

Relative Risk and Uranium Recovery

Presented To:

**National Mining Association (NMA) /
Nuclear Regulatory Commission (NRC)
Uranium Recovery Workshop**

Denver – April 29, 2008

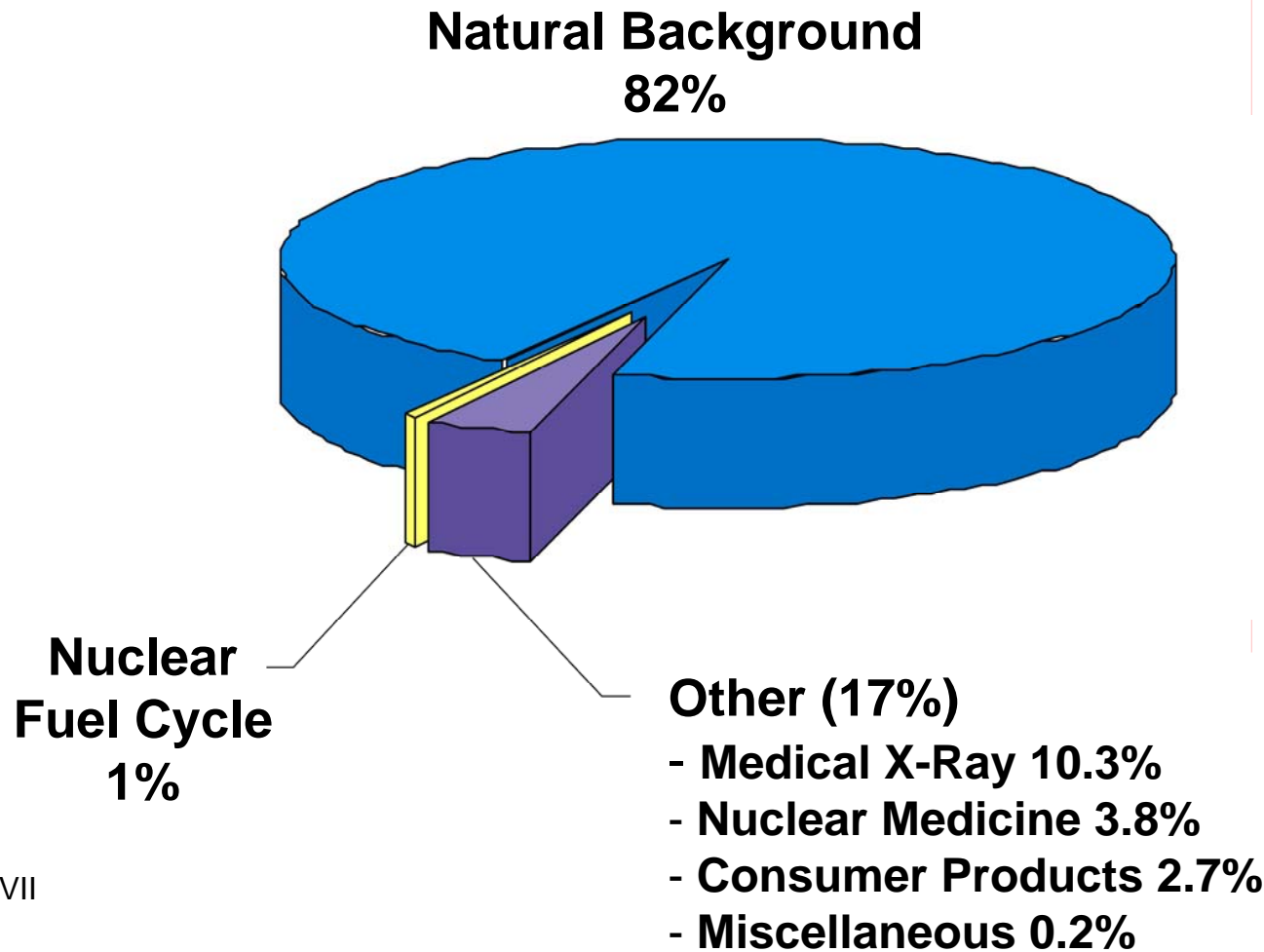
Presented By:

Dr. Douglas B. Chambers

Outline of Presentation

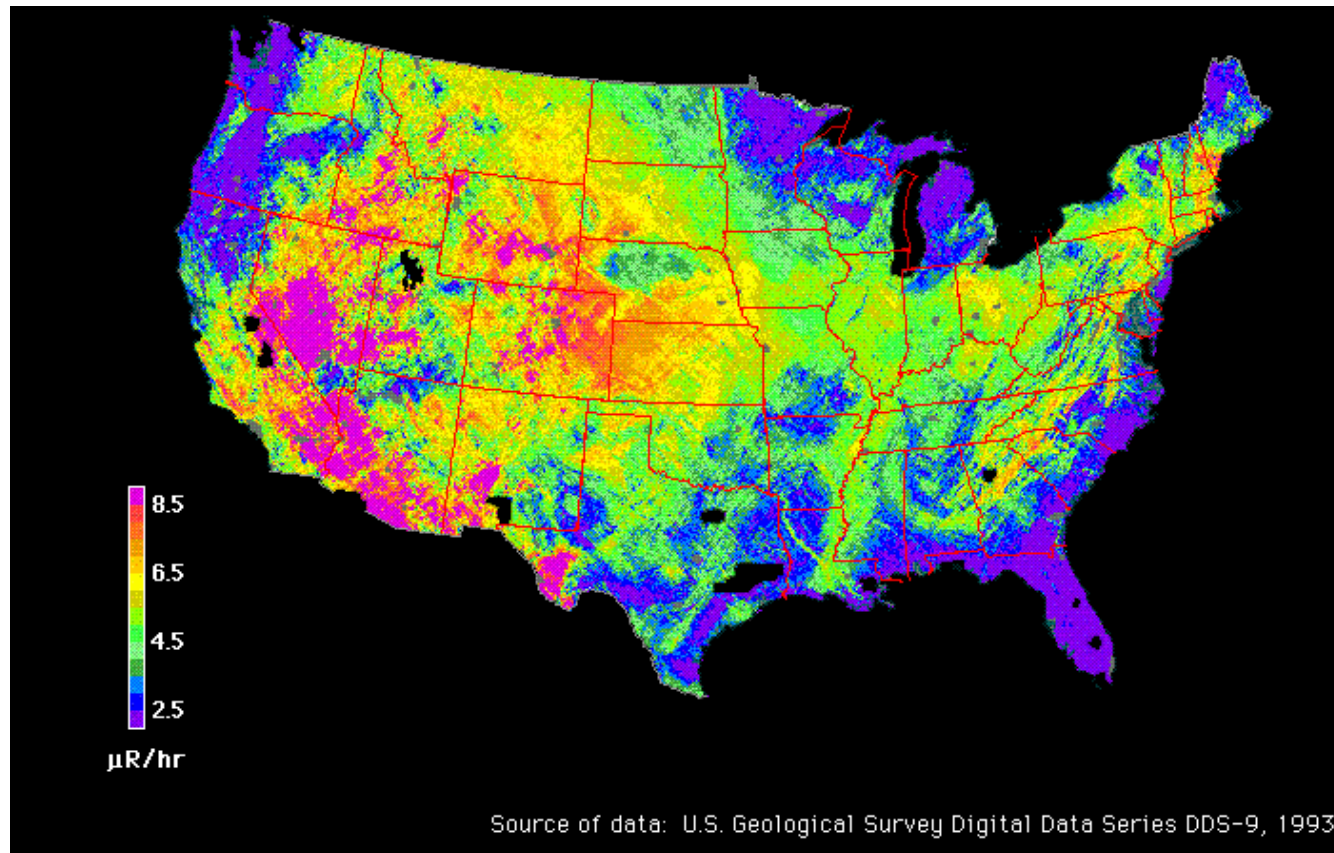
- ❑ **Radiation Doses from Natural Background**
- ❑ **Regulation of Radiation Dose from Mining and Milling**
- ❑ **Risks from Ionizing Radiation**
- ❑ **Radiation Doses from Mining and Milling**
 - ❖ **Workers**
 - ❖ **Members of the public**
- ❑ **Context**

Background Levels of Radiation

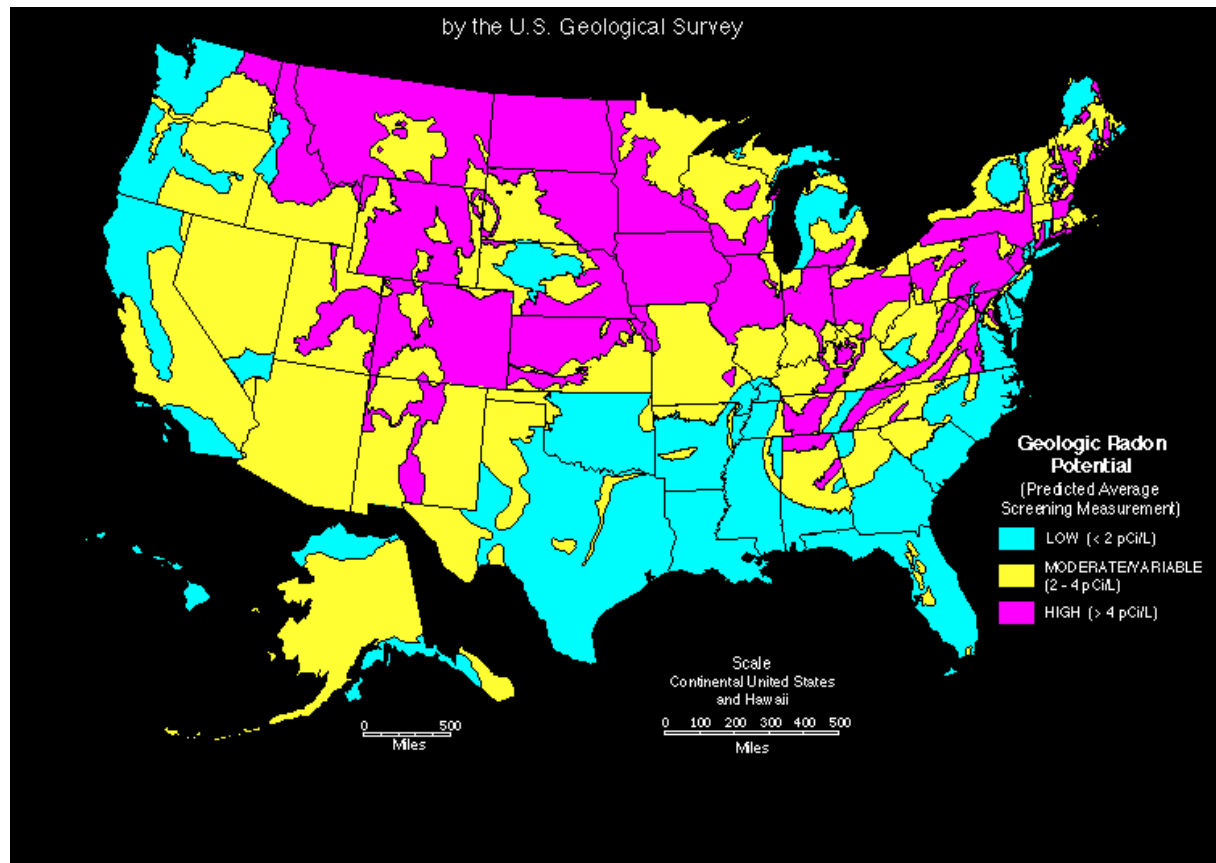


After BEIR VII

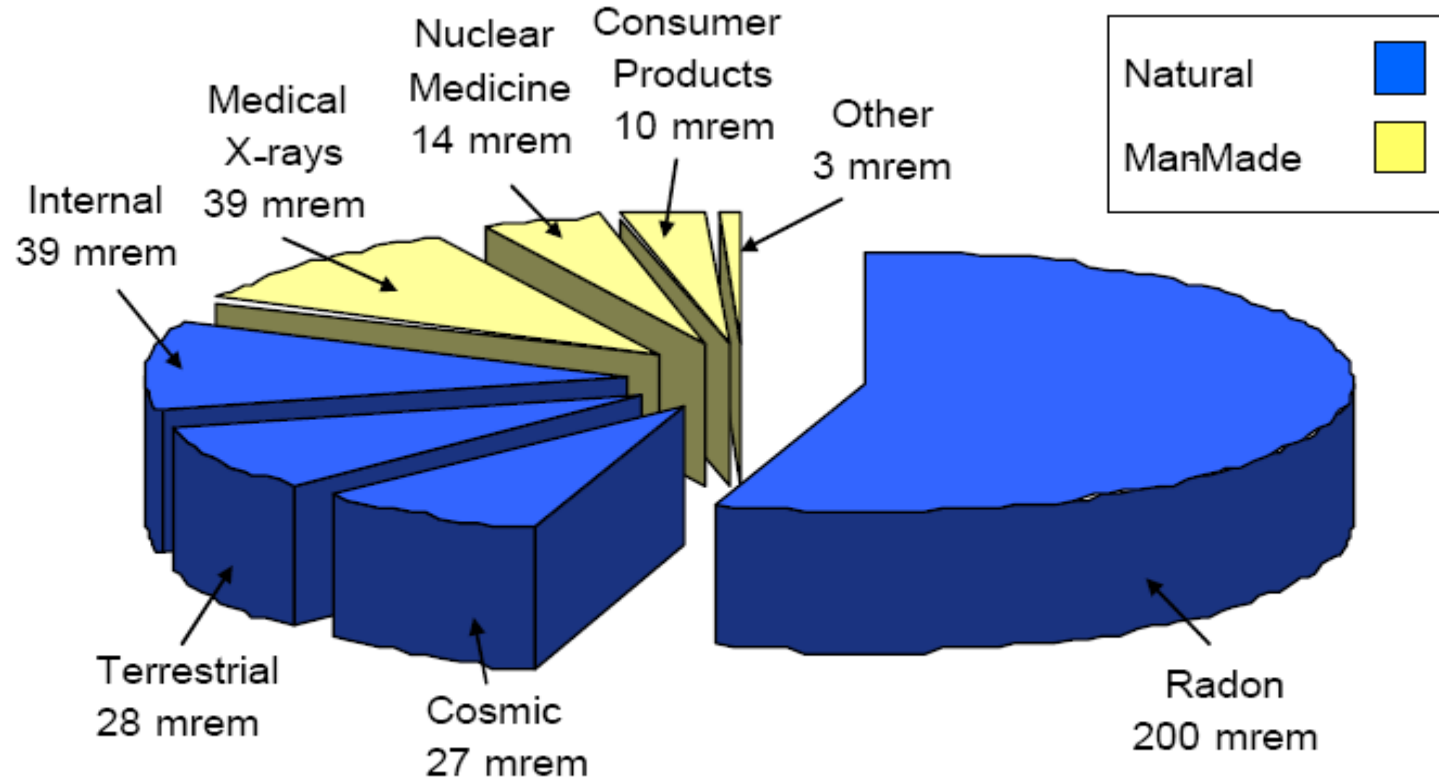
Terrestrial Gamma-Ray Exposure at 1m Above Ground



Generalized Geologic Radon Potential of the United States



Sources of Radiation Exposure to the U.S. Population



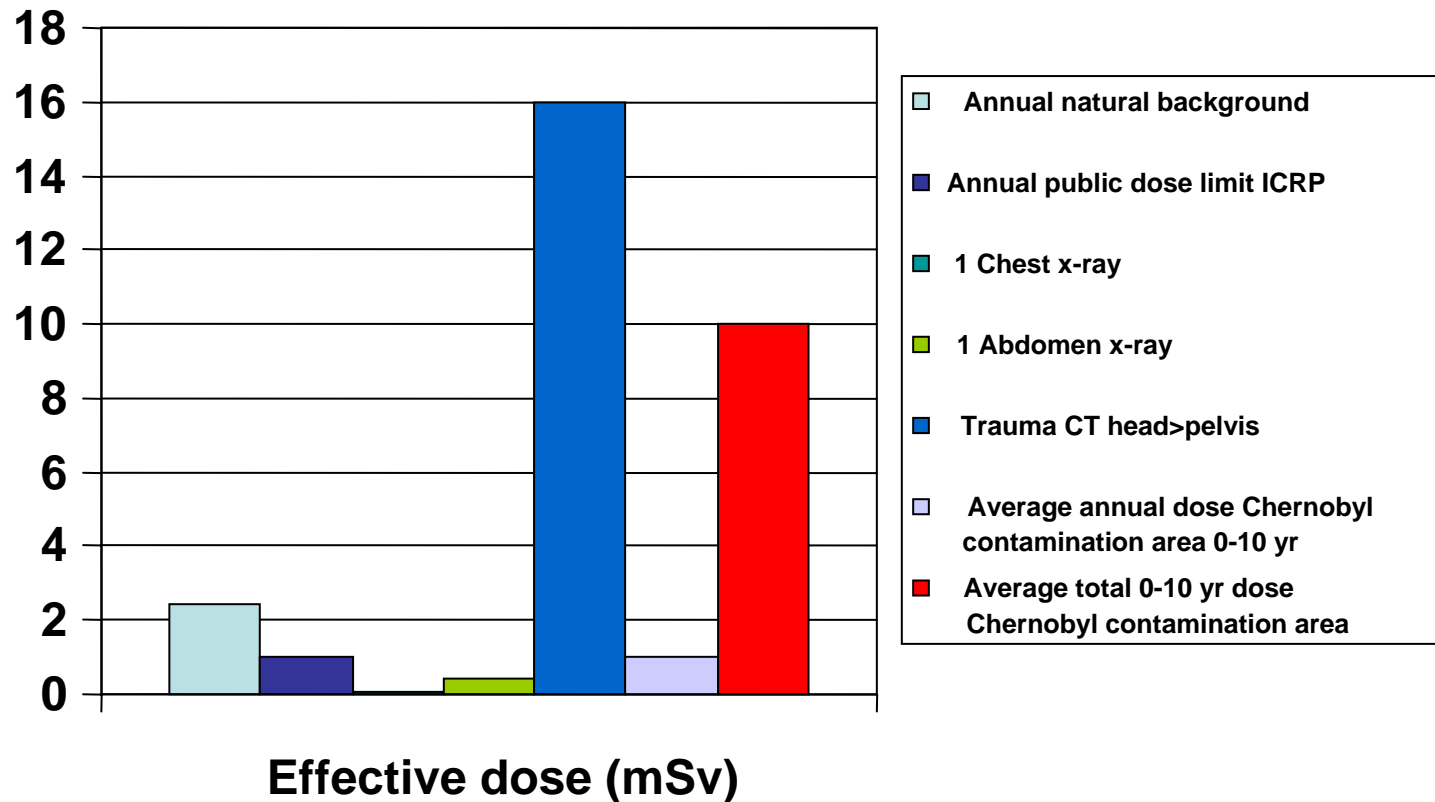
Source: U.S. EPA 2005. Assessment of Variations in Radiation Exposure in the United States

Natural Background Radiation in the U.S. (mrem/yr)

	Mean	Variability
Cosmic	27	20 - 60
Gamma	28	10 - 80
Internal	40	30 - 100
Inhaled	200	20 - 80
Total	300	100 - 1000

Sources: NCRP 94, NUREG-1496

Relative Magnitude of Individual Doses



SOURCE: Fred Mettler, NCRP 2007

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Radiation Dose Limits

❑ International

- ❖ International Commission on Radiological Protection (ICRP)

❑ United States

- ❖ Nuclear Regulatory Commission (NRC)
- ❖ Environmental Protection Agency (EPA)
- ❖ Mine Safety Health Administration (MSHA)

ICRP Recommendations

- ❑ Latest recommended dose limits (2007) unchanged from 1990 ICRP 60 limits
- ❑ Limits in terms of “effective dose” (mSv)
 - ❖ sum of organ doses weighted according to contribution of that organ to total health detriment resulting from whole body irradiation
- ❑ All occupational exposures considered-inhalation, ingestion, and external
- ❑ Considered equivalent to TEDE (total effective dose equivalent) in US

ICRP Dose Limits

❑ Workers

- ❖ 100 mSv in 5 years
 - In practice 20 mSv/year averaged over 5 years
- ❖ Maximum of 50 mSv in any single year not to exceed 100mSv in 5 years

❑ Public

- ❖ 1 mSy/year

❑ Overriding Principals

- ❖ Justification (benefit > harm)
- ❖ ALARA (optimization)

Note: 1mSv = 100mrem

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- ❑ **10 CFR Part 20**
 - ❖ Occupational: 5 rem
 - ❖ Public: 0.1 rem
- ❑ **Appendix B to Part 20 gives:**
 - ❖ Annual Limit on Intake (ALI) and Derived Air Concentration (DAC) values (Table 1)
 - ❖ Effluent Concentrations (Table 2)
- ❑ ***Total Effective Dose Equivalent (TEDE):***
 - ❖ The sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

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- ❑ **ALI's are the annual intakes of a given radionuclide by "Reference Man" which would result in either:**
 - ❖ **A committed effective dose equivalent of 5 rem (stochastic ALI)**
 - ❖ **A committed dose equivalent of 50 rem to an organ or tissue (non-stochastic ALI).**
- ❑ **DAC's are derived limits based on ALI's used to control exposure**
 - ❖ **DAC's are radionuclide concentrations which, if inhaled or ingested continuously over the course of a year, would produce a TEDE of 0.05 rem (50 mrem or 0.5 mSv).**

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	Class	Table 1			Table 2	
		Occupational Values			Effluent Concentrations	
		Oral Ingestion ALI (μCi)	Inhalation		Air	Water
			ALI (μCi)	DAC ($\mu\text{Ci}/\text{ml}$)	($\mu\text{Ci}/\text{ml}$)	($\mu\text{Ci}/\text{ml}$)
Rn-222	With daughters removed	-	1E+04	4E-06	1E-08	-
	With daughters present	-	1E+02 (or 4 WLM)	3E-08 (or 0.33WL)	1E-10	-

U.S. EPA

- ❑ A licensee with uranium fuel cycle operations shall comply with EPA's 40 CFR part 190 (Subpart B).
- ❑ Operations covered by this subpart shall be conducted in such a manner as to provide reasonable assurance that:
 - ❖ “The annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, **radon and its daughters excepted**, to the general environment from uranium fuel cycle operations and to radiation from these operations.”

MSHA

- ❑ 5 rem external and,
- ❑ 4 WLM radon decay products

... *But*

Applied Independently and Not a Sum Rule

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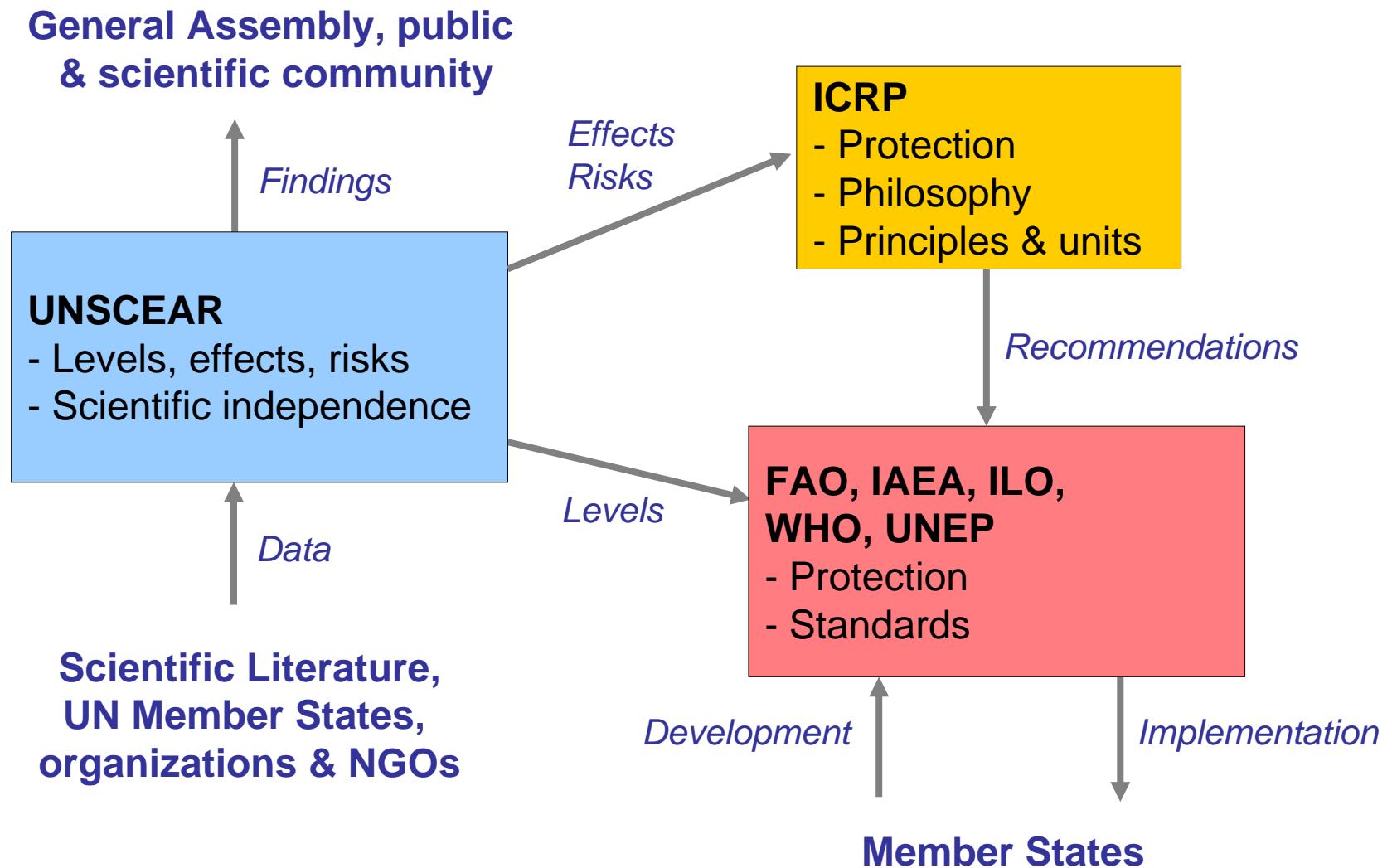
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Health Effects of Ionizing Radiation

□ International and National Authorities rely on the work of scientific committees such as:

- ❖ United Nations Scientific Committee on the Effects of Atomic Radiation (**UNSCEAR**);
- ❖ Biological Effects of Ionizing Radiation (**BEIR**) Committees;
- ❖ National Council on Radiation Protection and Measurements (**NCRP**), and others

for their scientific evaluation on the health effects of exposure to ionizing radiation





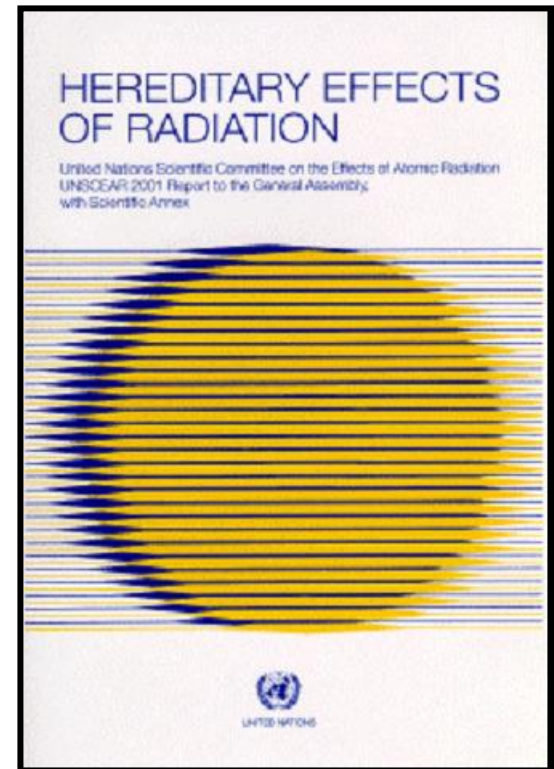
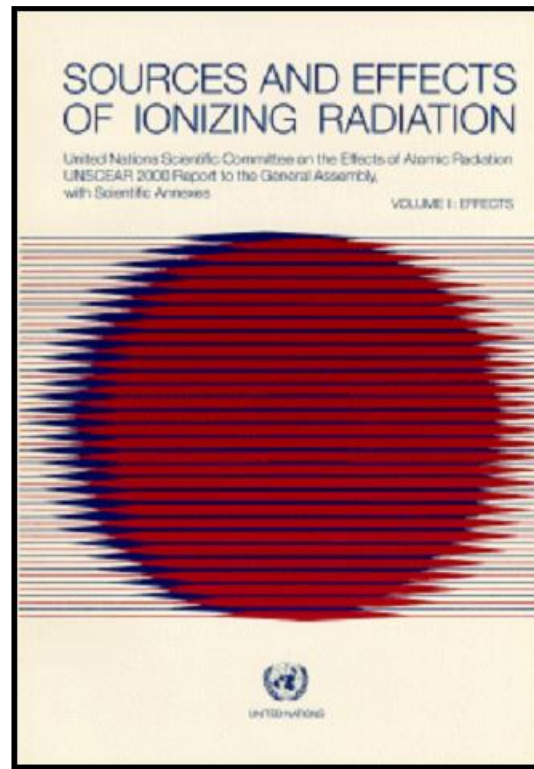
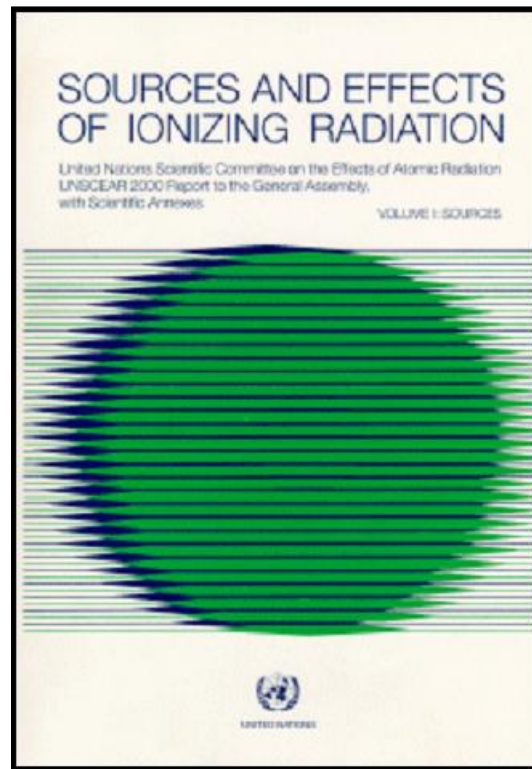
UNSCEAR



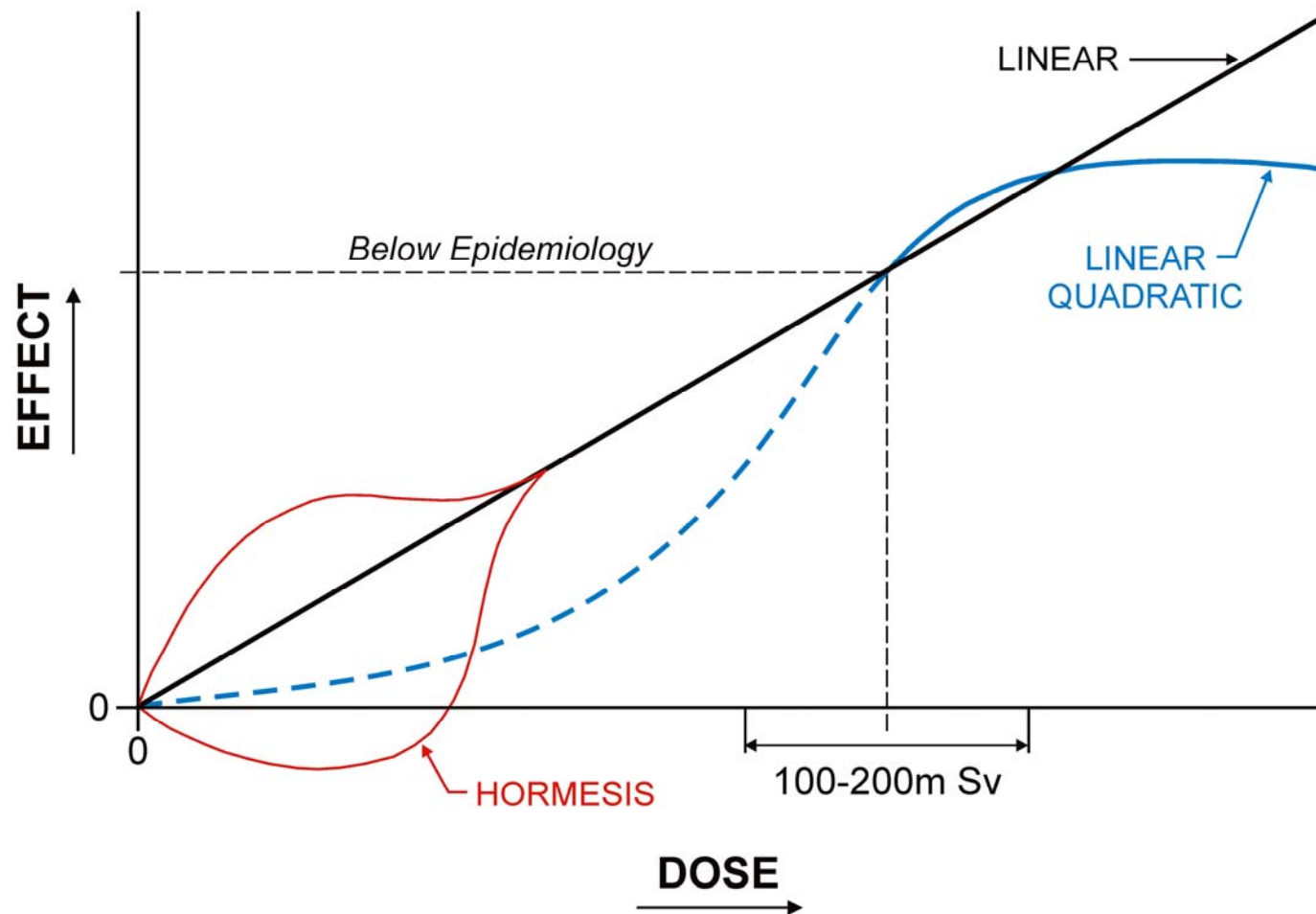
- ❑ Established by UN General Assembly resolution in 1955
- ❑ Scientists from 21 UN Member States
- ❑ Other States & organizations provide relevant data
- ❑ Holds annual sessions
- ❑ Assess as scientific information on levels and effects of ionizing radiation
- ❑ Disseminates findings to UN Assembly, UN agencies, scientific community & public

Most Recent UNSCEAR Reports

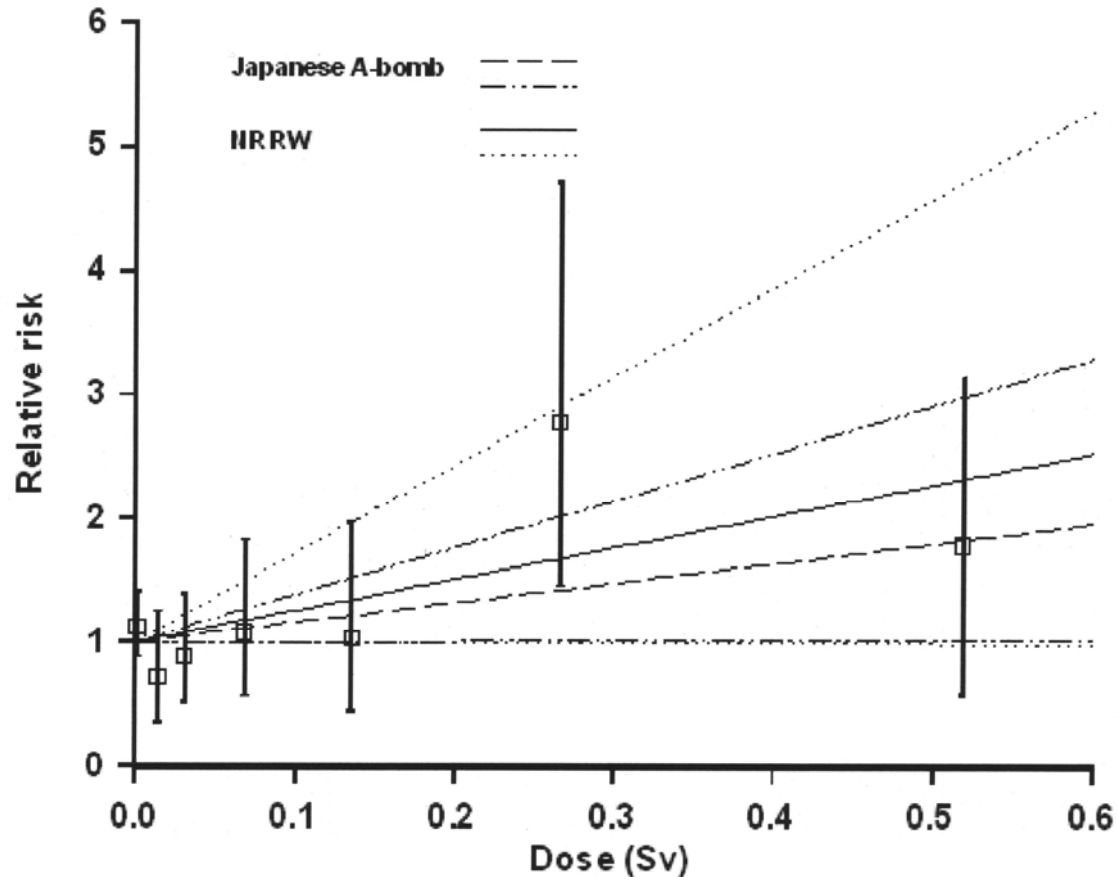
(available at unscear.org)



Dose Effect Models

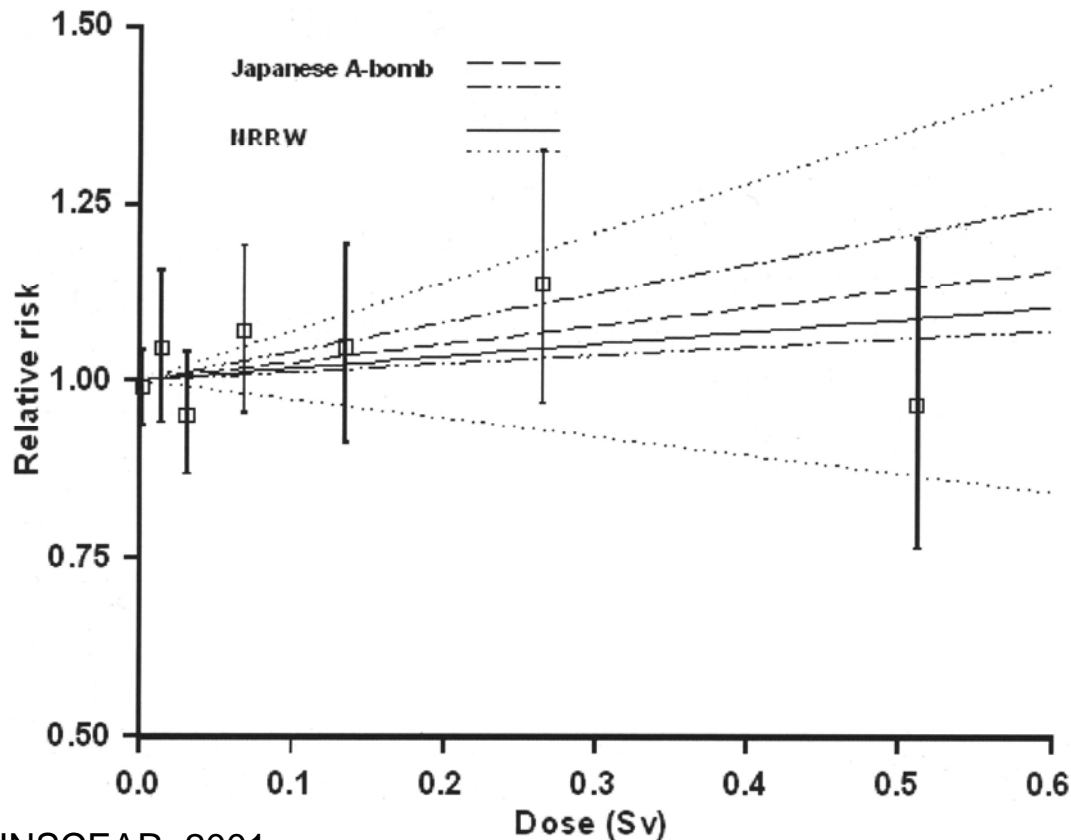


Trends In Relative Risk With Dose (and 90% CI) For Leukaemia



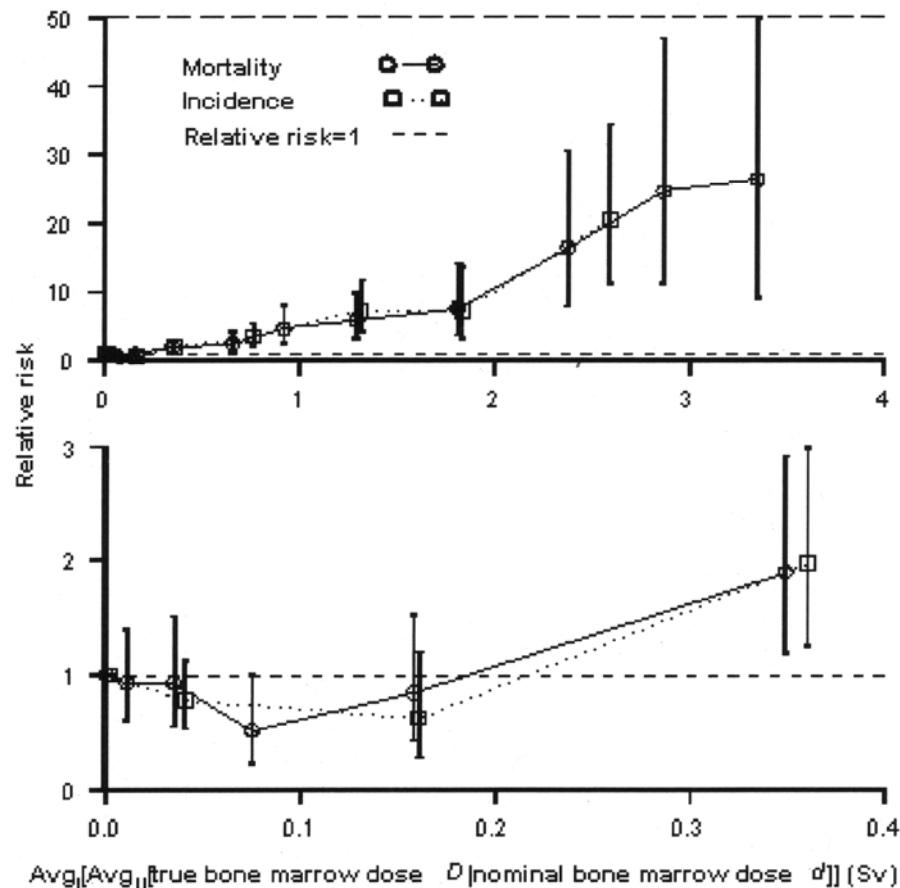
SOURCE: AFTER UNSCEAR, 2001

Trends In Relative Risk With Dose (and 90% CI) For All Malignant Neoplasms Other Than Leukaemia and Lung Cancer



SOURCE: AFTER UNSCEAR, 2001

Relative Risk Leukaemia Mortality and Incidence



SOURCE: AFTER UNSCEAR, 2001

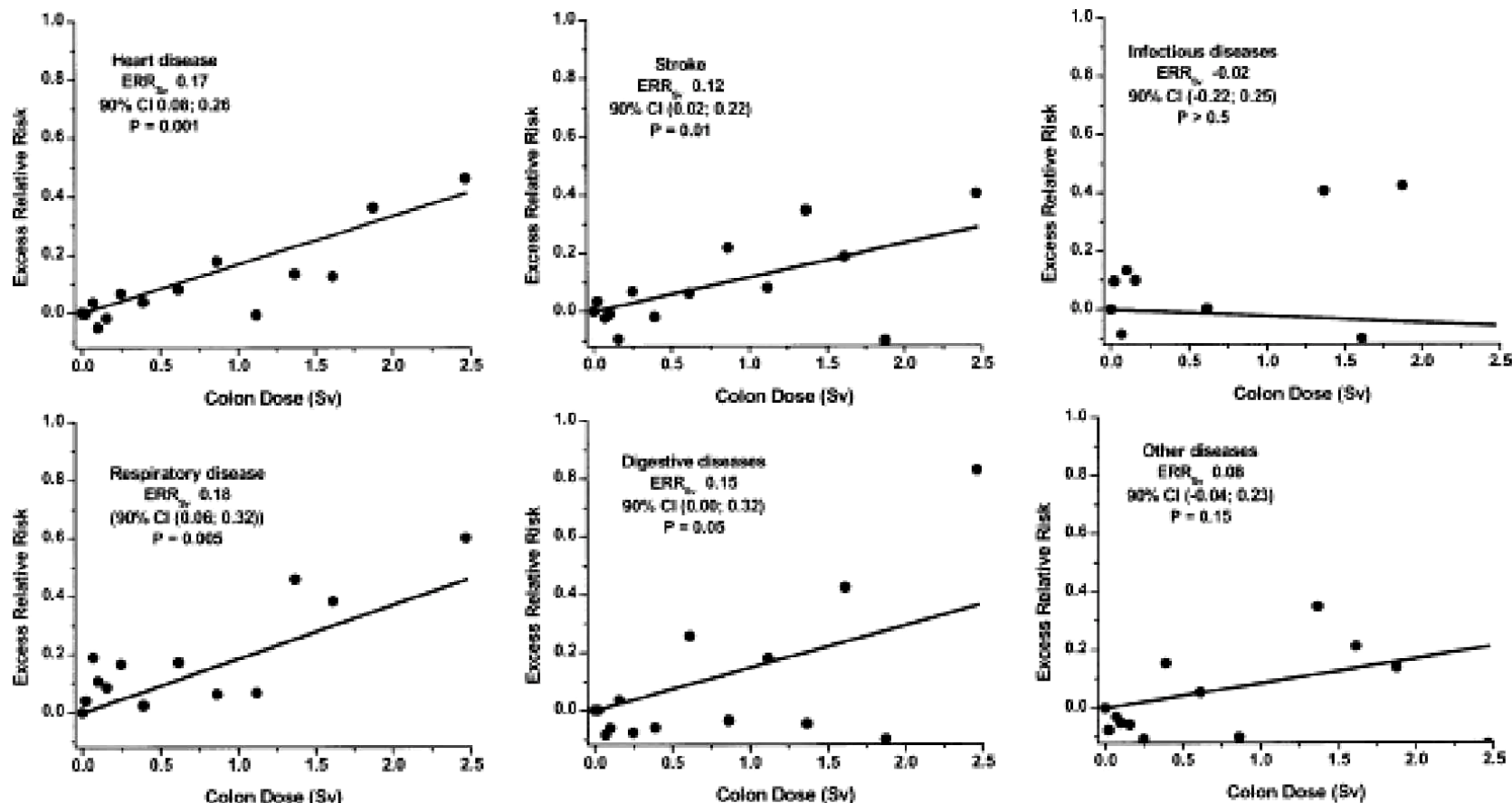
Key Observations from UNSCEAR 2006 and BEIR VII

- ❑ Cancer risk estimates have not changed much since 1990
- ❑ In general, a significant radiation effect is only detectable at doses above (about) 100 mSv

Non-Cancer Effects (cardiovascular disease)

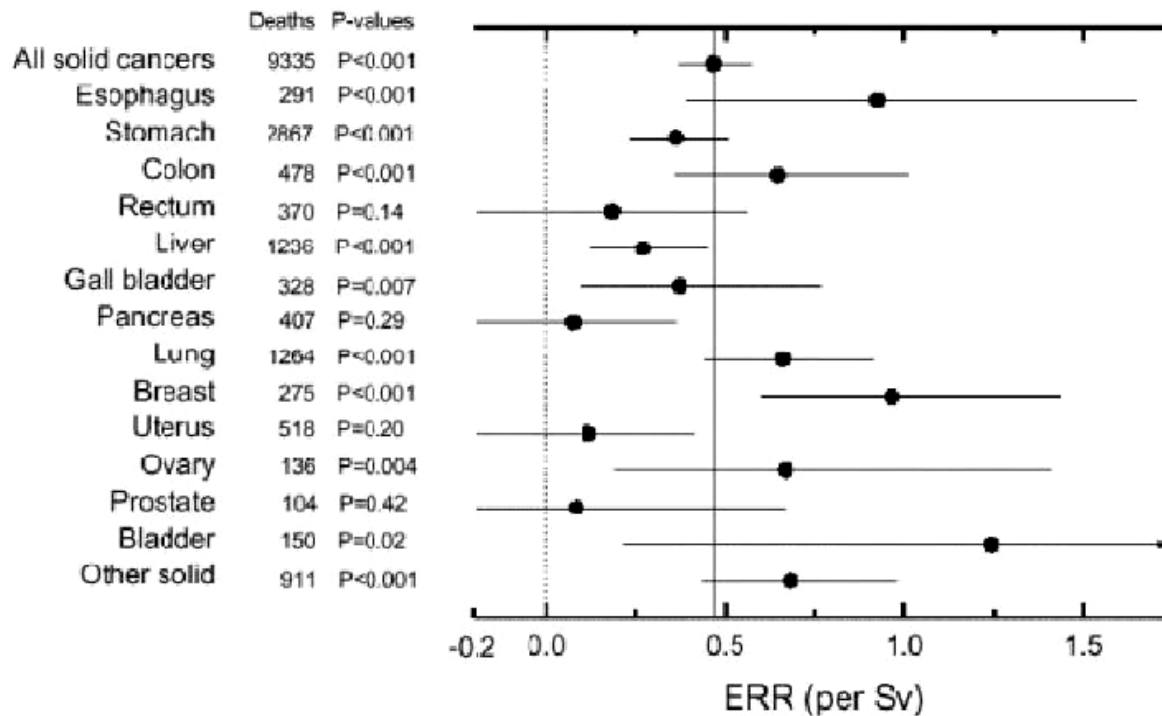
- ❑ Traditionally, effects of radiation on diseases other than cancer regarded as “non-stochastic”, i.e., a threshold is assumed to exist
- ❑ Annex focuses on recent follow-up of non-cancer endpoints in Japanese atomic bomb survivors (LSS) cohort and high-dose radiation therapy, in particular cardiovascular disease
- ❑ No clear evidence of risk at radiation doses below about 1 Gy

Dose-Response Curves for Non-Cancer Mortality (LSS 1968-1997)



Epidemiological Studies of Radiation and Cancer

Estimates of the Site-Specific Solid Cancer ERR with 90% Confidence Intervals and One-Sided P-Values for Testing the Hypothesis of No Dose Response



All estimates and P-values are based on a model in which the effects of age at exposure and of attained age were fixed at the estimates for all solid cancers as a group. The light dotted vertical line at 0 corresponds to no excess risk, while the dark solid vertical line indicates the sex-averaged risk for all solid cancers.

After UNSCEAR 2006

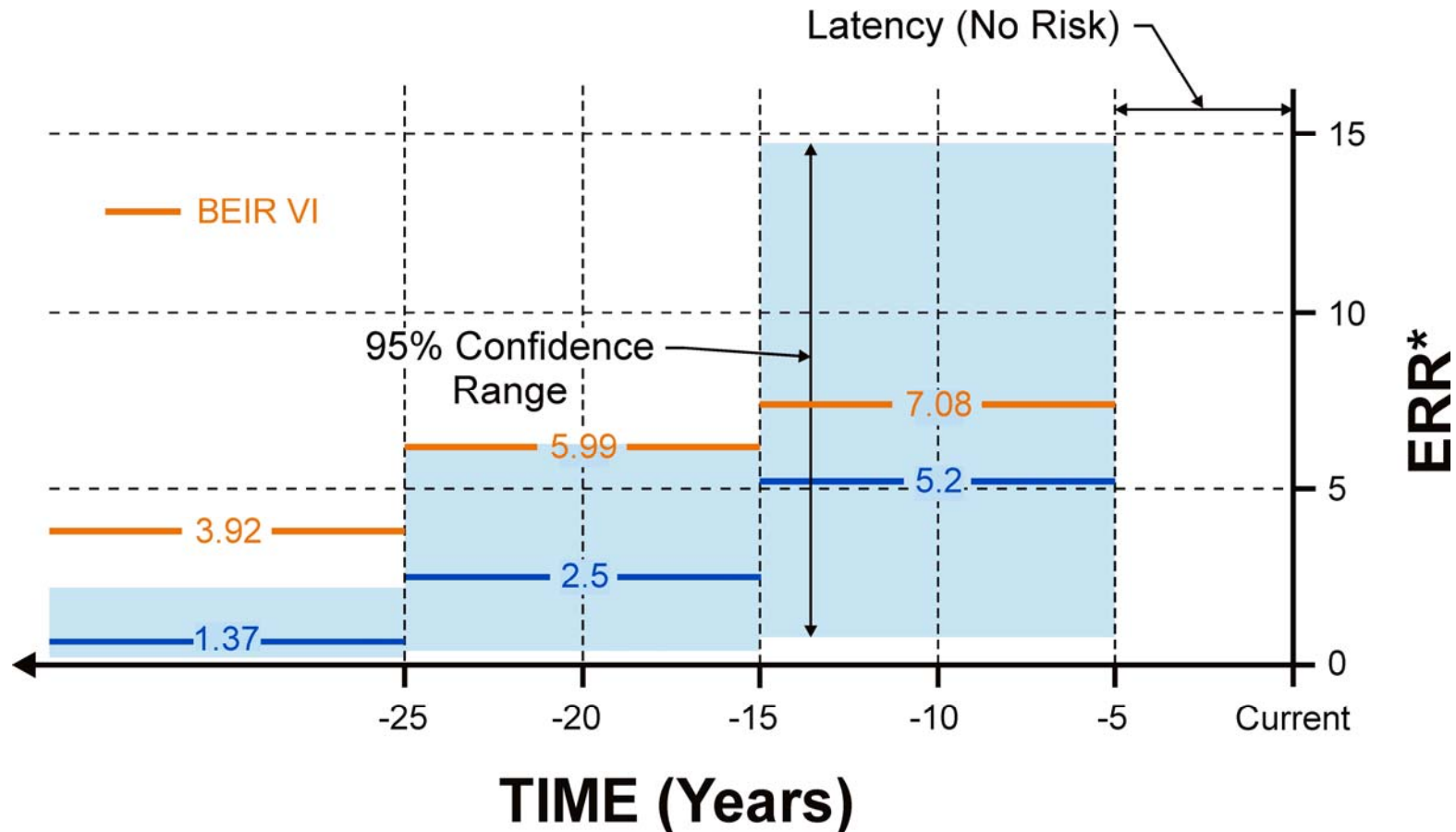
ICRP Risk Coefficients

- ❑ Latest cancer risk coefficients essentially unchanged from ICRP60 values (about 5% per Sv)
- ❑ Risk of heritable effects reduced 6 to 8 fold (risk now summed over two generations only – extending over a very large number of generations not now considered reasonable)
- ❑ LNT assumed for radiation protection purposes

ICRP Risk Coefficients (% per Sv)

Exposed Population	Cancer		Heritable Effects		Total	
	2007	ICRP 60	2007	ICRP 60	2007	ICRP 60
Whole	5.5	6.0	0.2	1.3	5.7	7.3
Adult	4.1	4.8	0.1	0.8	4.2	5.6

Time Since Exposure



*SOURCE: After Howe et al, 2005

Smoking is Main Cause of Lung Cancer

- ❑ Darby et al (2005) in a study of 13 European residential case control studies looked at combined effect of smoking and residential radon on the absolute risk of lung cancer and found that for lifetime (75 y) of exposure to 100 Bq m^{-3} and using the same relative risk factor of 0.16 per 100 Bq m^{-3} :
 - ❖ 0.47% risk from radon to never smokers
 - ❖ 11.6% risk from radon to smokers

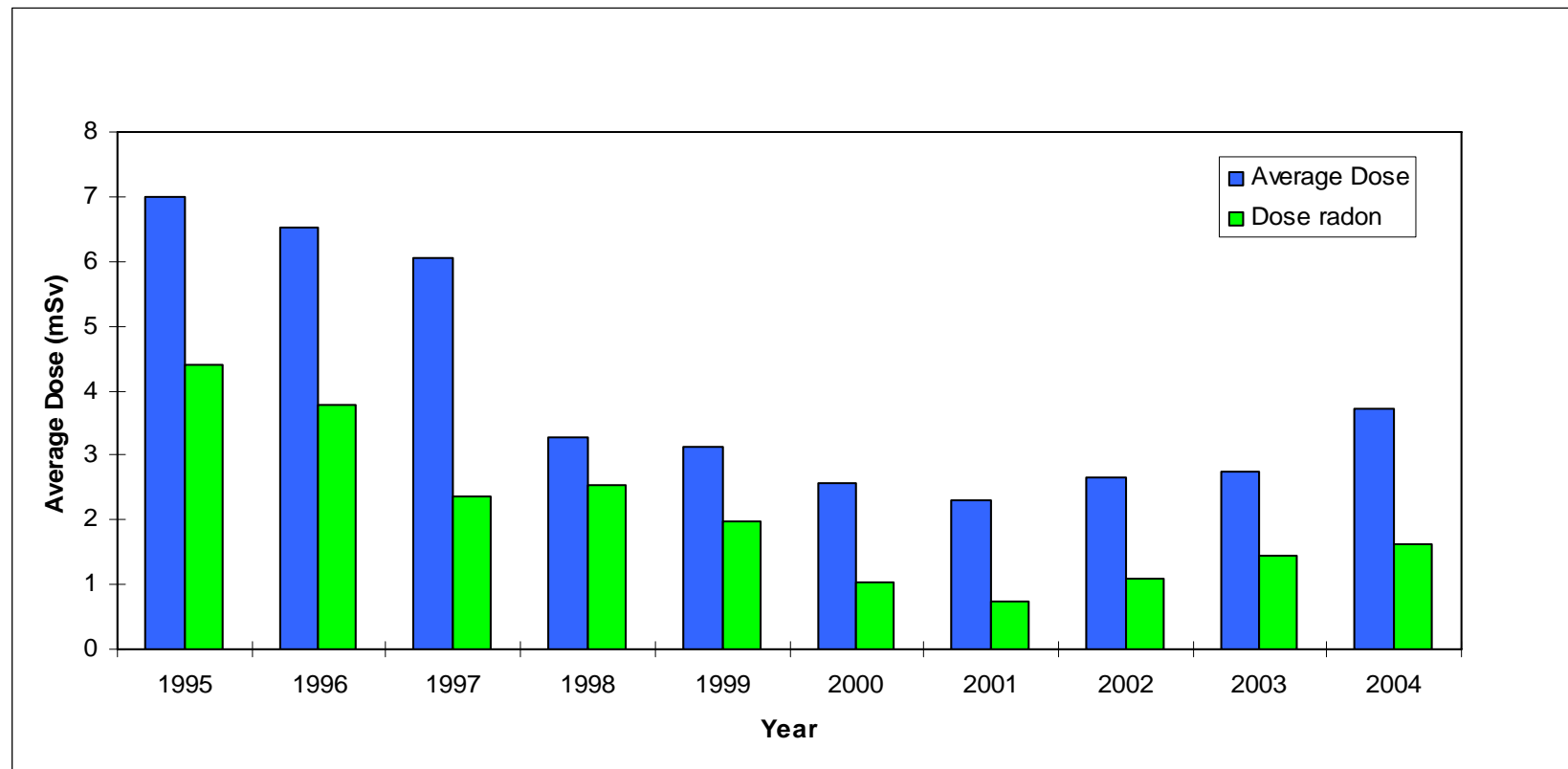
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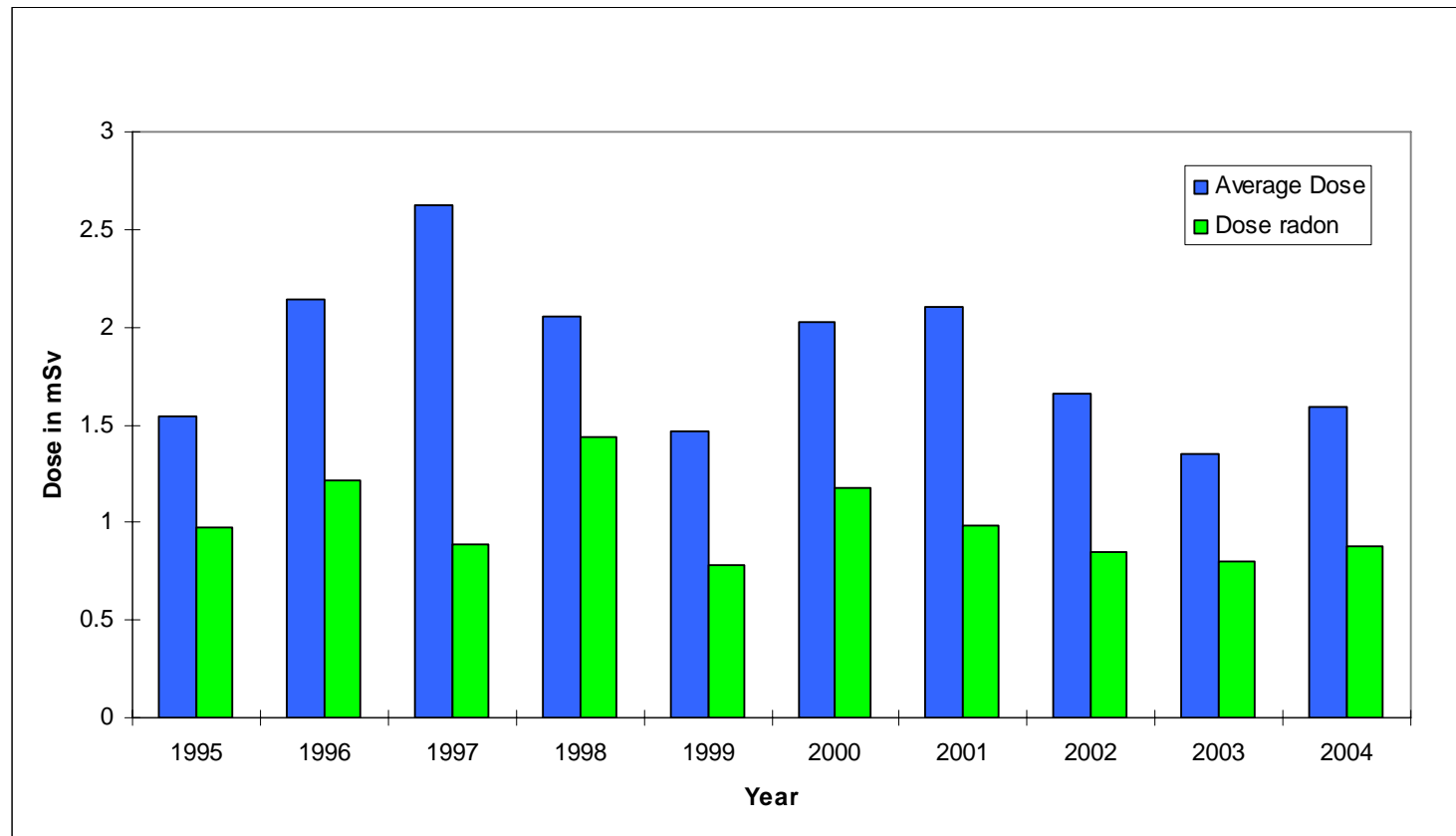
Radiological Effects of Uranium Mining and Milling

- ❑ **Uranium Mine and Mill Workers**
 - ❖ **No recent data for conventional mines in US and therefore illustrate with data from Canada**
- ❑ **People who live nearby to a uranium mine or mill**

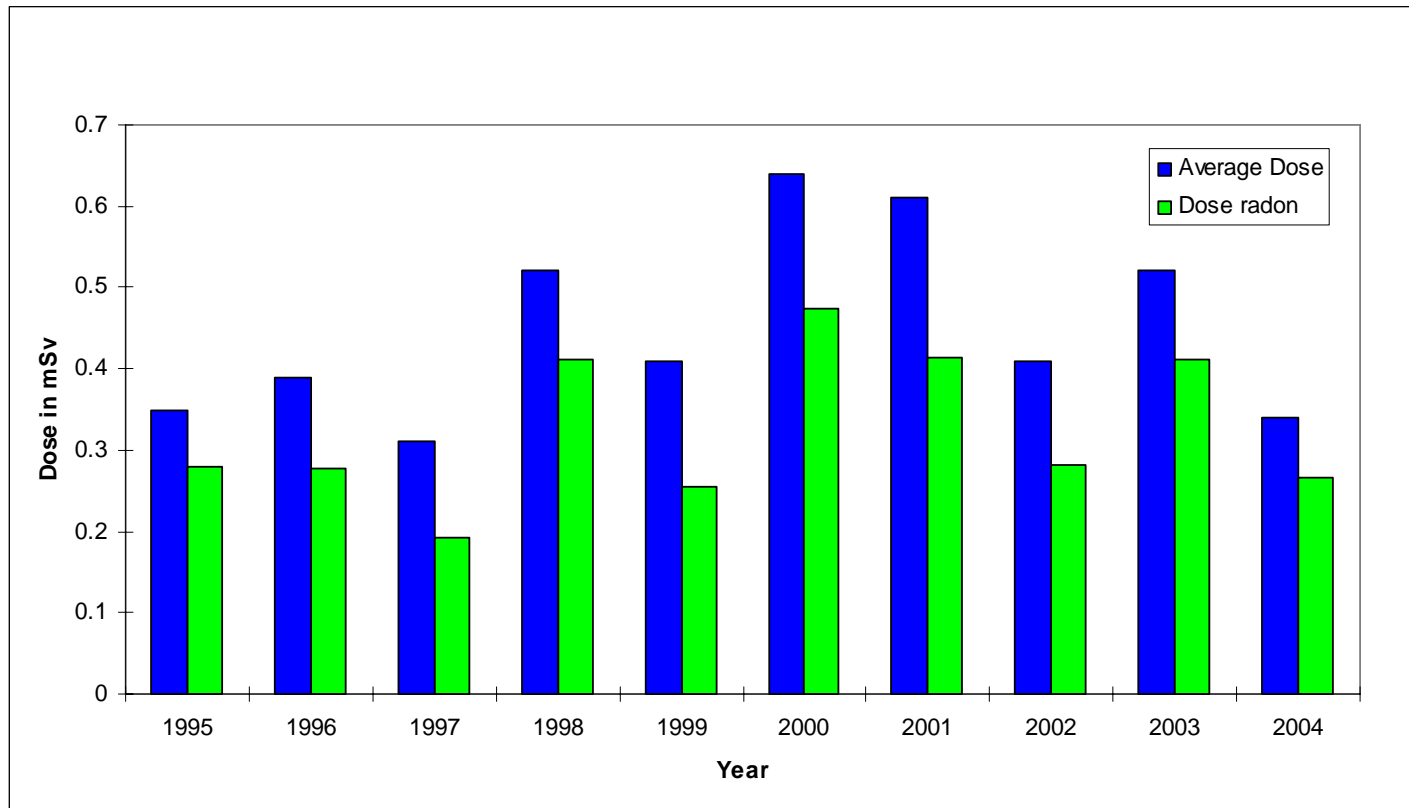
Average Annual Radiation Dose to Underground Miners at Uranium Mines in Canada



Average Annual Radiation Dose to Mill Workers at Uranium Mines in Canada



Average Annual Radiation Dose to Surface Personnel at Uranium Mines in Canada



Total Doses to Mill Workers

(All doses given in mrem per year)

Source	Total Dose (TEDE)	Comments
Uranium Milling GEIS (NUREG 0706)	380 mrem	Data for 17 U.S. uranium mills circa 1975
Canada 1997 to 2004	186 mrem	Data for 3 uranium mills in Canada
US Natural Background	296 mrem	US average (NCRP 1987)

Dose to People Living Nearby

Source	Annual Dose (TEDE, mrem per year)	Comment
Conventional Mine and Mill	50 mrem	NUREG 0706 and Chambers et. al, 1989
ISR	0.52 mrem	Average of airborne releases for 3 nearest residences, NUREG 1508
Surface Workers	47 mrem	Canadian Data
US Natural Background	296 mrem	U.S. average (NCRP 1987)

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Doses

- ❑ from natural background
 - ❖ 300 (200 – 800) mrem per year

- ❑ from mining and milling
 - ❖ Workers (500-1000) mrem
 - ❖ Public (50 -100) mrem

Baseline Risks

(NVSS 2005)

❑ Male - all causes

❖ All Ages	8.5×10^{-3}
❖ 25-34	1.4×10^{-3}
❖ 55-64	11.8×10^{-3}

❑ Male - Neoplasms

❖ All Ages	2.0×10^{-3}
❖ 25-34	0.06×10^{-3}
❖ 55-64	4.0×10^{-3}

❑ Male Accidents

❖ All Ages	0.49×10^{-3}
❖ 25-34	0.48×10^{-3}
❖ 55-64	0.45×10^{-3}

Risks from Radiation

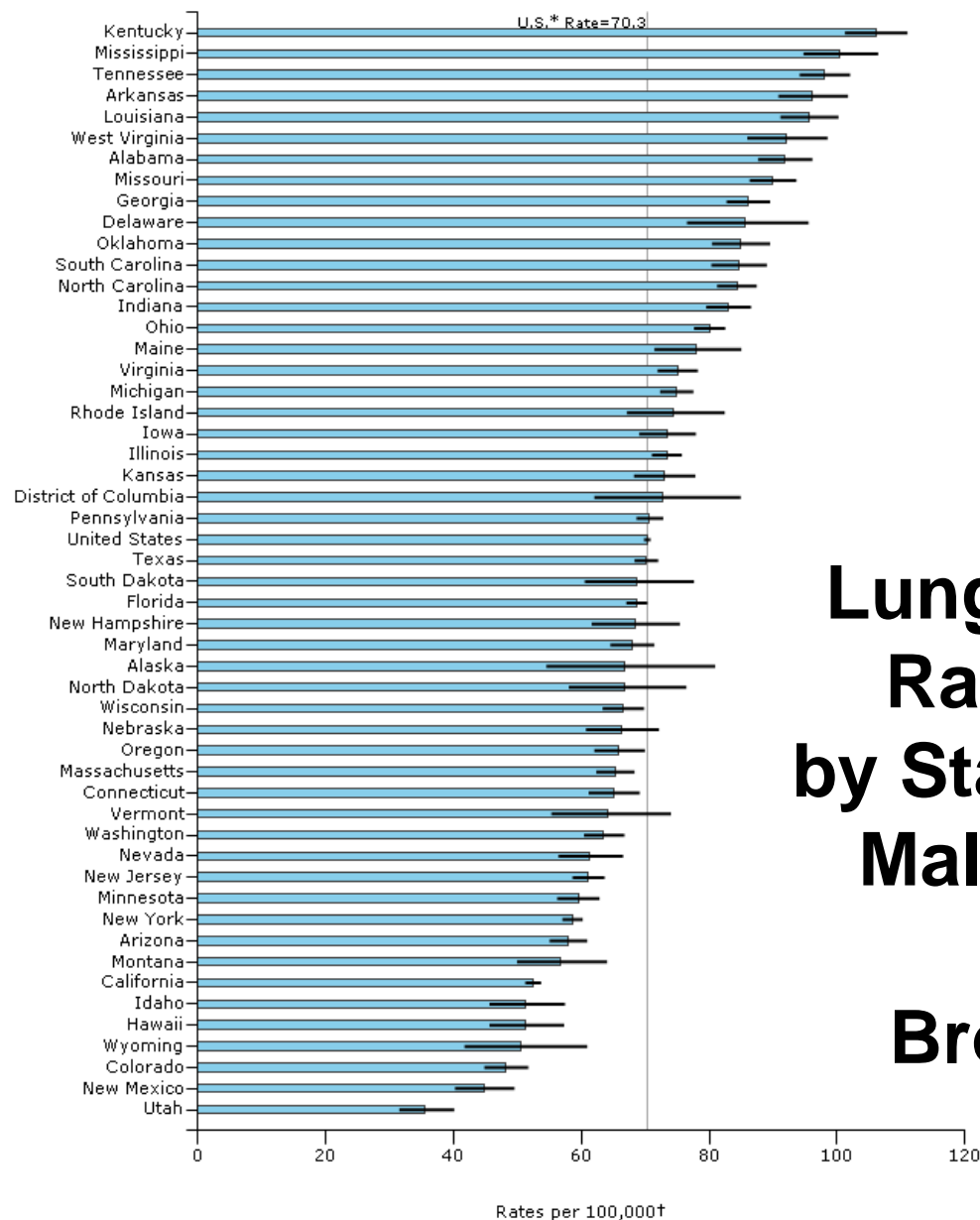
□ Lifetime risk per

- ❖ 1 mrem 5×10^{-7} (0.0005×10^{-3})
- ❖ 100 mrem 5×10^{-5} (0.05×10^{-3})
- ❖ 1000 mrem 5×10^{-4} (0.5×10^{-3})

□ Annual risk of accidental death

- ❖ 0.49×10^{-3}

□ Consider Risk of Lung Cancer



Lung Cancer Rankings by State: 2004, Male, Lung and Bronchus

Age-standardized Death Rates in 2004

Males: 2004 Age Standardized Death Rates per 100,000 for Cancer					
	U.S.	New Mexico	Colorado	Utah	Arizona
Total	228.3	194.8	189.7	167.4	202.3
Lung and Bronchus^a	70.3	44.7	48.2	35.6	57.9
Leukemias^b	9.7	8.4	9.5	8.6	8.6

Source: <http://apps.nccd.cdc.gov/uscs> on 24 April 2008

Notes:

- a) Four corner area statistically significantly lower than U.S. Average
 - other factors (smoking prevalence, industrial pollution) may differ.
- b) Four corner area lower than U.S. average, but not statistically significant.

Study of Colorado Populations Near U Mining/Milling Operations

- ❑ Boice et al (Rad. Res. 2007) examined mortality rates (1950-2000) around historical mining areas (early 1900s-1980s)
- ❑ No statistically significant increases for any cause of death except LCs in males (associated with historical occupational exposures); no increase in females
- ❑ No evidence that residents experienced increased risk of death due to environmental exposures from uranium mining and milling