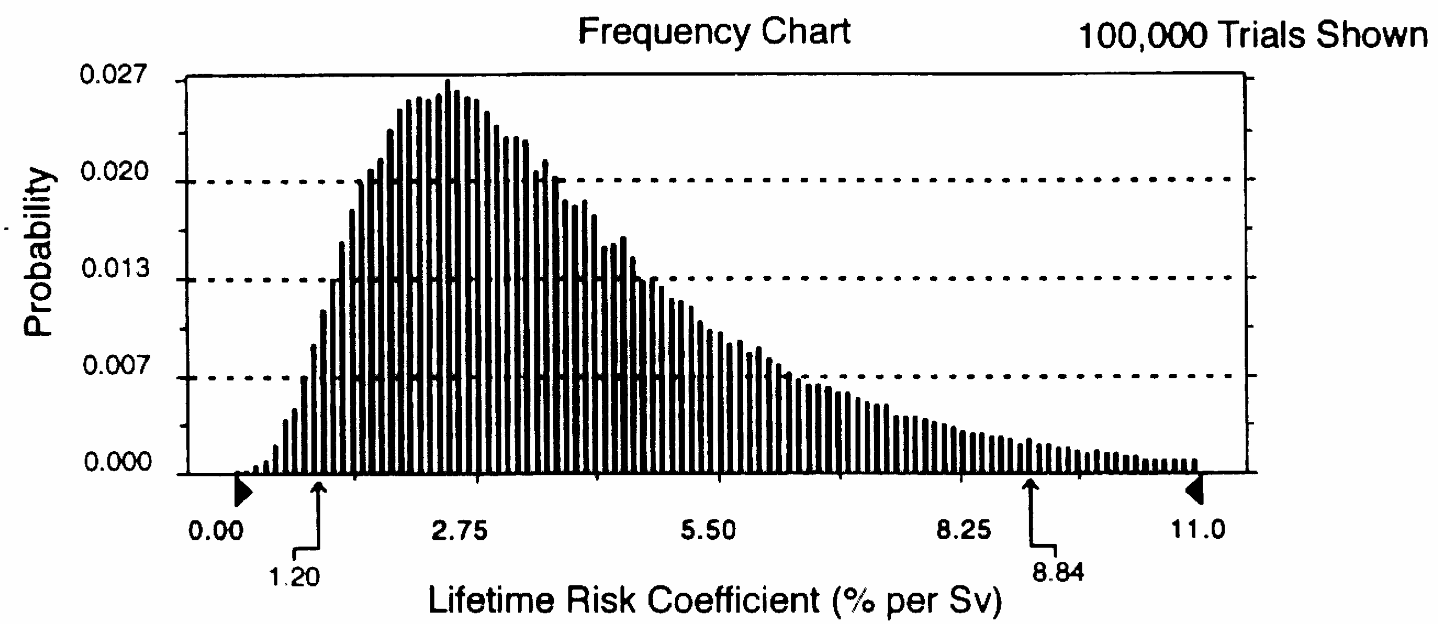
- Epidemiology determines the numerator, dosimetry physical) determines the denominator.
- Each equally important for accurate estimate of risk.
- “Dose” is the absorbed dose to the organ or tissue in question.
- Even in comparatively uniform exposure situations like the A bomb survivors, absorbed dose varies from organ to organ.

Uncertainties in Nominal Cancer Risk (NCRP 126)

- the dosimetry
- epidemiological sampling, etc.
- projection from observed cancers to end of life
- transfer from the Japanese population to other populations
- the DDREF for acute to protracted exposure

Although some of these uncertainties are large e.g. dosimetry – the largest is the uncertainty in the DDREF which is finally a judgment based on dose rate studies in radiobiology and radioepidemiology.

Diagram of uncertainties from NCRP 126



Dosimetry – A Bomb Survivors

The development of a sophisticated dosimetry system to specify the dose to each of the survivors of the A bomb exposures has had several stages.

- **T57** (1957): first crude system (T = tentative)
- **T65** (1965): an improved system, based also on some experimental work

Dosimetry – A Bomb Survivors

- **DS86** (1986): first comprehensive system based on tested codes for radiation transport – very good system, broadly verified, changed risk estimates. Unresolved neutron discrepancy in Hiroshima
- **DS02*** (2002, published 2004) Complete revision of all features of the dosimetry in joint U.S.-Japan re-study

**(No neutron discrepancy. Installed at RERF 2003. Believed to be the final word on the dosimetry. Small changes only in risk estimates based on DS86.)*

Impacts of Dosimetry System on Risk Estimates

- DS86 had a major effect on risk estimates (1.5 to 2.0 x higher) and reduced the effect of the neutron component
- DS02 neutron component still small, changes in gamma ray risk estimates minor.Experimental results in excellent agreement with calculation
- Confidence in dosimetry and risks based on it enormously improved

And remember,
“The Genie is out of the bottle!”