Radon Risk in Uranium Mining and the ICRP

Presented To:

The 13th International Congress of the International Radiation Protection Association

Glasgow, Scotland, 13-18 May 2012

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This Talk

- Epidemiology and ICRP DCC
- Life table modelling of risk from exposure to radon
- Role of smoking
- Dosimetry (and DCF) – very brief
- Looking ahead

ICRP Nov 2009 Statement

- Currently ICRP uses a dose conversion convention (DCC) to calculate effective dose per unit exposure to radon progeny based on epidemiology;
- The detriment adjusted risk coefficient for radon is likely to double;
- ICRP intends that in the future, doses from radon and its progeny would be calculated using ICRP biokinetic and dosimetric models;
- Current dose conversion values may continue to be used until dose coefficients are available.

Epidemiological Dose Conversion Convention (DCC)

- **Obtain DCC by dividing the risk (LEAR) per WLM by the risk coefficient per mSv**

$$DCC(mSv/WLM) = \frac{risk(LEAR) \quad / WLM}{risk / mSv}$$

- risk per Sv has been reduced from 5.6% (ICRP 60) to 4.2% (2007) for occupational (adults) and 7.3% (ICRP 60) to 5.7% (2007) for the general population (whole)
- if risk per mSv is increased then it follows that the “allowable” mSv dose would decrease if the same degree of protection was required

Life Table Modelling

- **Required to estimate lifetime excess absolute risk (LEAR) from exposure**
- **Application of risk projection models to various populations**
  - ICRP 103 Populations (4)
  - Canada by smoking status
- **Risk / WLM (and DCC) depends on**
  - relative projection risk model
  - baseline lung cancer mortality (dominated by smoking)
- **Implications of smoking prevalence needs to be considered**

Risk Models

- **Absolute risk**

$$r(x) = r_o + \beta x$$

- **Relative risk**

$$r(x) = r_o (1 + \beta x) = r_o + r_o \beta x$$

- **Multiple causes and relative risk**

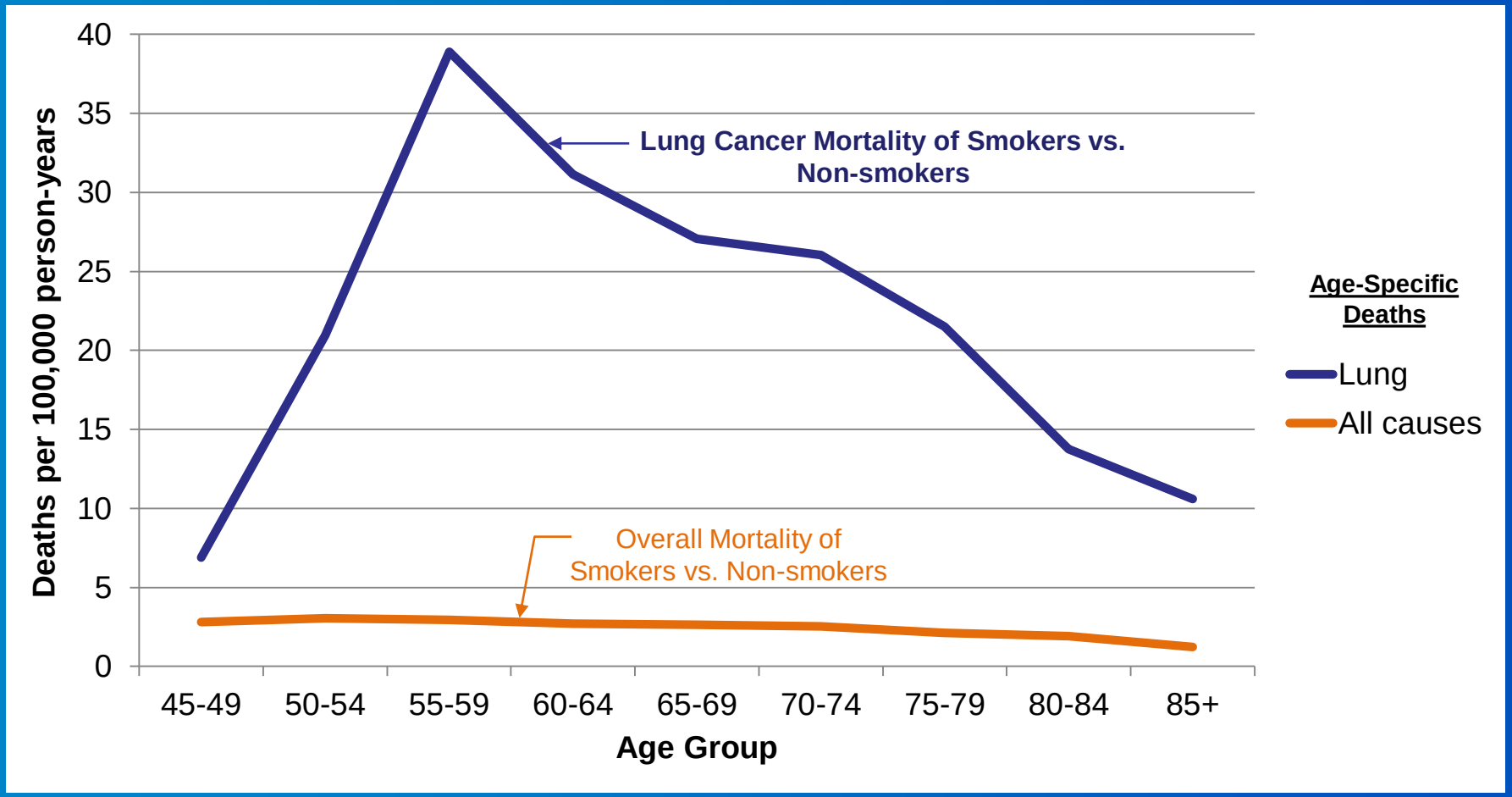
$$r(x_1 x_2) = [r_{ns}(1 + \beta_1 x_1)] (1 + \beta_2 x_2)$$

Packs

WLM

$[r_o$ (genetics, exogenous, x_3, x_4, ….etc.)]

Ratio of Risks of Age-specific Deaths in Male Smokers/Non-Smokers



After : American Cancer Society CPS -II

Seven Risk Models Considered

- **ICRP 65**
  - GSF Model
- **TG 64 (under ICRP Committee 2)**
  - BEIR VI - "in vogue" current model, complex formulation, incorporation of many different studies
  - French/Czech combined study of two very different experiences
- **Additional Models**
  - Ontario - large cohort with low exposures (being updated)
  - Wismut – large with recent mortality update
  - Darby – residential model
  - Eldorado – BEIR VI model formulation

LEAR for ICRP Reference Populations

Population	Sex	Baseline Lung (Proportion)	LEAR/WLM[a]	mSv/WLM[b]
Asian	F	0.026	0.00032	7.6
Asian	M	0.059	0.00069	16
EuroAmerican	F	0.034	0.00045	11
EuroAmerican	M	0.063	0.00078	19
Average	-	-	0.00056	13

a) Calculated using the BEIR VI low exposure rate model for working age population exposed at 2 WLM/y from 18 to 64 years with follow-up to 95 years,

b) Using a detriment of 4.2×10^{-2} detriment per Sv

Summary for Average ICRP 103 Populations

	Occupational		Residential	
	LEAR/WLM*	mSv/WLM	LEAR/WLM**	mSv/WLM
GSF	0.00028	6.7	0.00031	4.3
BEIR VI	0.00056	13	0.0006	8.5
French Czech	0.0005	12	0.00053	7.5
Ontario	0.00025	5.9	0.00031	4.3
Darby	0.00027	6.3	0.00027	3.7
Eldorado	0.0007	17	0.00069	9.8
Wismut	0.00031	7.4	0.00034	4.7

* 2 WLM/y for 18 to 64 years, follow-up to 95 years

** 0.44 WLM/y for lifetime, follow-up to 95 years

Effect of Smoking

	mSv per WLM						
	GSF (ICRP 65)	BEIR VI	French Czech	Ontario	Darby	Eldorado	Wismut
Occupational*							
CanadaEver	15	30	26	13	14	38	16
CanadaNever	1.6	3.2	3.1	1.5	1.5	3.3	1.9
Public**							
CanadaEver	9.4	20	17	9.4	8.2	23	10
CanadaNever	1.1	2	2	1.1	0.97	1.9	1.5

- mSv/WLM to non-smokers is about 1/10th the mSv/WLM for ever smokers.
- Smoking Prevalence is decreasing

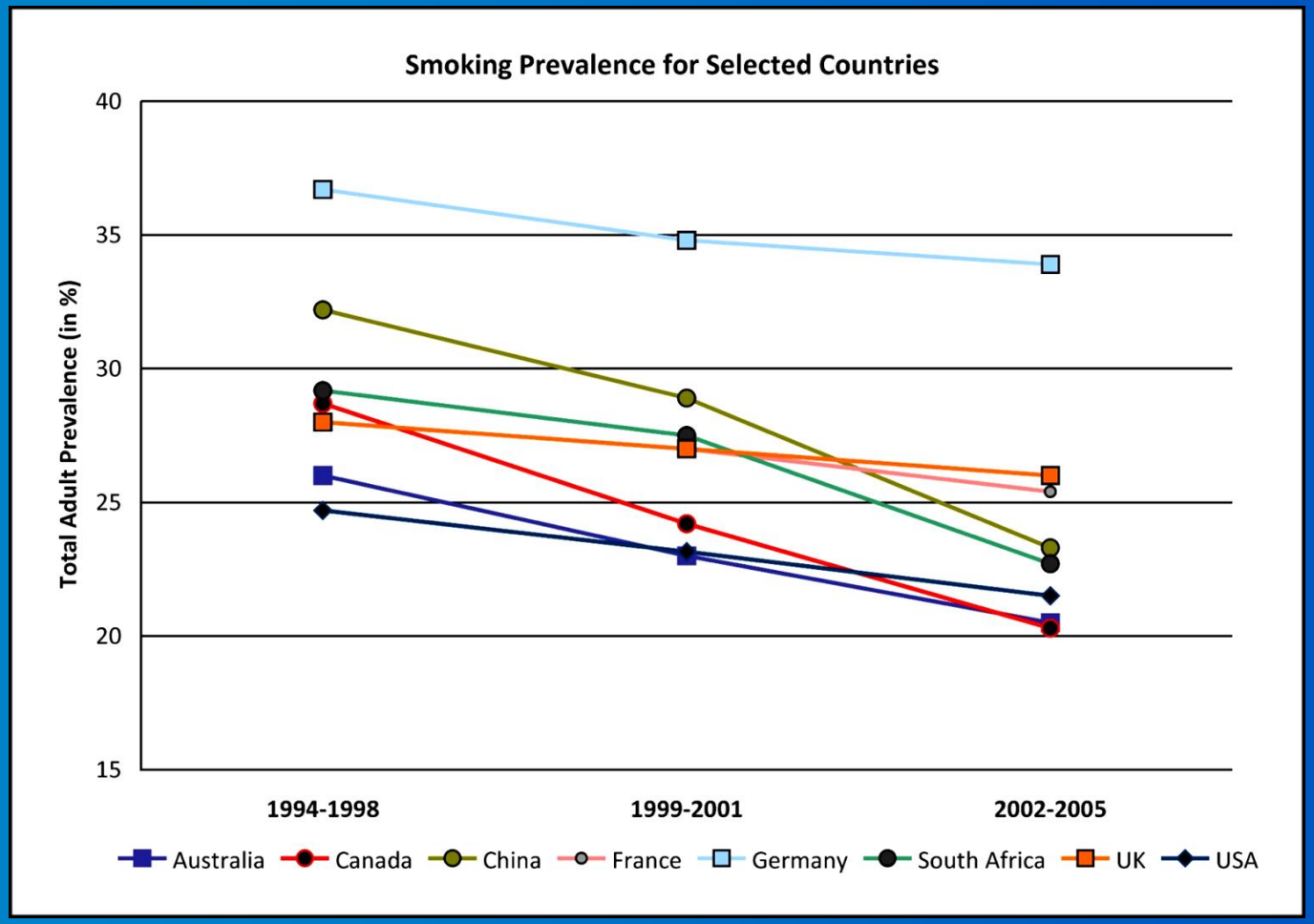
* exposure at 2 WLM/y from 18 to 65 years, follow-up to 95 years

** exposure at 0.44 WLM/y from 0 to 95 years, follow-up to 95 years

Life Table Modelling …cont'd

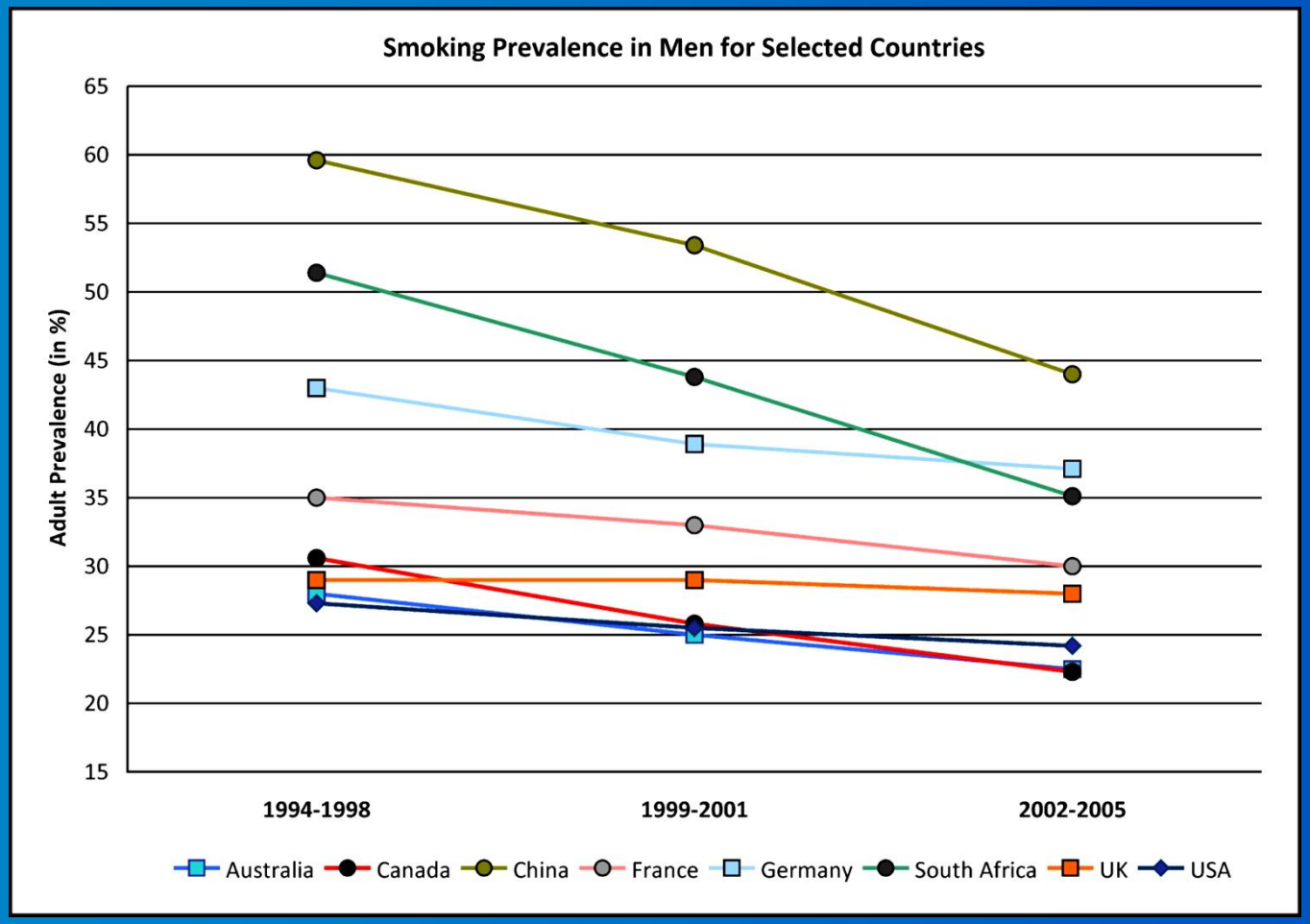
- 7 excess relative risk projection models including those considered in TG 64
- LEAR/WLM and mSv/WLM vary more than factor of 2 across the 4 ICRP 103 reference populations
- Smoking prevalence has generally declined across the world
- LEAR/WLM and mSv/WLM depend on risk model and baseline lung cancer rates (in turn depend on smoking history)

Smoking Prevalence (Country)

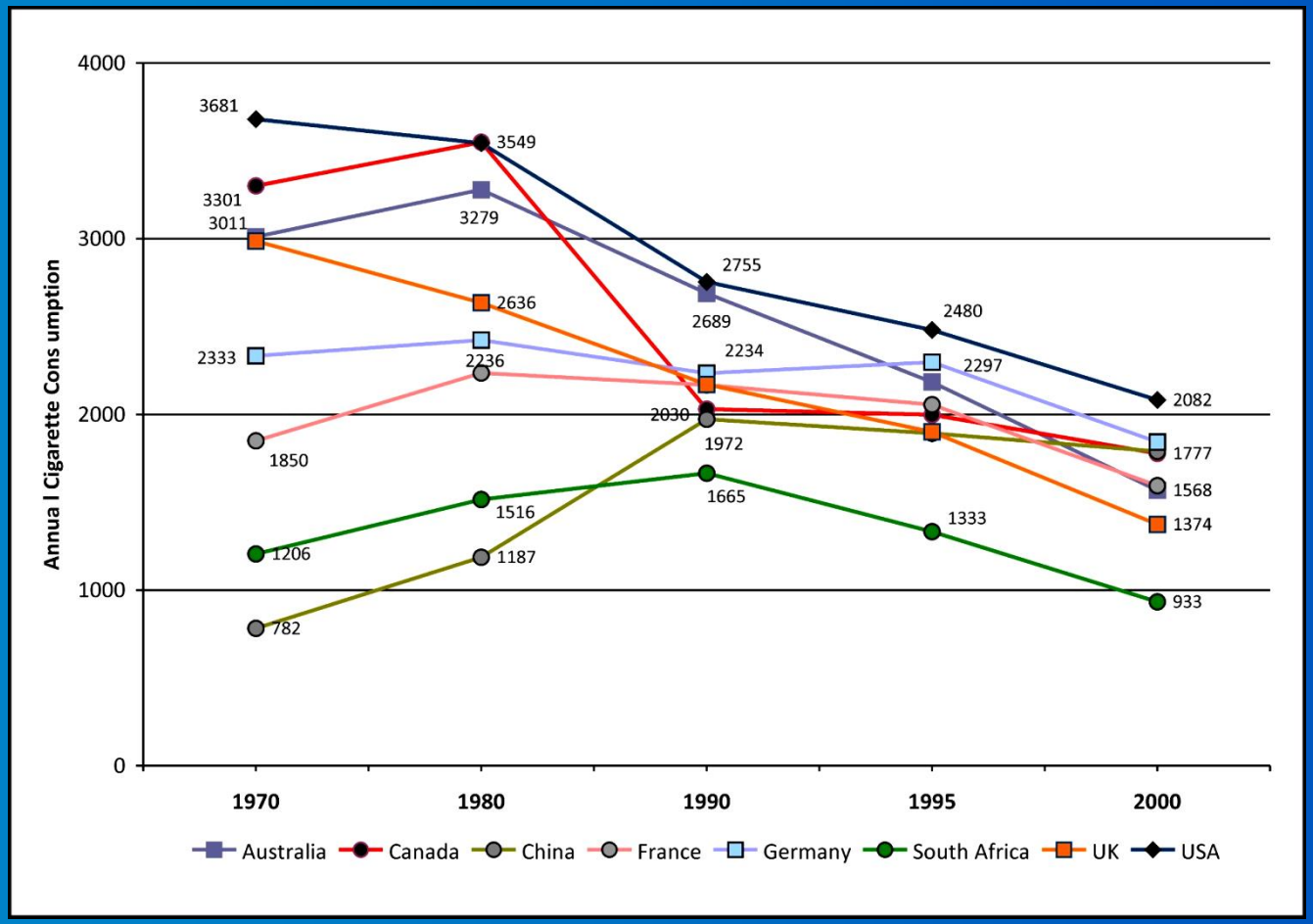


Various WHO and other reports on smoking

Smoking Prevalence (Male)



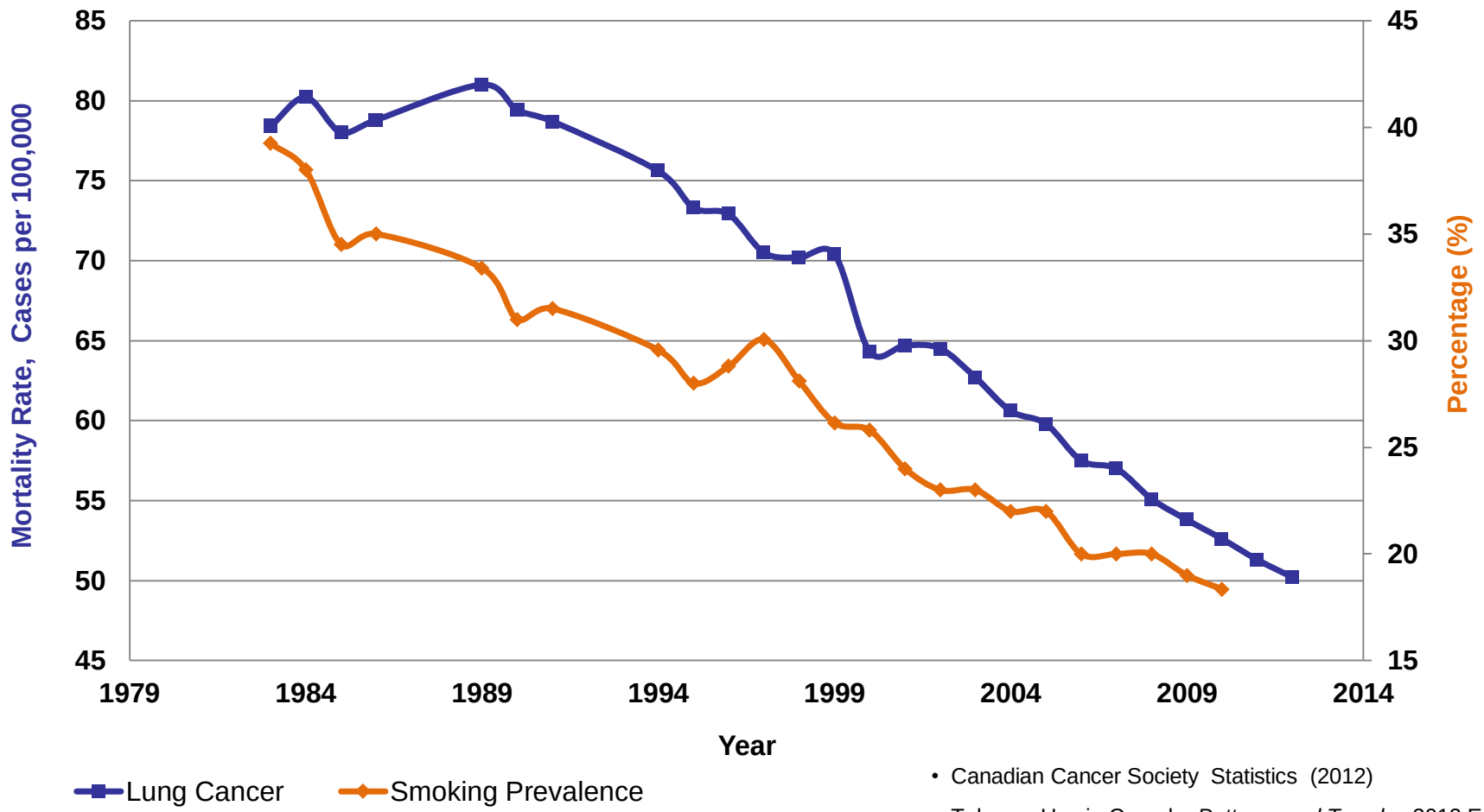
Cigarette Consumption Per Capita (Country – Cigarette Sticks)



DCC (mSv per WLM) as Function of Prevalence of Non-Smokers

	% Non-smokers					
	100	**90**	**80**	**70**	**60**	**50**
GSF (ICRP 65)	2	3	4	6	7	8
BEIR VI	3	6	8	11	14	16
FrenchCzech	3	5	8	10	12	15
Ontario	1	3	4	5	6	7
Eldorado	3	7	10	14	17	21
Wismut	2	3	5	6	8	9
Darby	1	3	4	5	6	8

Age-Standardized Mortality Rates and Smoking Prevalence for Lung Cancer in Males, Canada, 1983-2012



- Canadian Cancer Society Statistics (2012)
- Tobacco Use in Canada: *Patterns and Trends* , 2012 Edition

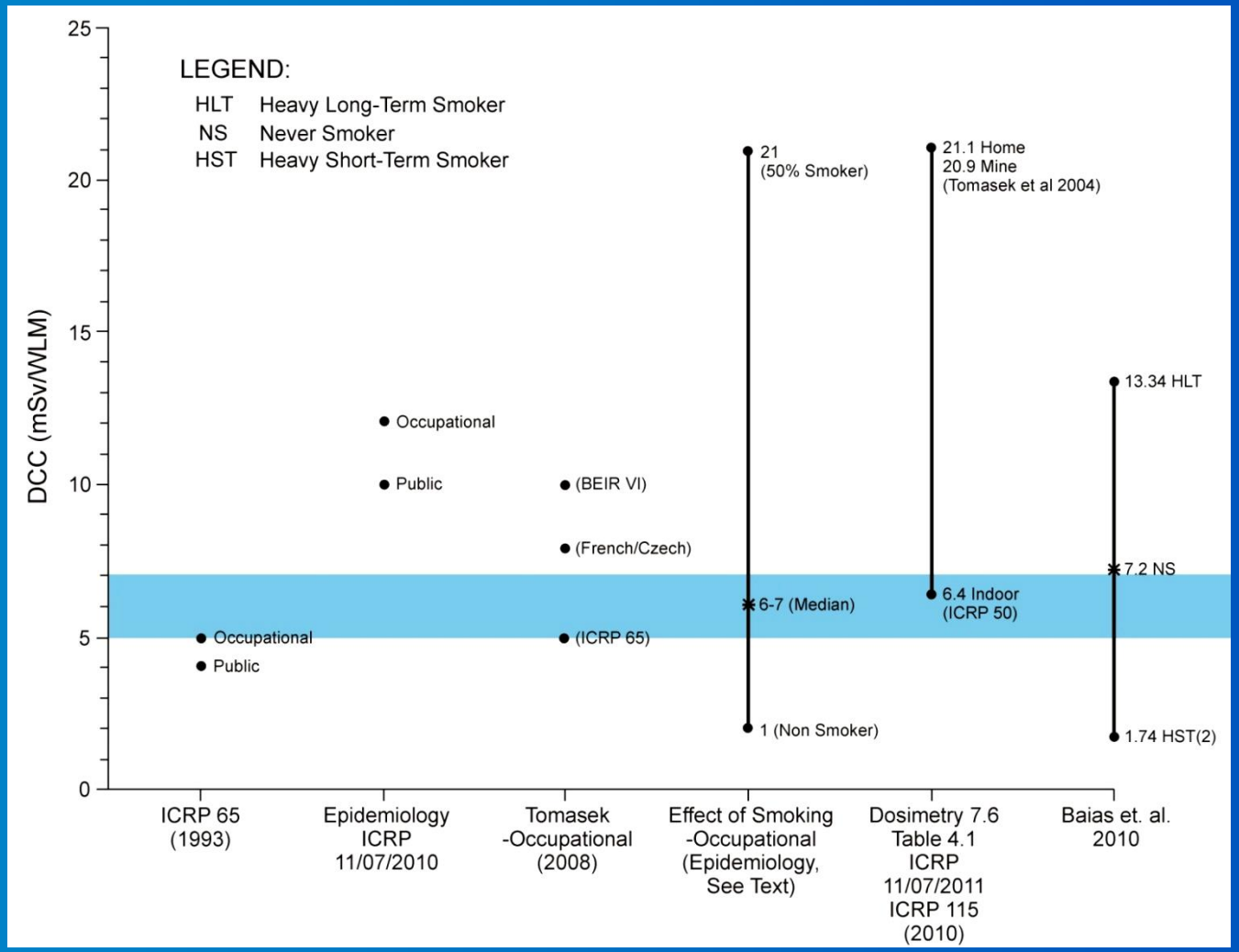
Epidemiological Results

- **Risk projection models are relative risk models and characteristics of underlying populations are important**
- **Smoking is the dominant risk for lung cancer**
  - ICRP 115 report notes risk is on the order of 20 times greater for smokers vs. non-smokers
- **General trend of declining smoking rates**

Dosimetric Approach

- **Dose coefficients for radon and progeny will replace the current *Publication 65* dose convention**
- **Dose coefficients will be given for different reference conditions of domestic and occupational exposure**
- **”Sufficient” information will be given to allow specific calculations to be performed in a range of situations**
- **Very limited data on mine aerosols**
  - Particle size
  - unattached fraction
  - Total alpha activity
- **Current dosimetric models cannot account for smoking**

Radon Dose Conversion Ranges



An Opinion

- **Uncertainty is present in both epidemiological and dosimetric approaches**
  - Range of epidemiological-based DCCs supports both 5 and 10 mSv/WLM,
  - Dosimetry supports range of DCF's from about 6 to 20 mSv/WLM, but
  - Dosimetry can not yet account for smoking.
- **Is the apparent agreement between the average DCF from the epidemiological studies and "typical" dosimetric parameters fortuitous?**

An Opinion cont'd

- Lack of relevant field data for modern mines combined with lack of measurement protocol => data are needed to support the derivation of ICRP dosimetric based reference levels for mines

- In interim, nominal DCC in the range of 6-7 mSv/WLM (for nominal 30% smoking rate) seems reasonable, not so different from current value and in concept, consistent with ICRP's use of (average) age, sex and smoking nominal average effective dose