

Worldwide mesothelioma mortality trends

Harvard Symposium 24th July 2009

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Asbestos-related diseases

Asbestosis (non-malignant lung fibrosis) is caused by prolonged heavy exposure to any type of asbestos.

Lung cancer is caused by all types of asbestos, but the risk is much lower in non-smokers.

Mesothelioma is caused mainly by blue and brown asbestos. The risk is much lower with white asbestos.

Asbestos epidemiology – the past and the future

Mesothelioma projections

Better methodology

Actuarial issues – future liability

Developing countries

Asbestos epidemiology – the past and the future

The role of amosite

Fibre type – length, diameter, surface properties, persistence, dose-response

Managing asbestos in buildings and waste sites

Nanofibres

Continuing use in developing countries

Differences between mesothelioma and lung cancer

Chrysotile and mesothelioma

“At present day levels of exposure to commercial chrysotile, whether or not contaminated with tremolite, the risk must be vanishingly small”

JC & AD McDonald 1997

“Exposure to chrysotile probably remains the leading cause of mesothelioma in the world in view of the far wider use of this material than of other types of asbestos.....The proposition of putting more asbestos into the environment.....is foolhardy”

MR Cullen 1998

Chrysotile – mesothelioma and lung cancer

The quantitative risks of mesothelioma and lung cancer
in relation to asbestos exposure

Hodgson & Darnton (2000) *Ann. Occup. Hyg.* 44:565-601

“The exposure specific risk of mesothelioma.....is broadly in the ratio 1:100:500 for chrysotile, amosite and crocidolite respectively.”

“The risk differential between chrysotile and the two amphibole fibres for lung cancer is between 1:10 and 1:50.”

Exaggeration of the hazards of chrysotile diverted attention from amosite

**The hazards of chrysotile asbestos: a critical
review. Landrigan, Nicholson, Suzuki, Ladou
Ind Health. 1999 Jul;37(3):271-80**

**Comparative analyses have established that
chrysotile is 2 to 4 times less potent than
crocidolite asbestos in its ability to cause
malignant mesothelioma, but of equal potency of
causation of lung cancer.**

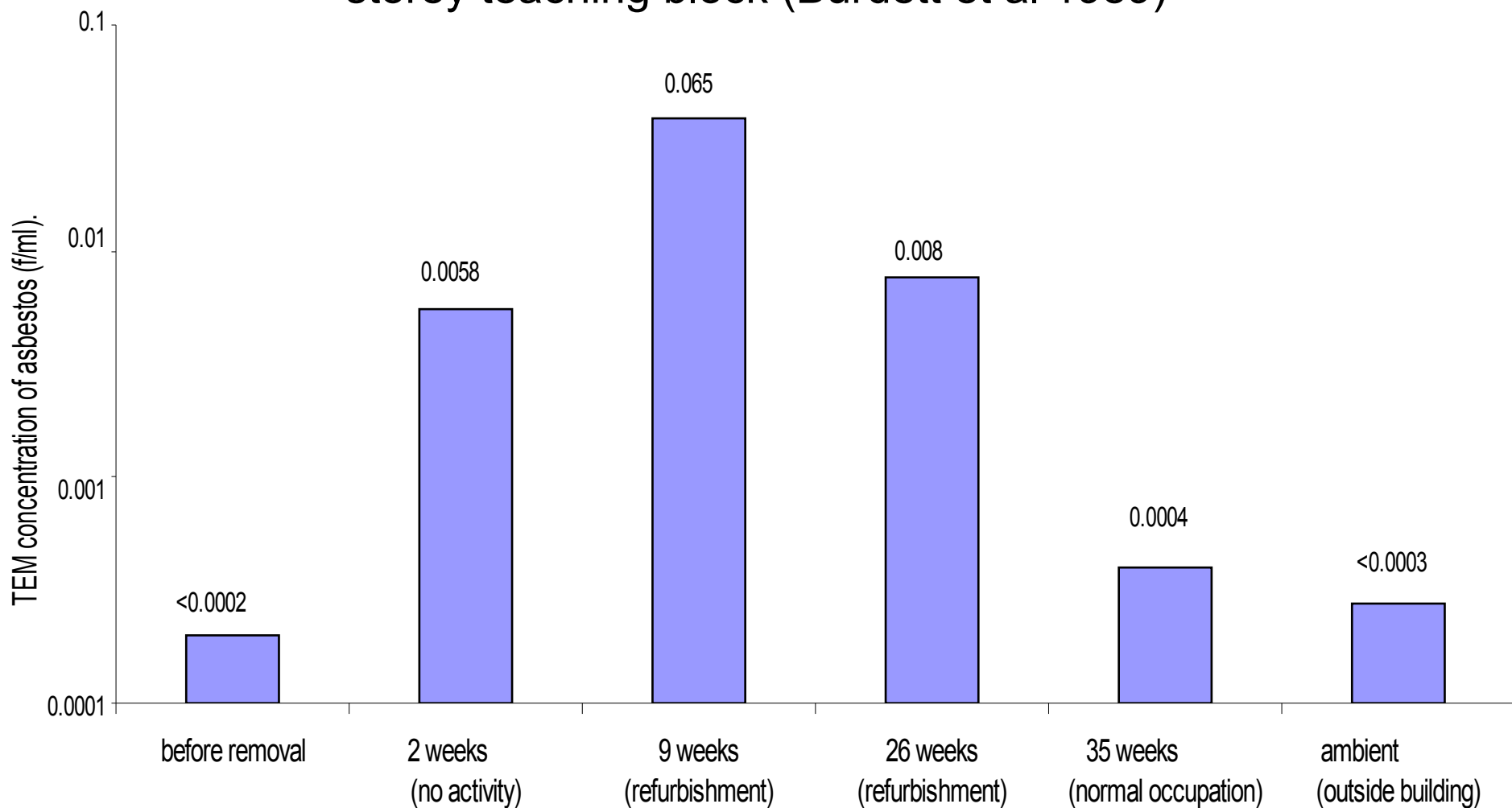
Asbestos use in Britain

After 1970 crocidolite was not used, and asbestos exposure was < 2 fibre/ml in most British factories.

Uncontrolled use continued in construction into the 1980s, including amosite (brown) asbestos cement board.

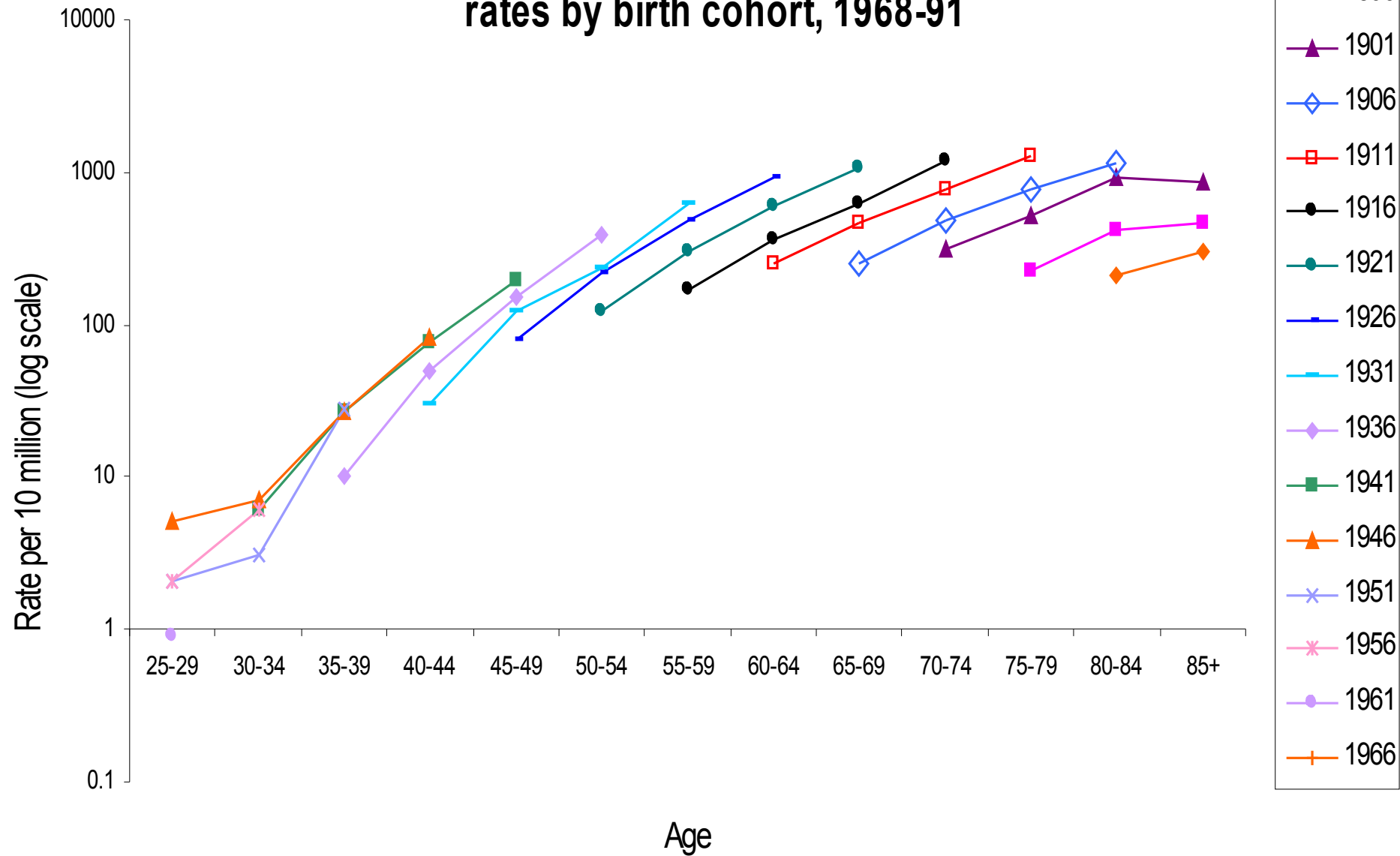
Environmental exposure was very low, but after 1980 public concern led to extensive removal from schools and public buildings, and asbestos use had virtually

Average ambient air concentrations of asbestos fibres >5µm long before, during and after an asbestos removal programme from a six-storey teaching block (Burdett et al 1989)



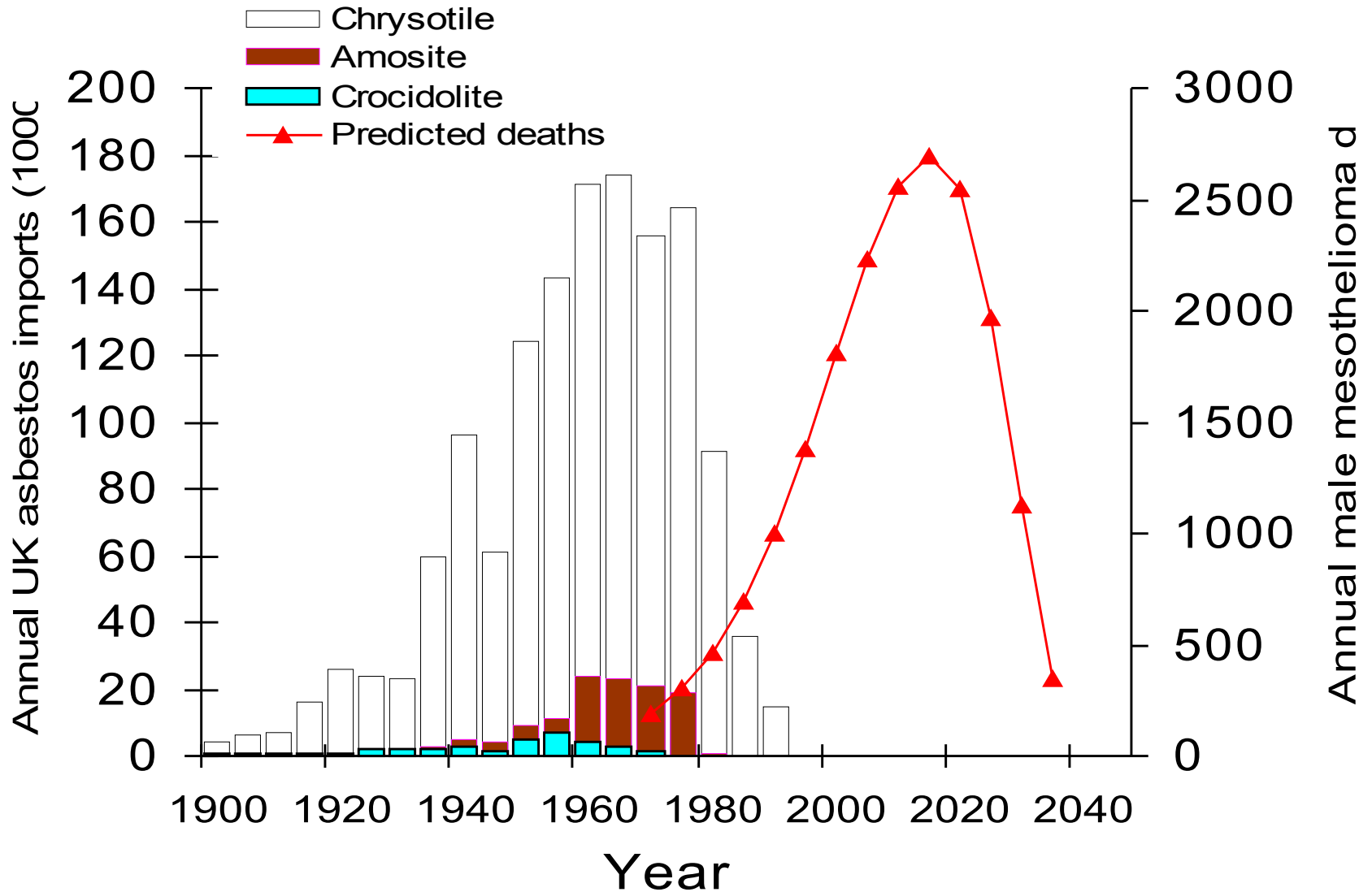
1995 – recognition of the
mesothelioma epidemic
in Britain

The HSE Mesothelioma Register: British mesothelioma death-rates by birth cohort, 1968-91



UK asbestos imports, and observed (1970-91) and predicted (1992-2040) mesothelioma deaths in men

Peto et al 1995: Lancet 345: 535-39



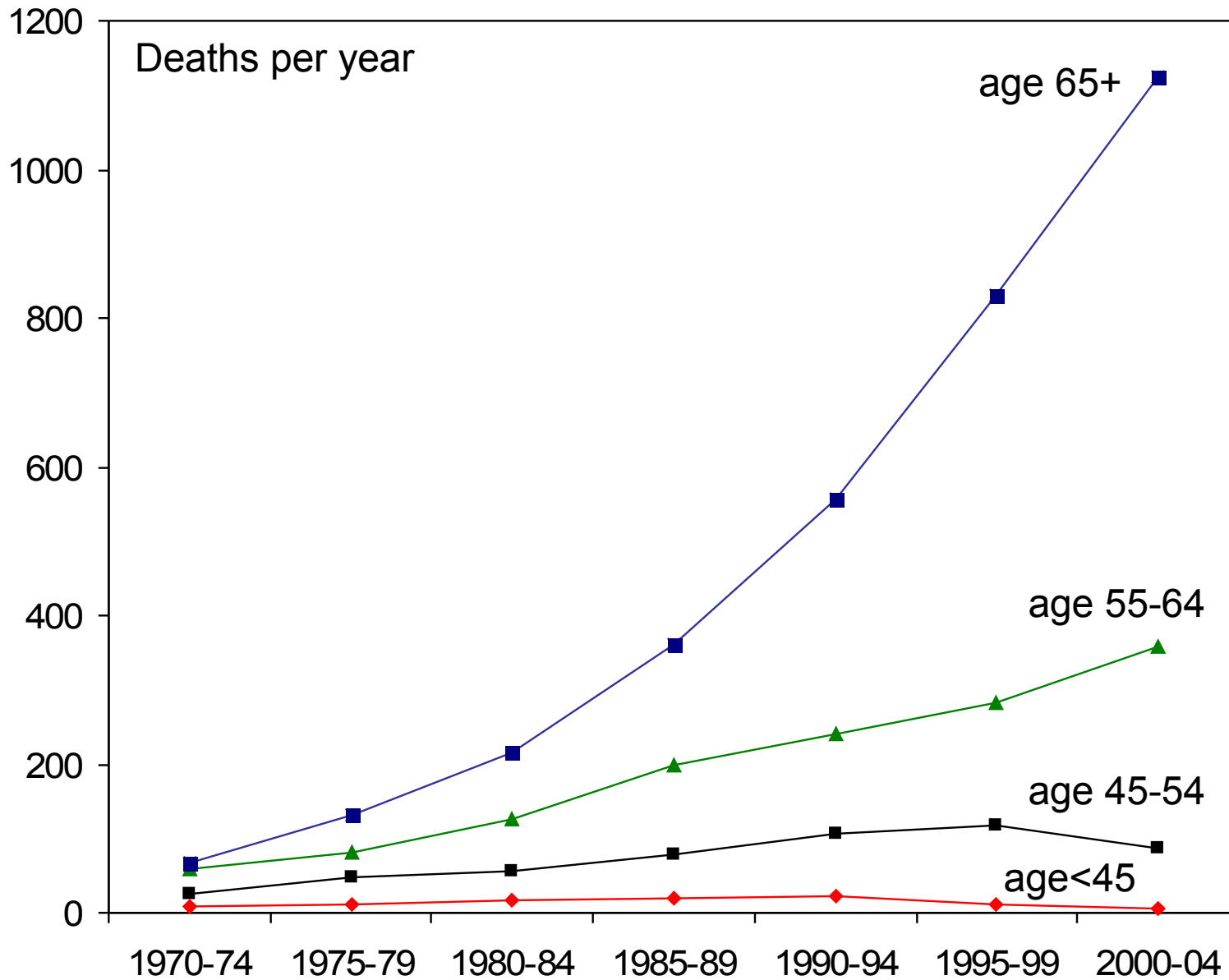
UK Health and Safety Executive Asbestos Workers Mortality Survey

Deaths 1971-91 in 50,000 workers covered by the 1969 Asbestos Regulations

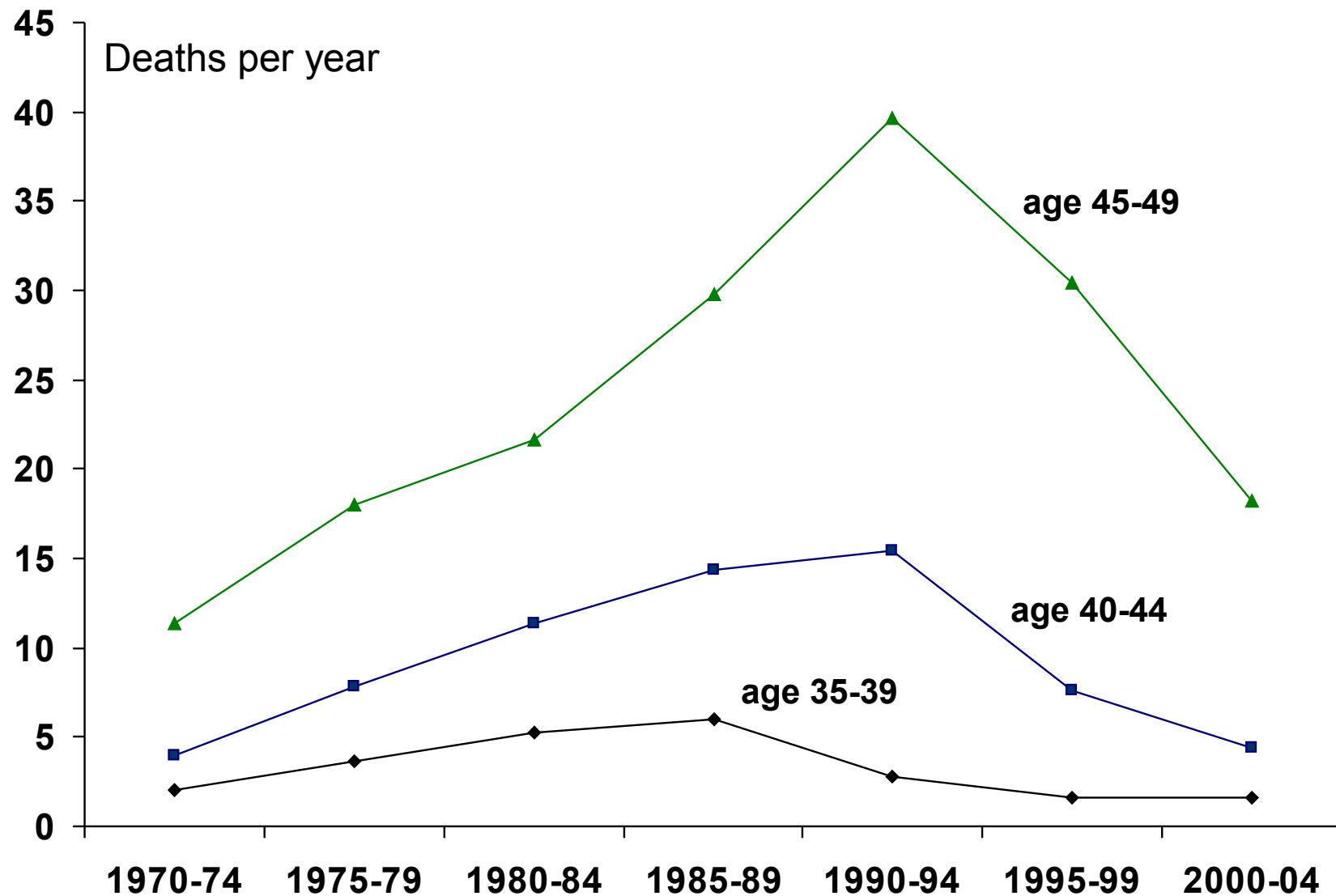
(Hutchings, Jones and Hodgson: Decennial Supplement, OPCS 1995)

Industry	Lung Cancer				
	Obs	Exp	O-E	Meso	Asbestosis
Textile manufacture	58	44.6	13.4	11	5
Asbestos cement manufacture	95	87.7	7.3	19	15
Asbestos/rubber/bitumen manufacture	156	110.1	45.9	20	5
Asbestos board/paper manufacture	35	23.4	11.6	4	2
Garment manufacture	3	2.5	6.5	0	2
Insulation/plaster manufacture	7	3.5	3.5	0	1
Maintenance in manufacture	69	66.2	2.8	18	4
Asbestos removal	14	15.8	-1.8	12	1
Shipbuilding	50	47.3	2.7	17	6
Construction	12	8.9	3.1	6	6
<u>Insulation</u>	<u>169</u>	<u>64.0</u>	<u>105.0</u>	<u>67</u>	<u>47</u>
Total	668	474.0	194.0	170	88

British male mesothelioma deaths since 1970



British male mesothelioma deaths below age 50 since 1970



The worldwide mesothelioma epidemic

The tenth revision of ICD death coding, introduced in different countries between 1995 and 2003, includes mesothelioma as a specific cause of death, so worldwide data are now available for the first time

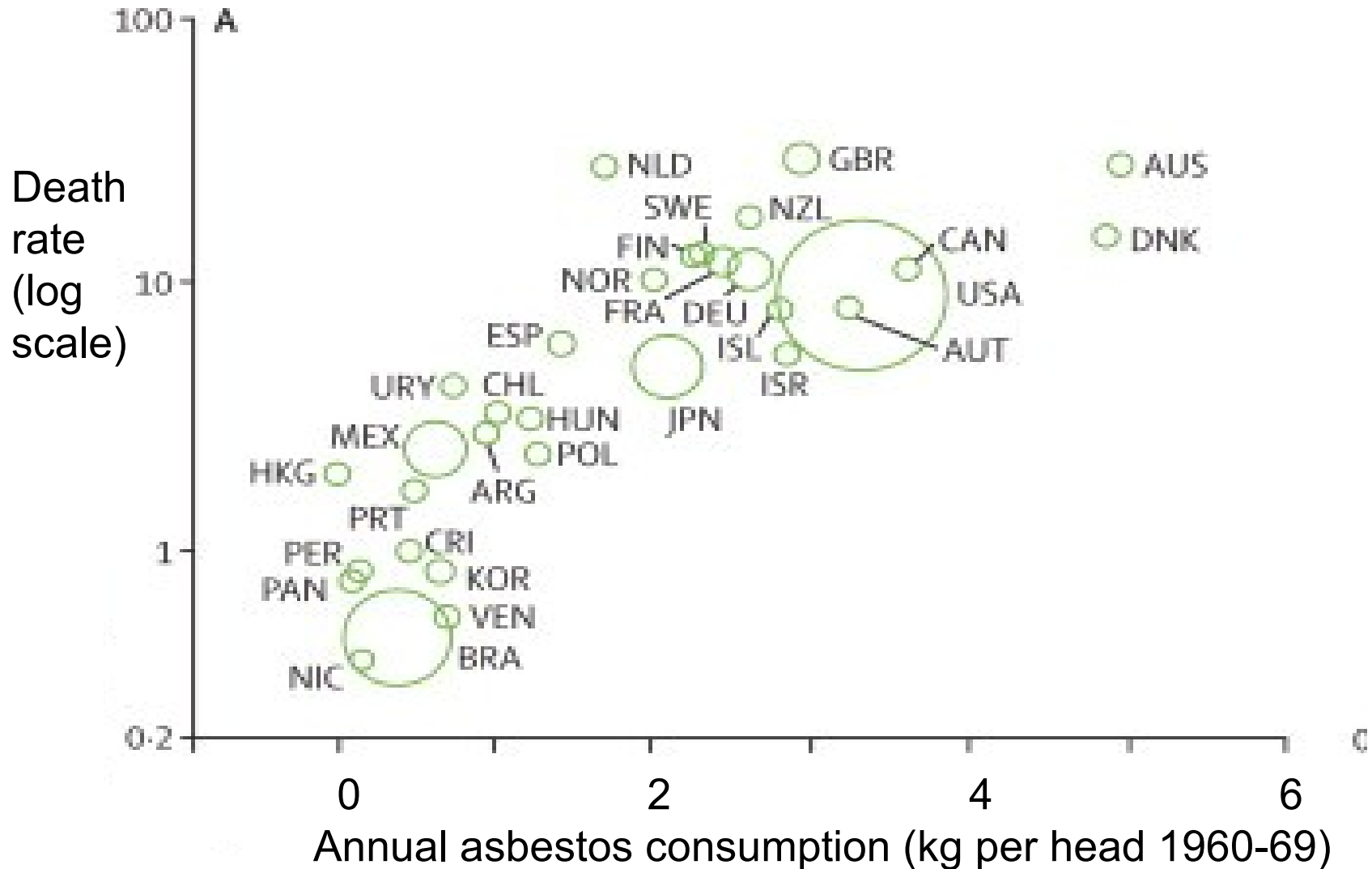
Mesothelioma mortality data 2000-2004

(WHO database – all countries with 10 or more mesothelioma deaths per year and at least 90% death registration)

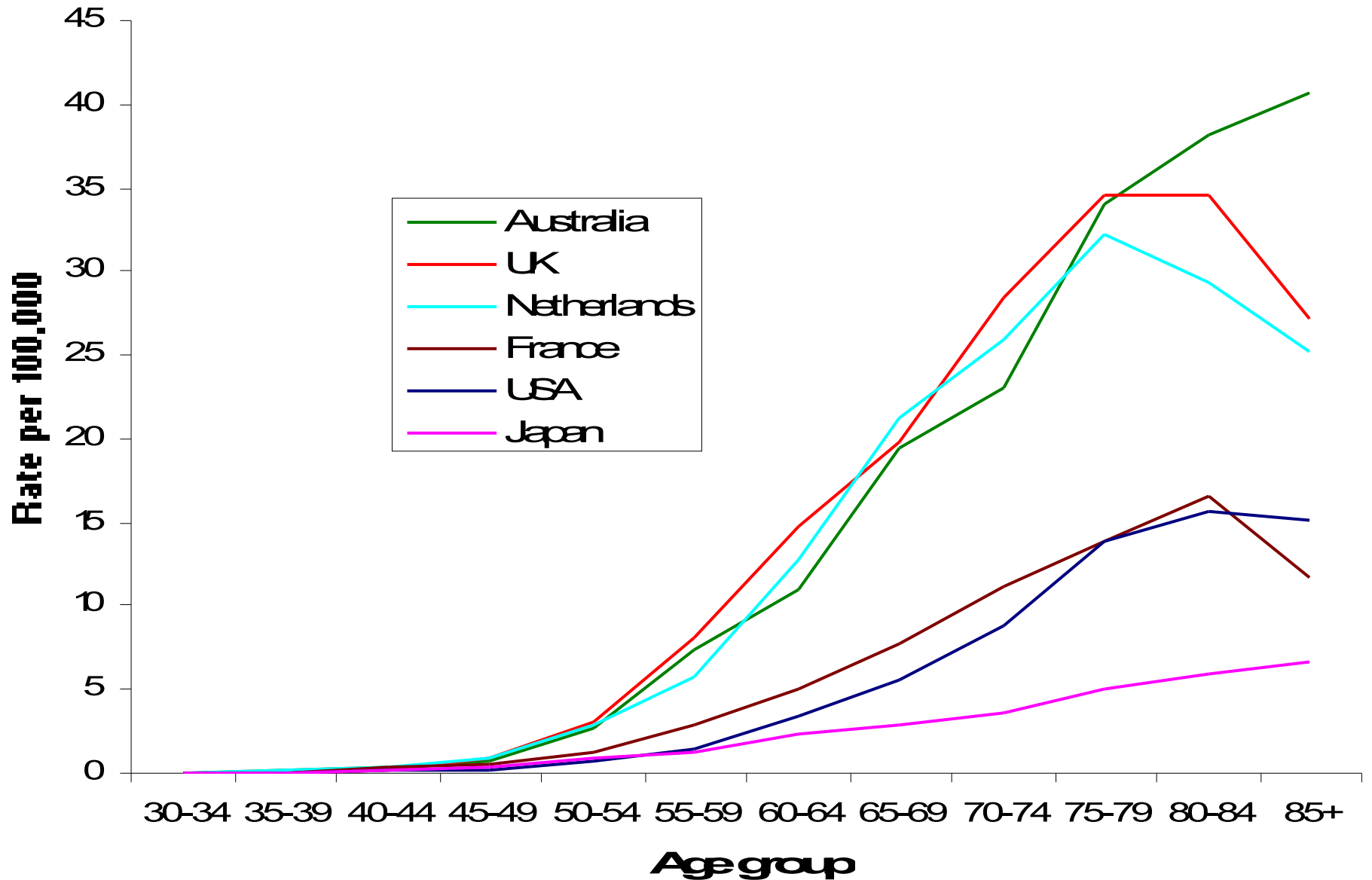
Country	Population (millions)	Mesothelioma deaths per year	
		Male	Female
Australia	20	410	79
New Zealand	4	58	10
UK	60	1548	272
W Europe (other)	333	2324	642
E Europe	106	217	123
USA	291	1971	462
Canada	31	264	53
Japan	128	620	205
Israel	6	19	7
Argentina	38	62	34
Chile	16	25	14
Mexico	102	93	49

Male mesothelioma mortality 2000-2004 and asbestos consumption 1960-69

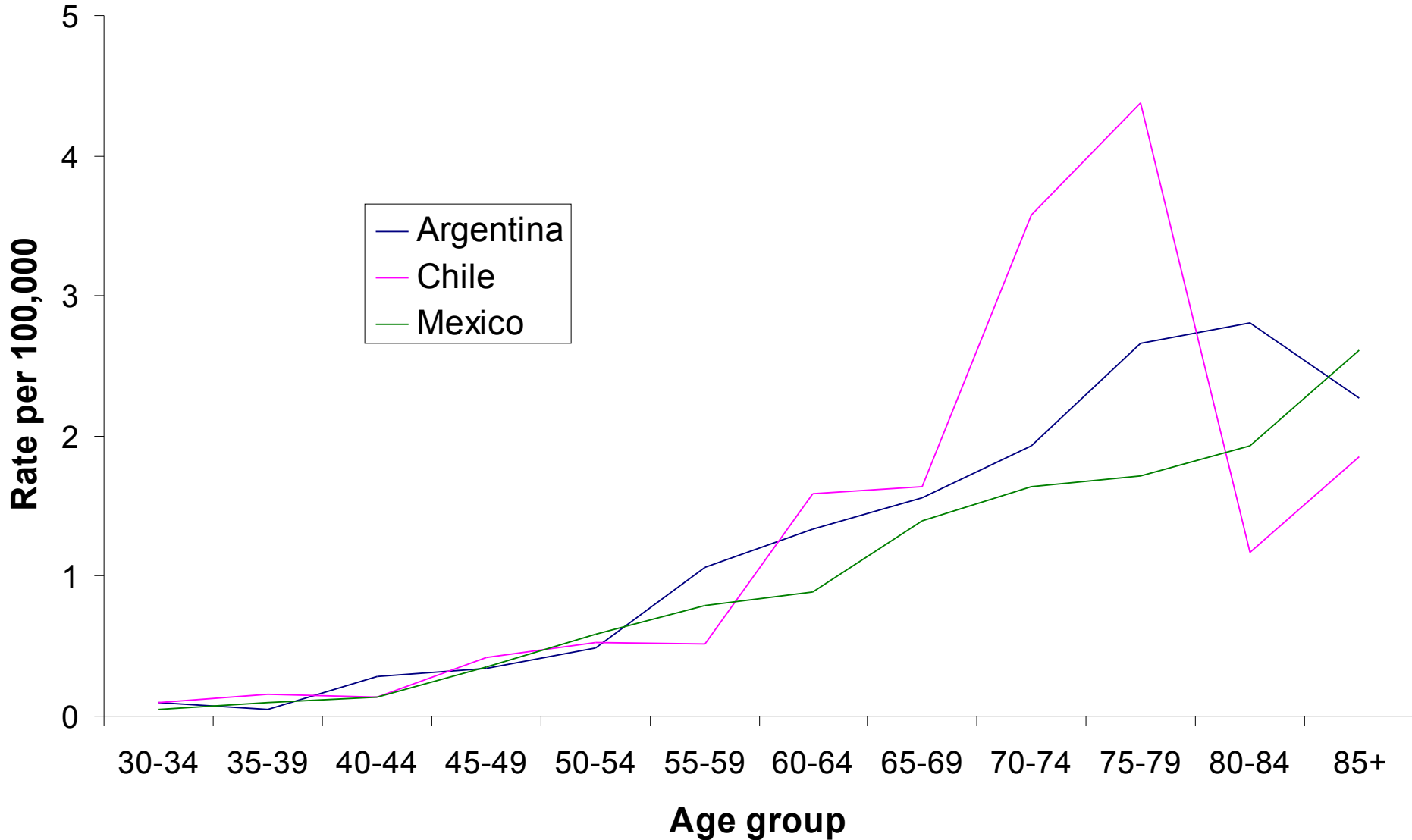
Lin et al 2007 Lancet 369: 844-849



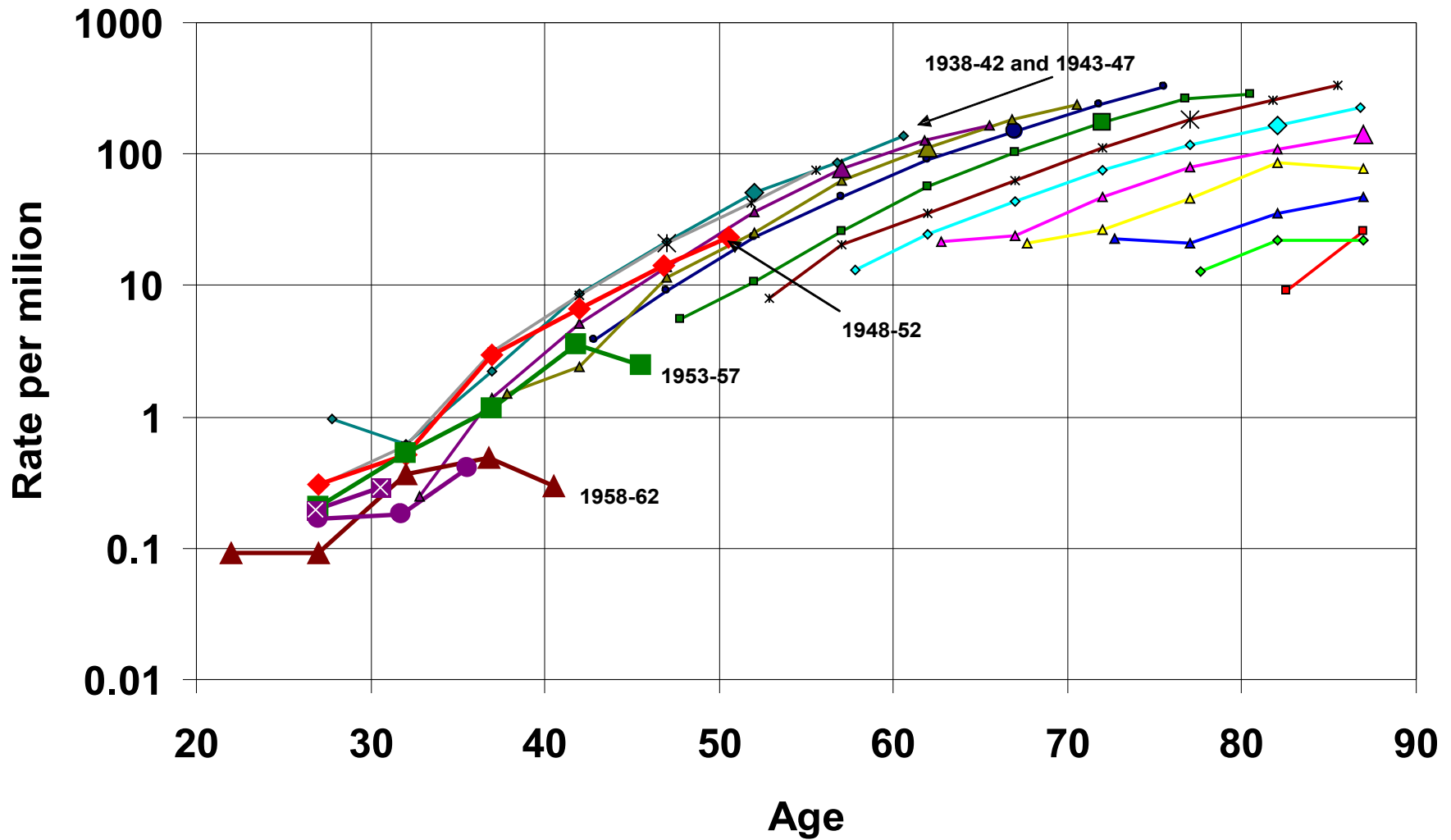
Male mesothelioma death-rates in 2000-04 in developed countries



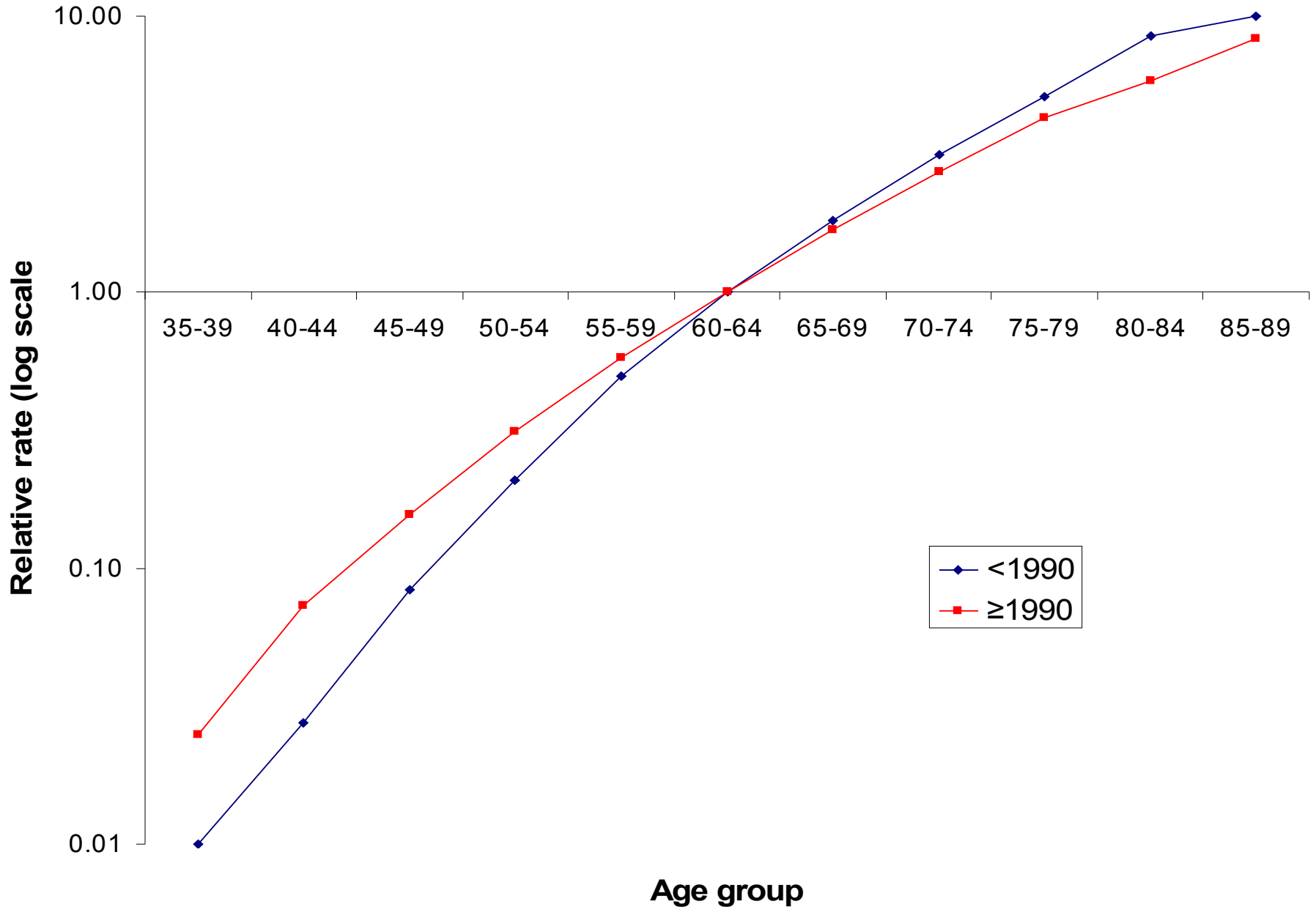
Male mesothelioma death-rates in 2000-04 in Central and South America



British male mesothelioma mortality rates by age and birth cohort 1968-2001



Comparison of British birth cohort trends in male mesothelioma death-rates before and after 1990

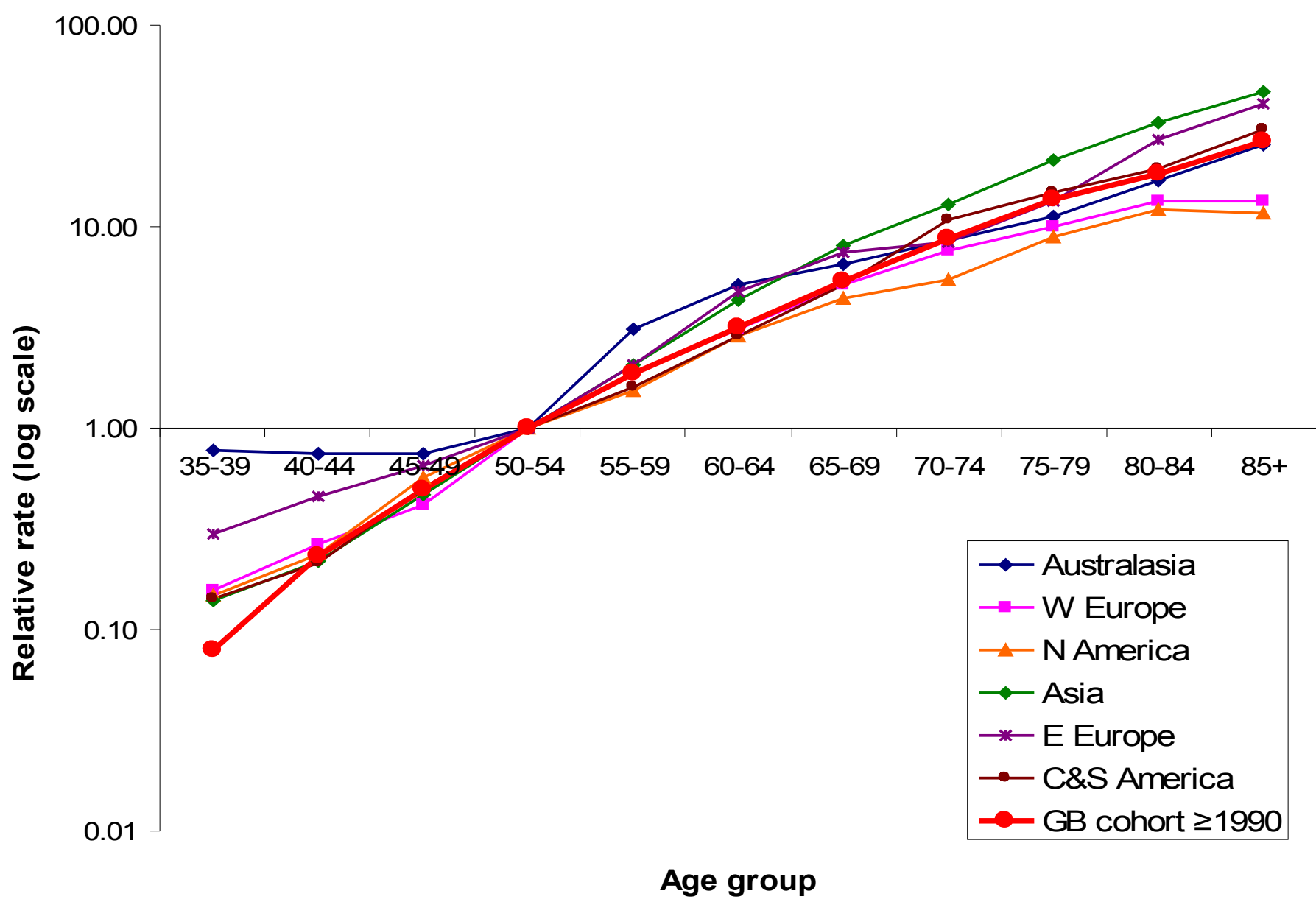


Modelling assumption

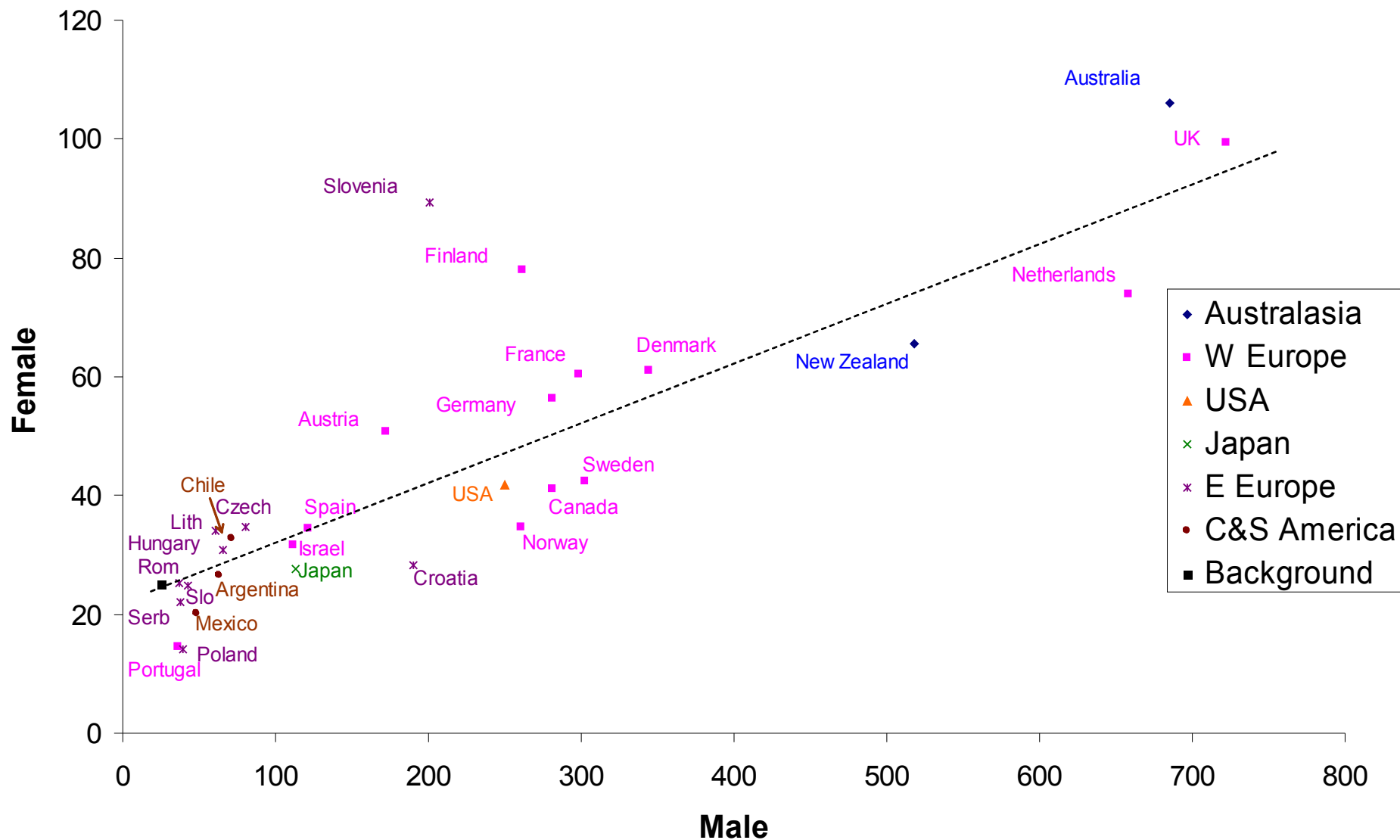
After asbestos exposure has largely stopped, the mesothelioma rate in each birth cohort follows the same age-distribution in all countries. In other words, the simple age and birth cohort model is correct.

International mesothelioma trends can therefore be modelled from the 1995-1999 and 2000-2004 death-rates

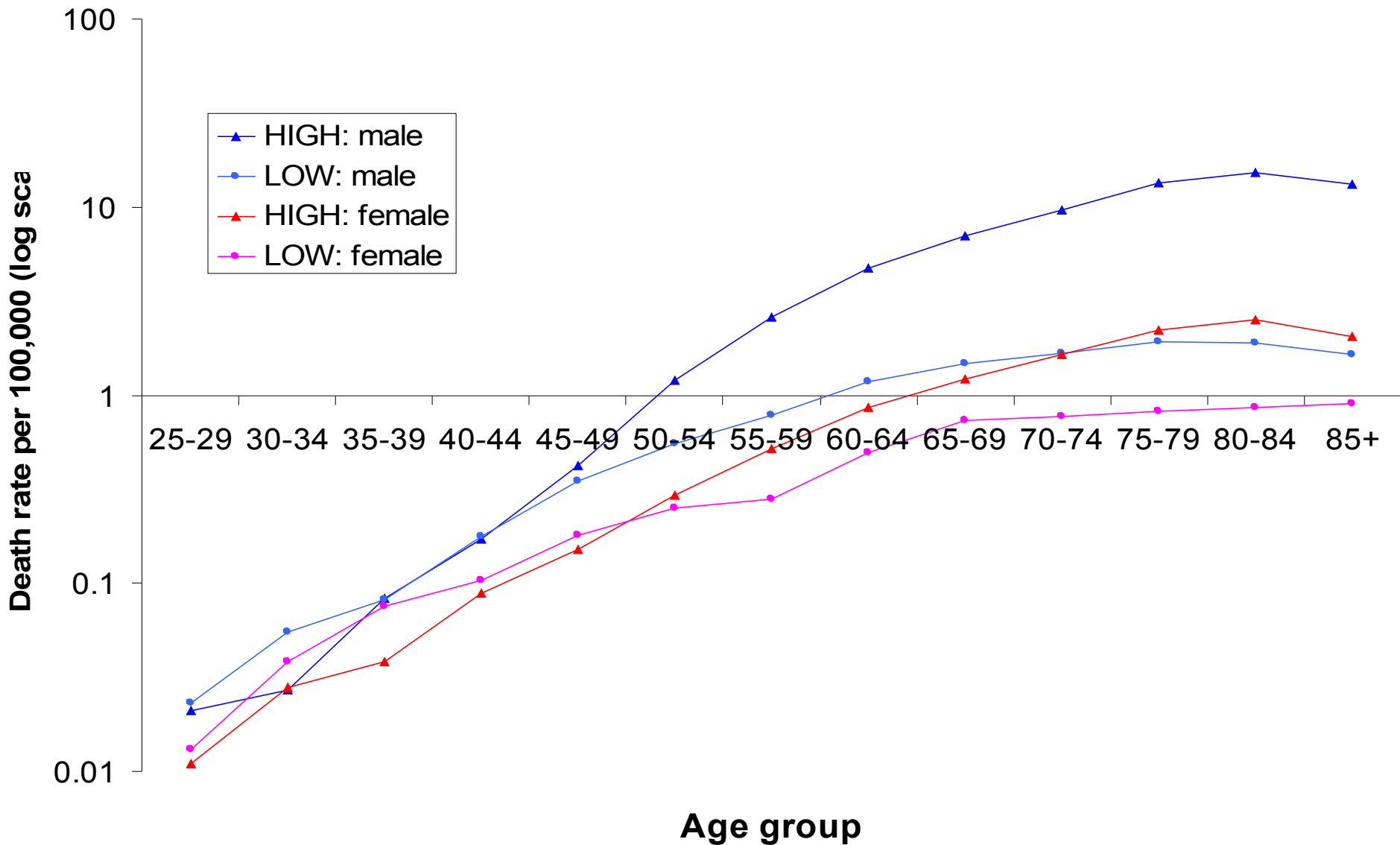
Proportional increase in mesothelioma death-rates from each age-group to the next (Based on male rates in 1995-1999 and 2000-2004)



Cumulative mesothelioma death-rates up to age 85 in men and women (rates per 100,000 in 2000-04)



Male and female mesothelioma death-rates in 2000-04 in countries with high rates (i.e. cumulative male rate by age 90 over 100 per 100,000) and low rates



Background and work-related mesothelioma rates

Background rate (unrelated to occupation, and the same in men and women)

- ١. Spontaneous – the same worldwide
- ٢. Environmental – related to asbestos consumption

Work-related rate

Predominantly in men

Modelling assumption on work-related plus environmental rate:

Male rate = 10 x female rate

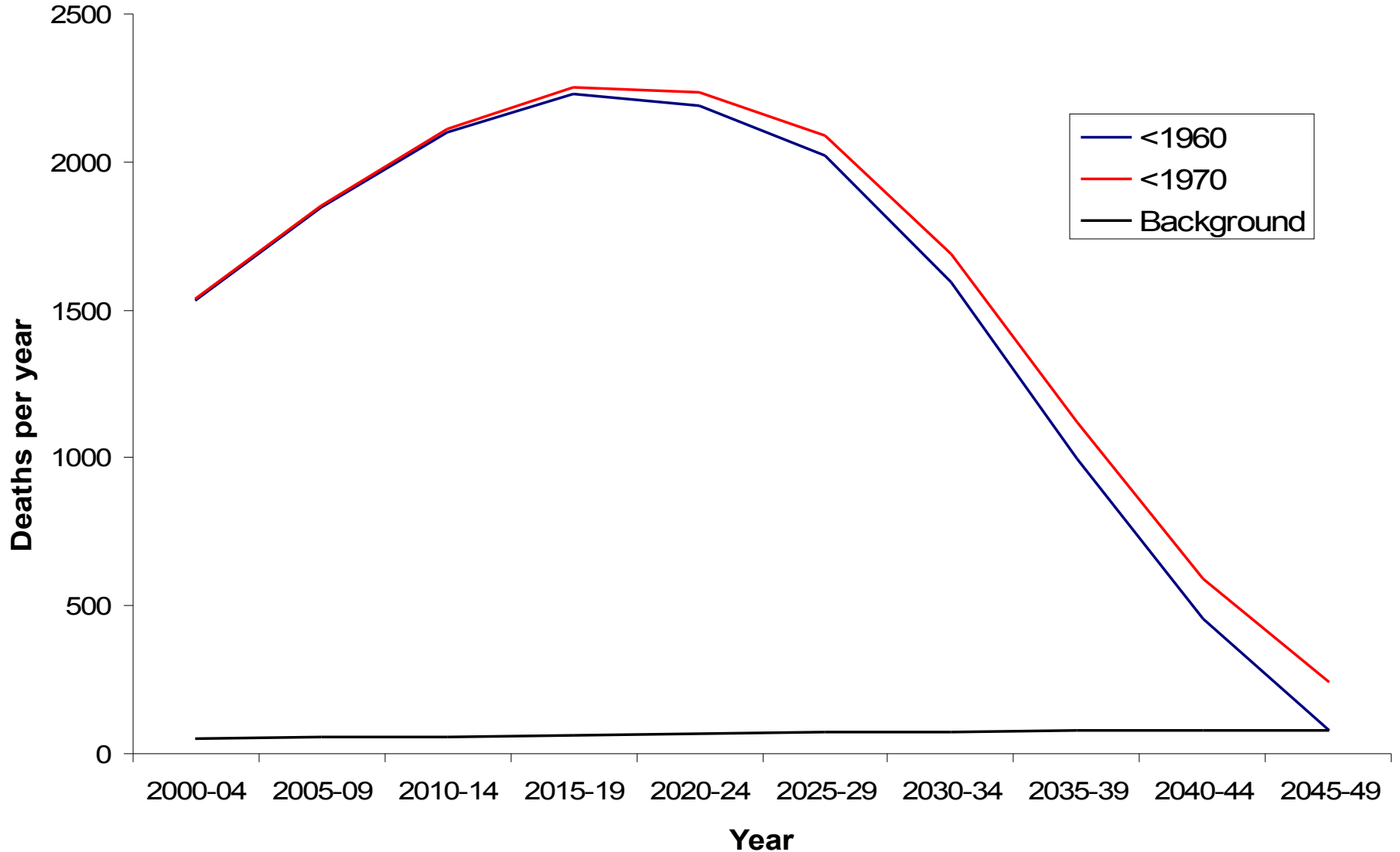
Male mesothelioma death-rates in 2000-2004

	Age: 35-39	40-44	45-49
	<u>rate (no.)</u>	<u>rate (no.)</u>	<u>rate (no.)</u>
UK	0.05 (5)	0.19 (16)	0.87 (66)
USA	0.07 (41)	0.12 (66)	0.26 (139)
Background (USA women)	0.03 (19)	0.09 (53)	0.13 (69)

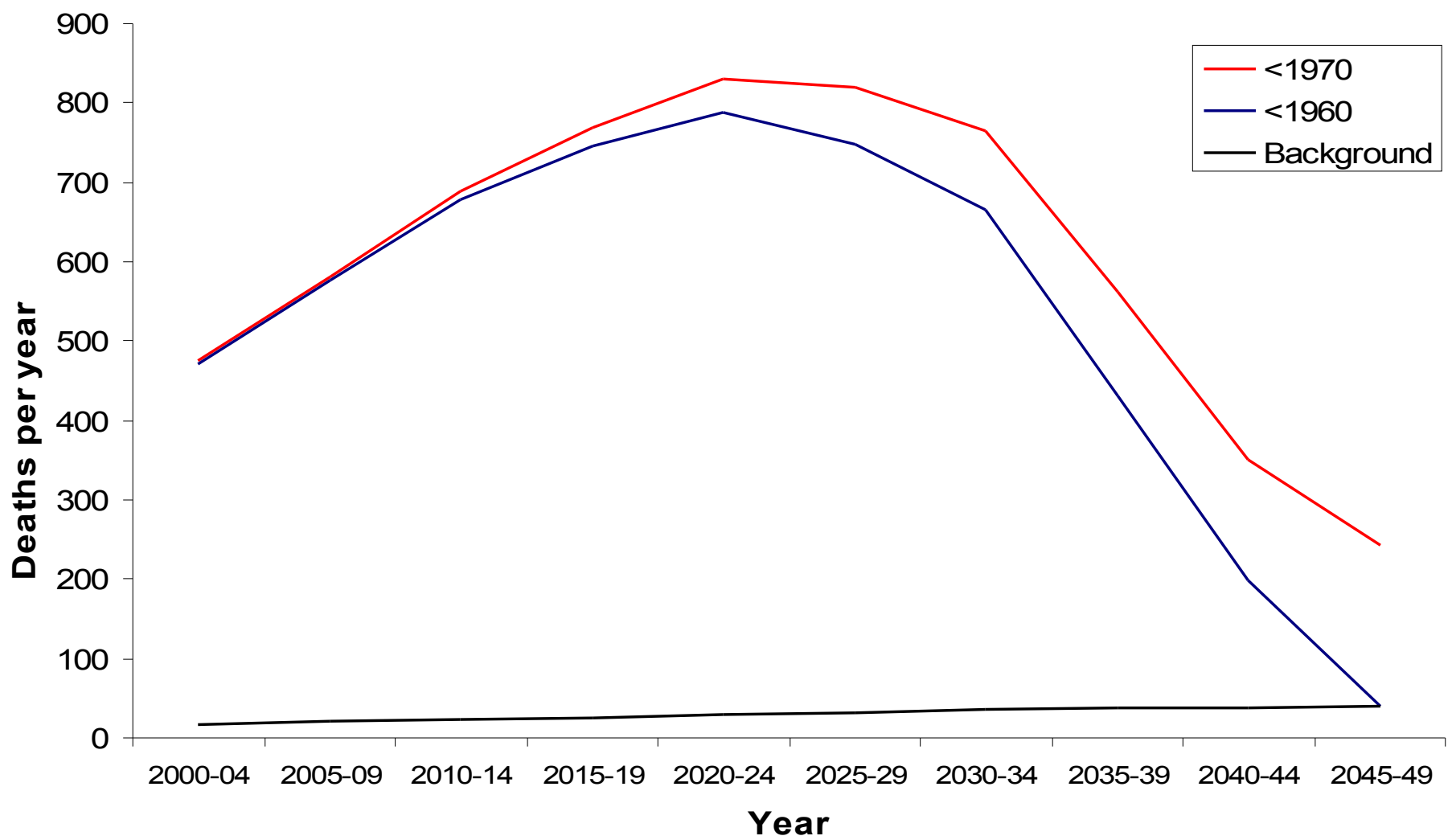
Predicted excess rates 40 years later in 2040-2044

	Age: 75-79	80-84	85-89
UK	1.7	10.3	38.1
USA	3.2	3.5	7.1
Background	9.8	11.0	9.5

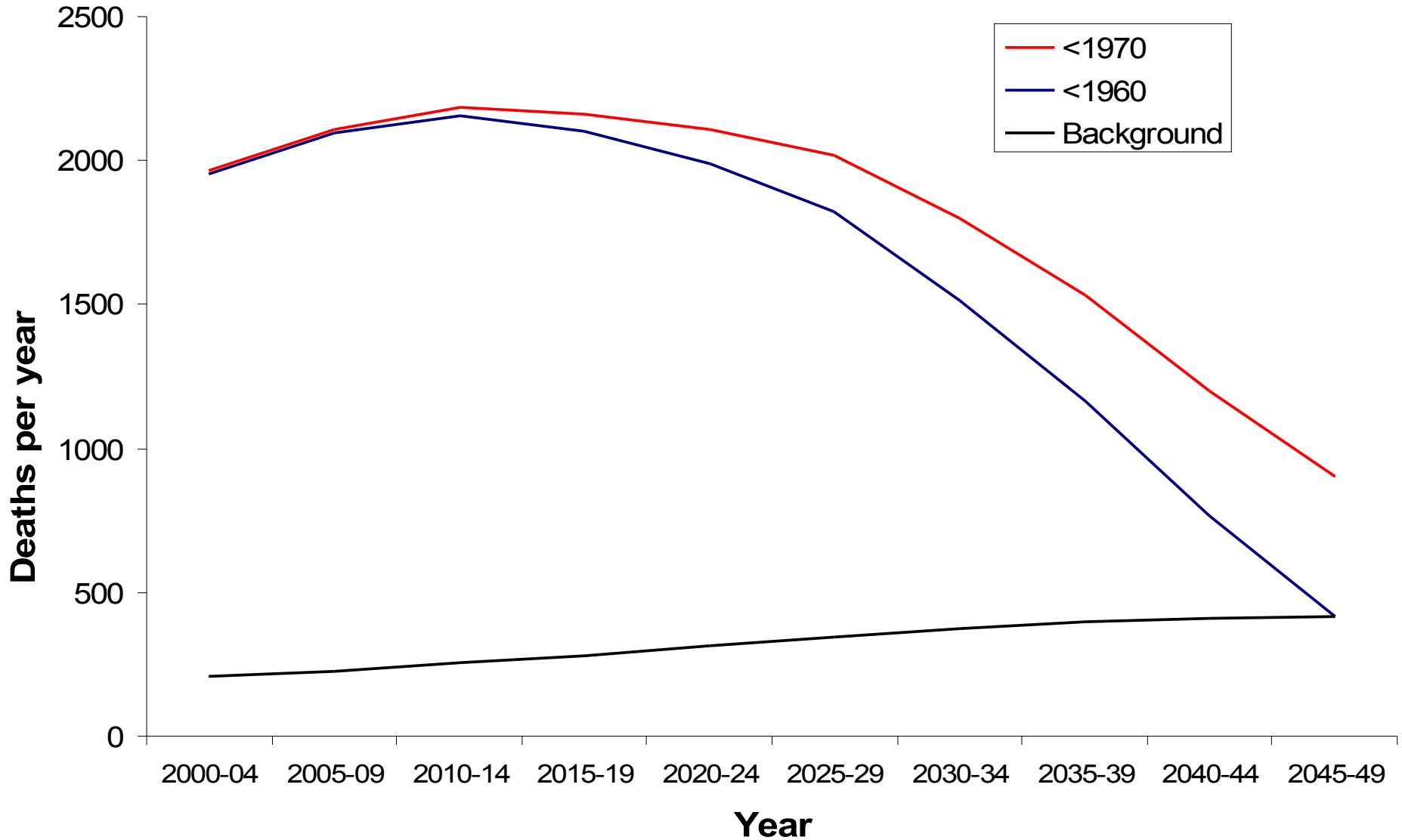
Projection of annual numbers of male mesothelioma deaths in the UK, assuming no asbestos exposure in men born after 1970 (red line) or after 1960 (blue line)



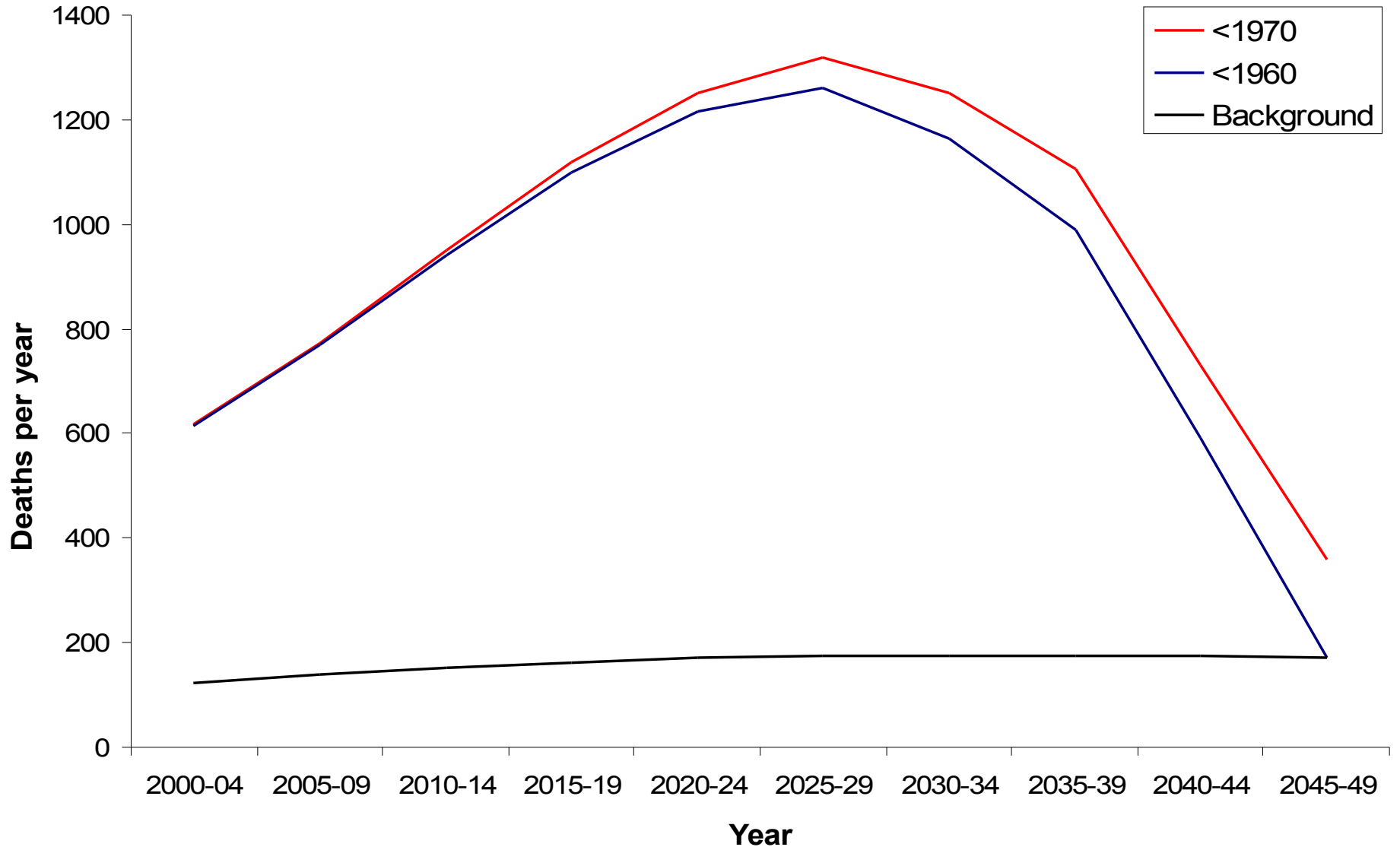
Projection of annual numbers of male mesothelioma deaths in Australasia, assuming no asbestos exposure in men born after 1970 (red line) or after 1960 (blue line)



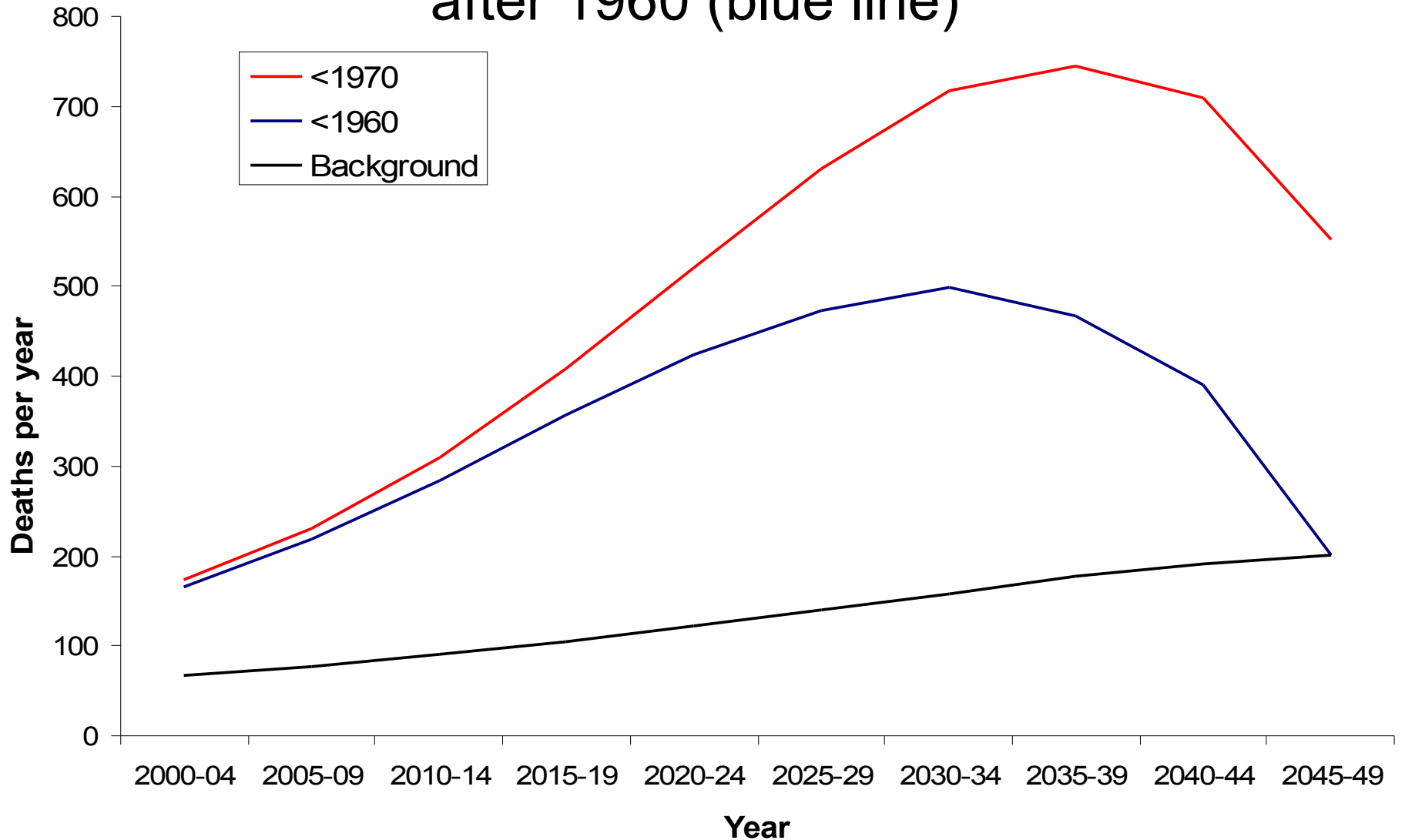
Projection of annual numbers of male mesothelioma deaths in USA, assuming no asbestos exposure in men born after 1970 (red line) or after 1960 (blue line)



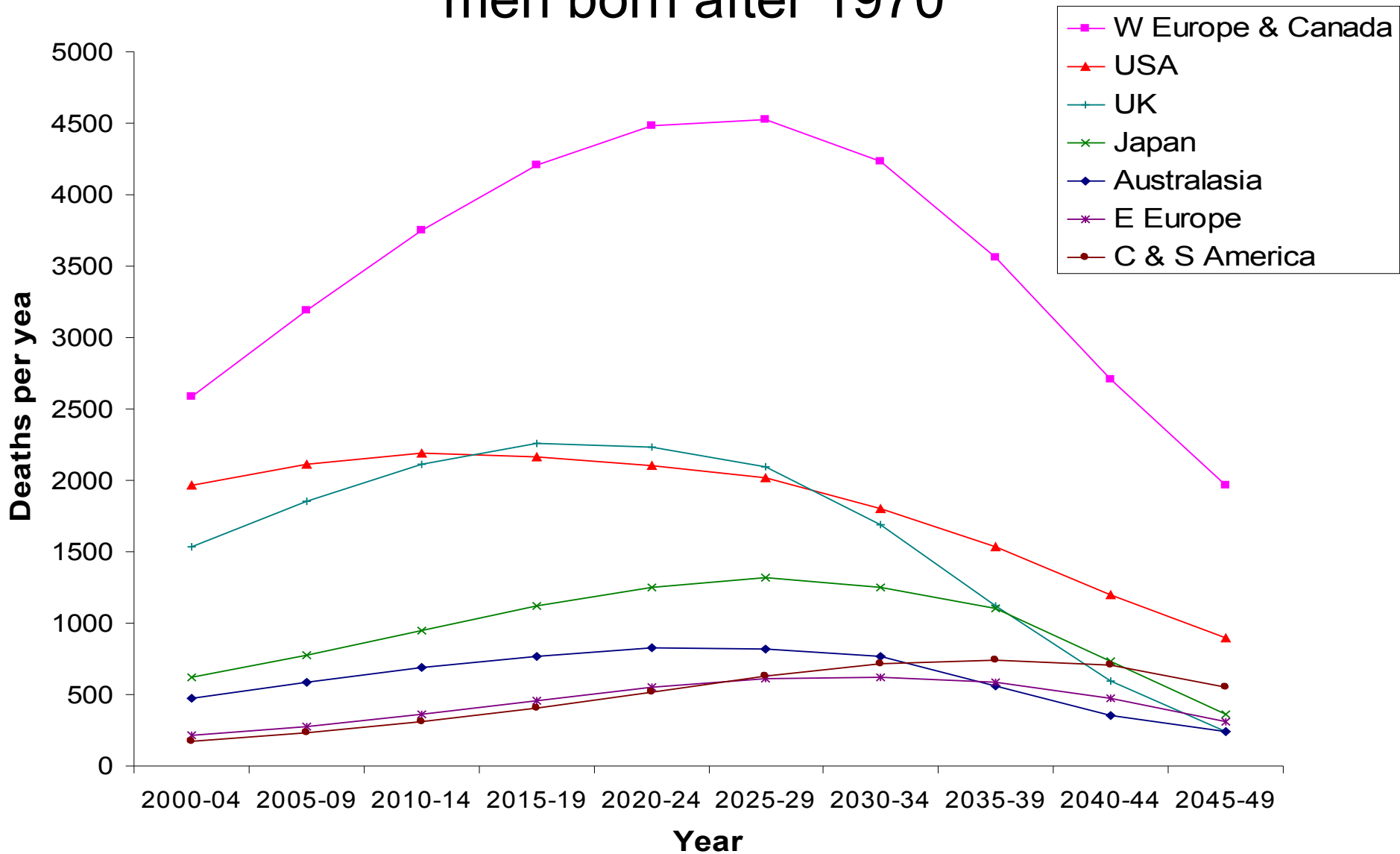
Projection of annual numbers of male mesothelioma deaths in Japan, assuming no asbestos exposure in men born after 1970 (red line) or after 1960 (blue line)



Projection of annual numbers of male mesothelioma deaths in Central and S America, assuming no asbestos exposure in men born after 1970 (red line) or after 1960 (blue line)



Projection of annual numbers of male mesothelioma deaths 2000-2050, assuming no asbestos exposure in men born after 1970



Predicted male mesothelioma deaths 2000-49

Australia 27,000

New Zealand 4,000

UK 78,000

W Europe (except UK and Italy) 154,000

USA 90,000

Japan 47,000

E Europe 22,000

Argentina 7,000

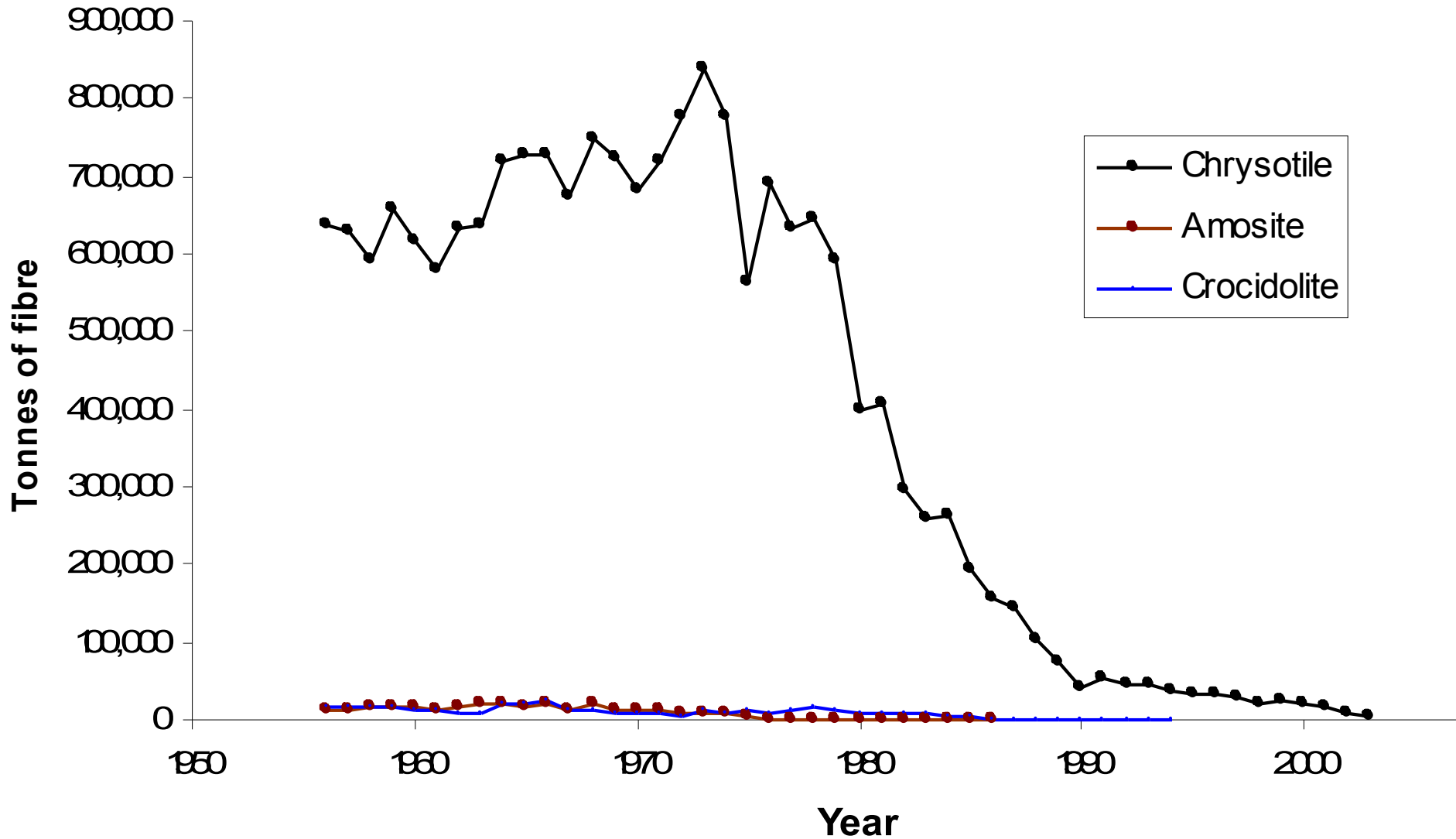
Chile 4,000

Mexico 14,000

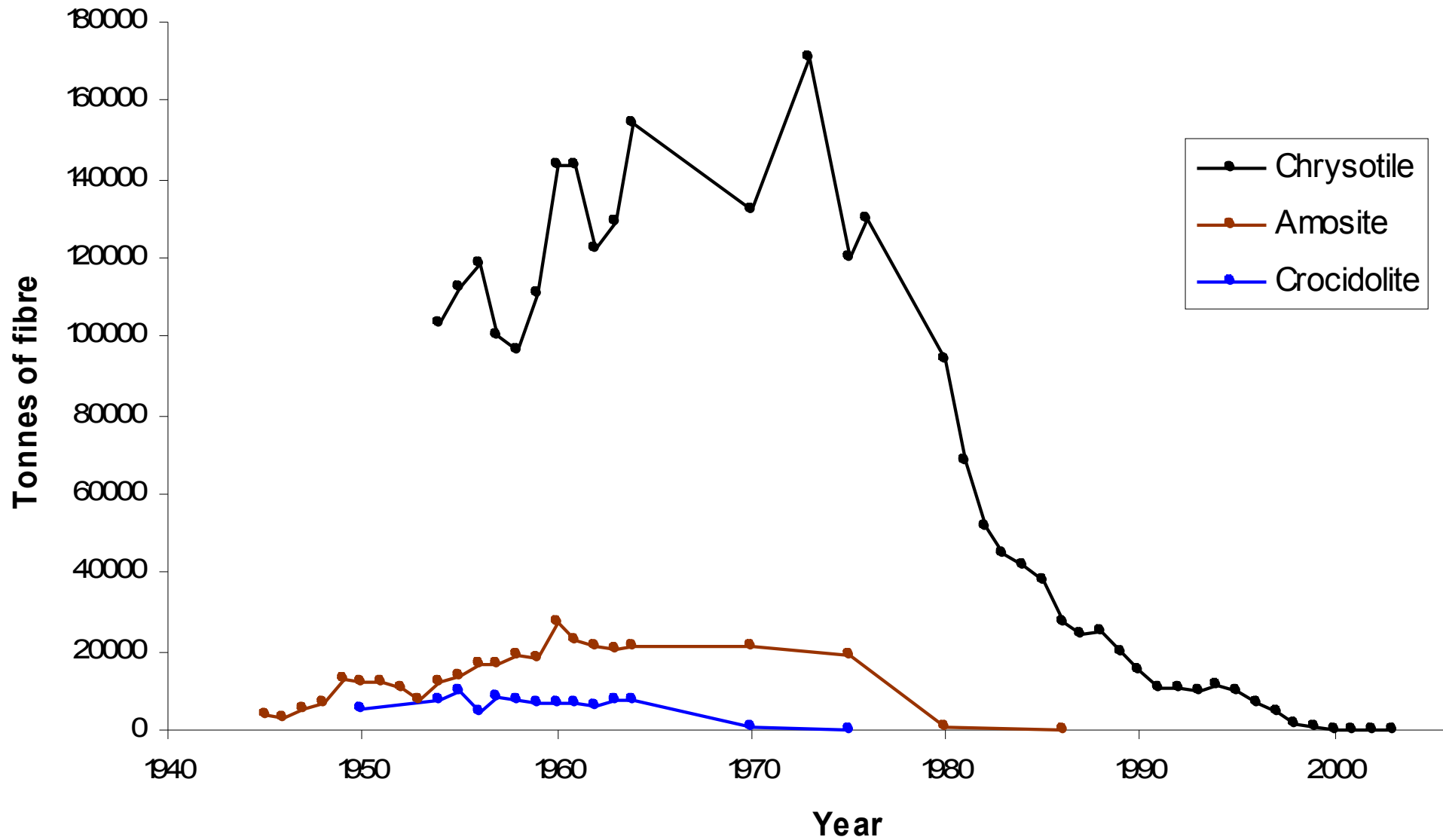
Why are male mesothelioma death-rates in 2000-2004 almost five times higher in Britain than in the USA?

	Age: 35-39	40-44	45-49	50-54
Born:	1965	1960	1955	1950
	<u>rate (no.)</u>	<u>rate (no.)</u>	<u>rate (no.)</u>	<u>rate (no.)</u>
UK	0.05 (5)	0.19 (16)	0.87 (66)	3.14 (242)
USA	0.07 (41)	0.12 (66)	0.26 (139)	0.68 (314)

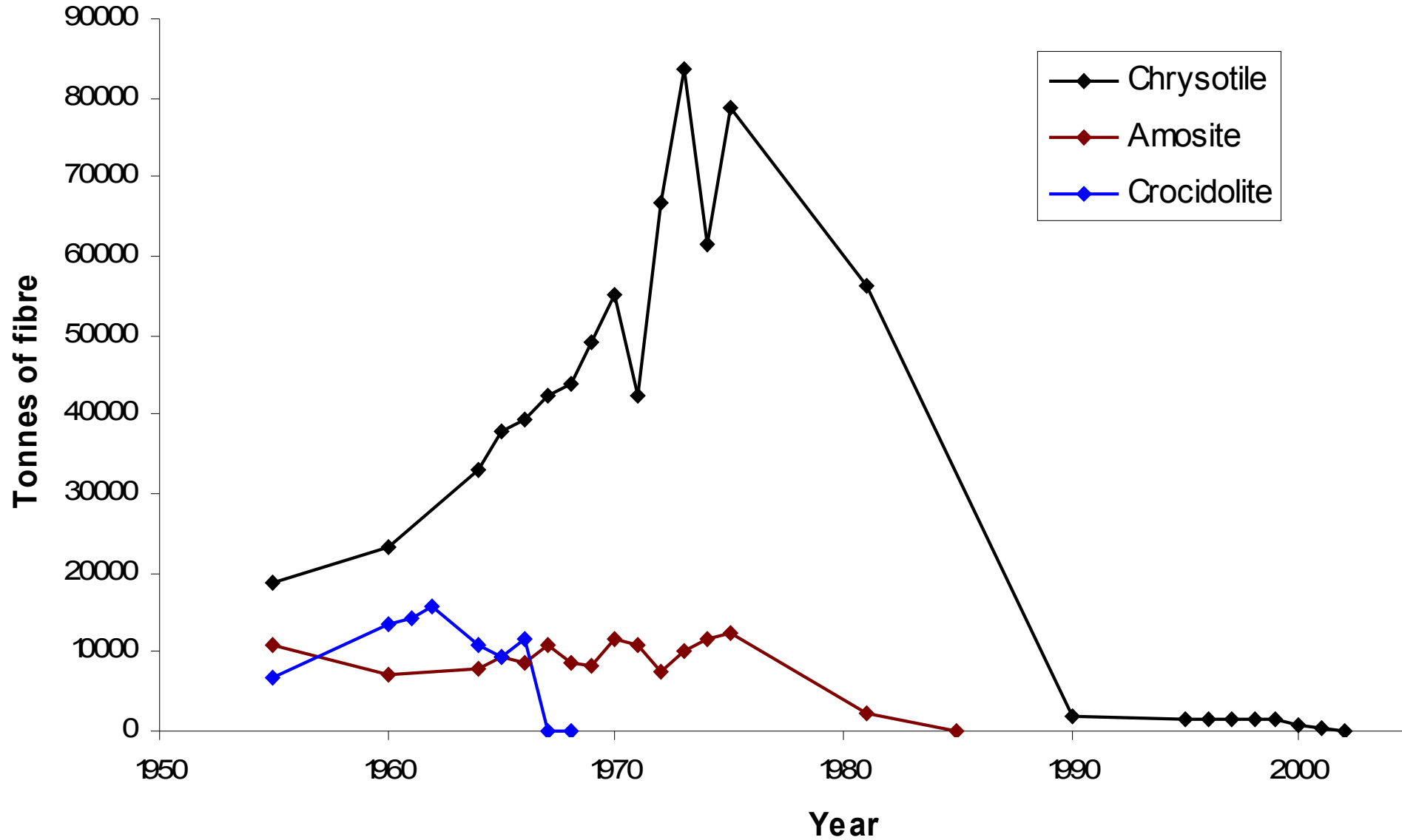
Asbestos imports into the US (includes small percentage of US mined chrysotile)



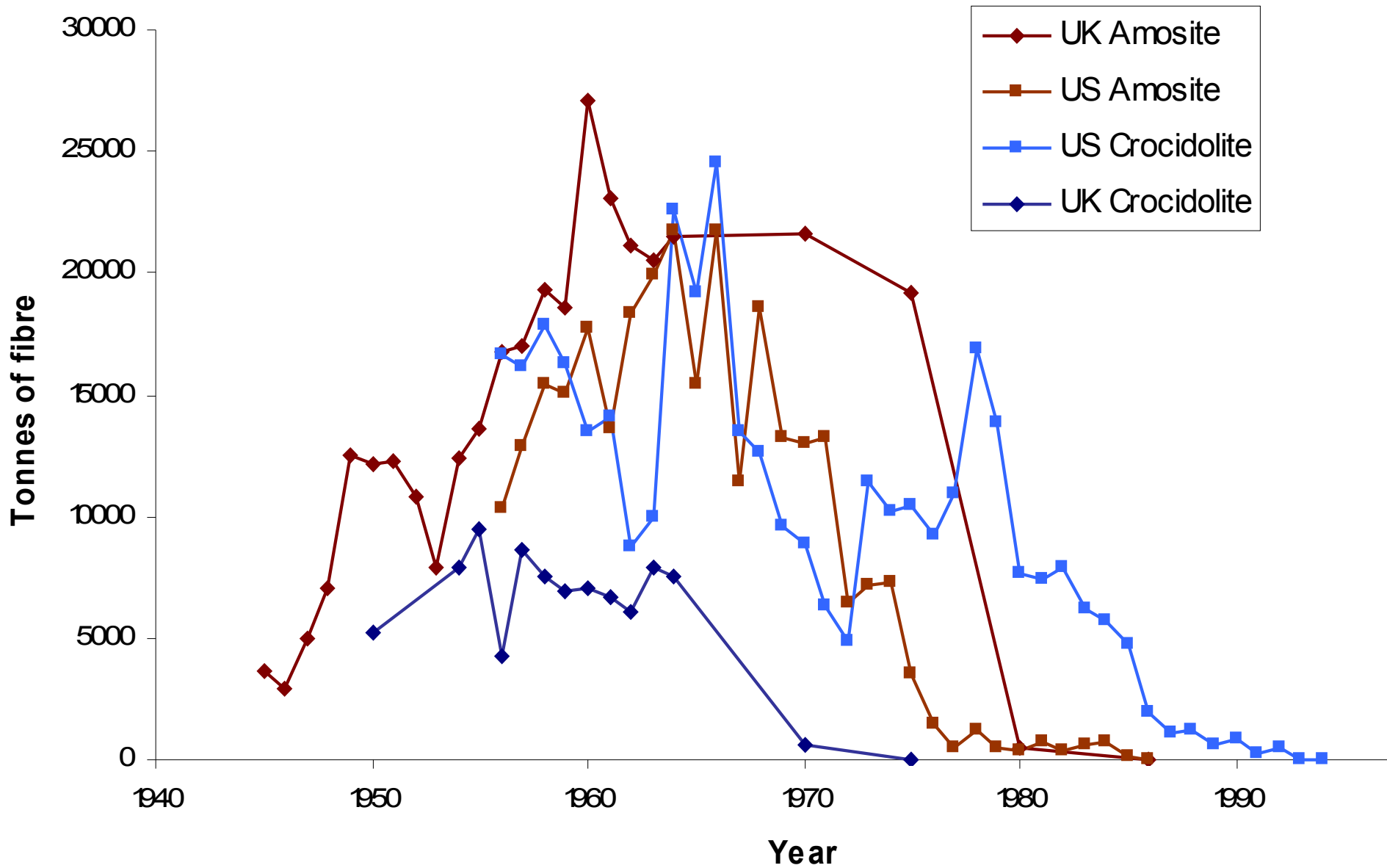
Asbestos imports into the UK



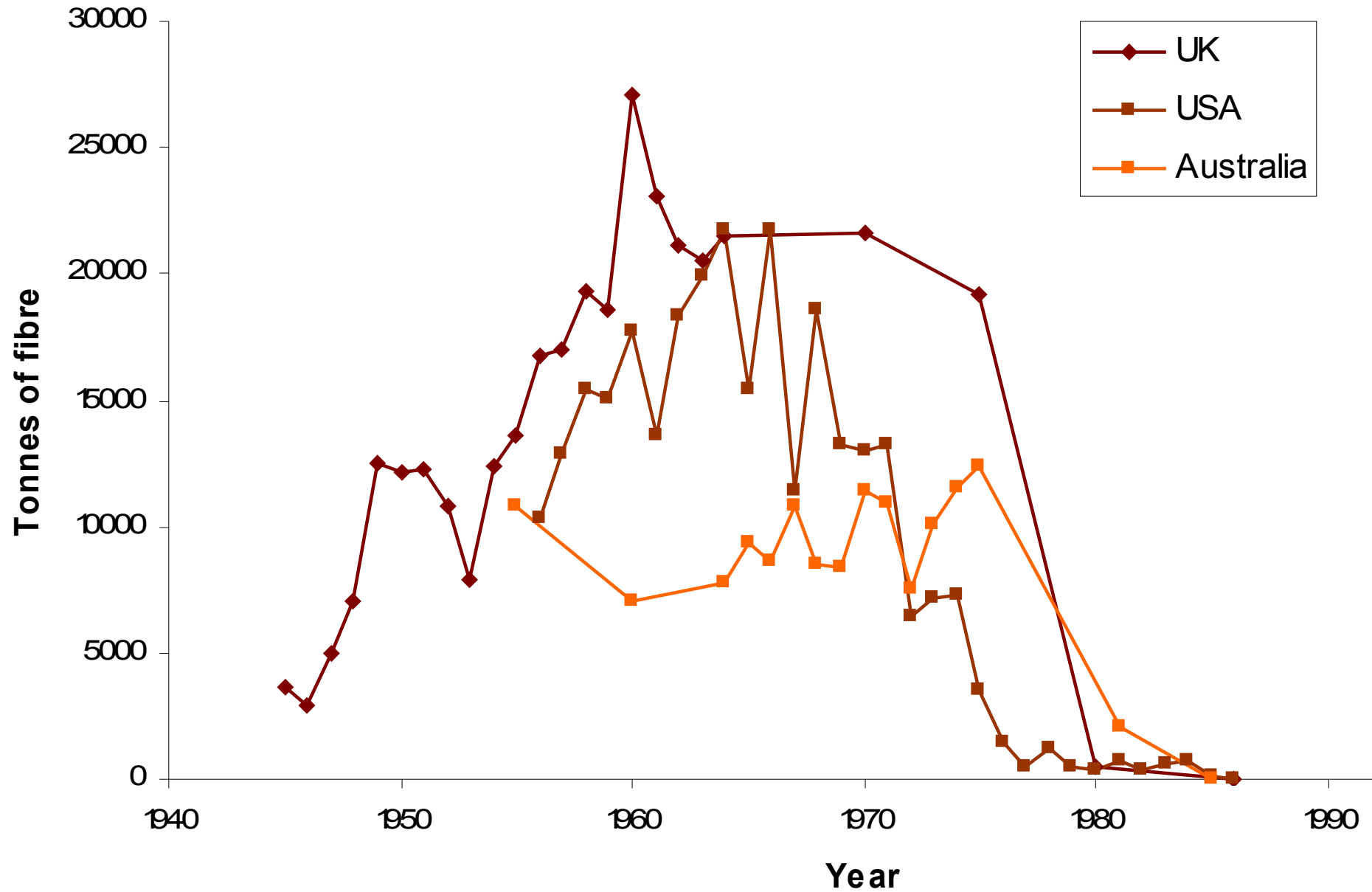
Australian asbestos production + imports



Amphibole imports into UK and US



Amosite imports



US insulation workers were exposed to amosite (brown) but much less crocidolite (blue)

Asbestos in the lungs of persons exposed in the USA

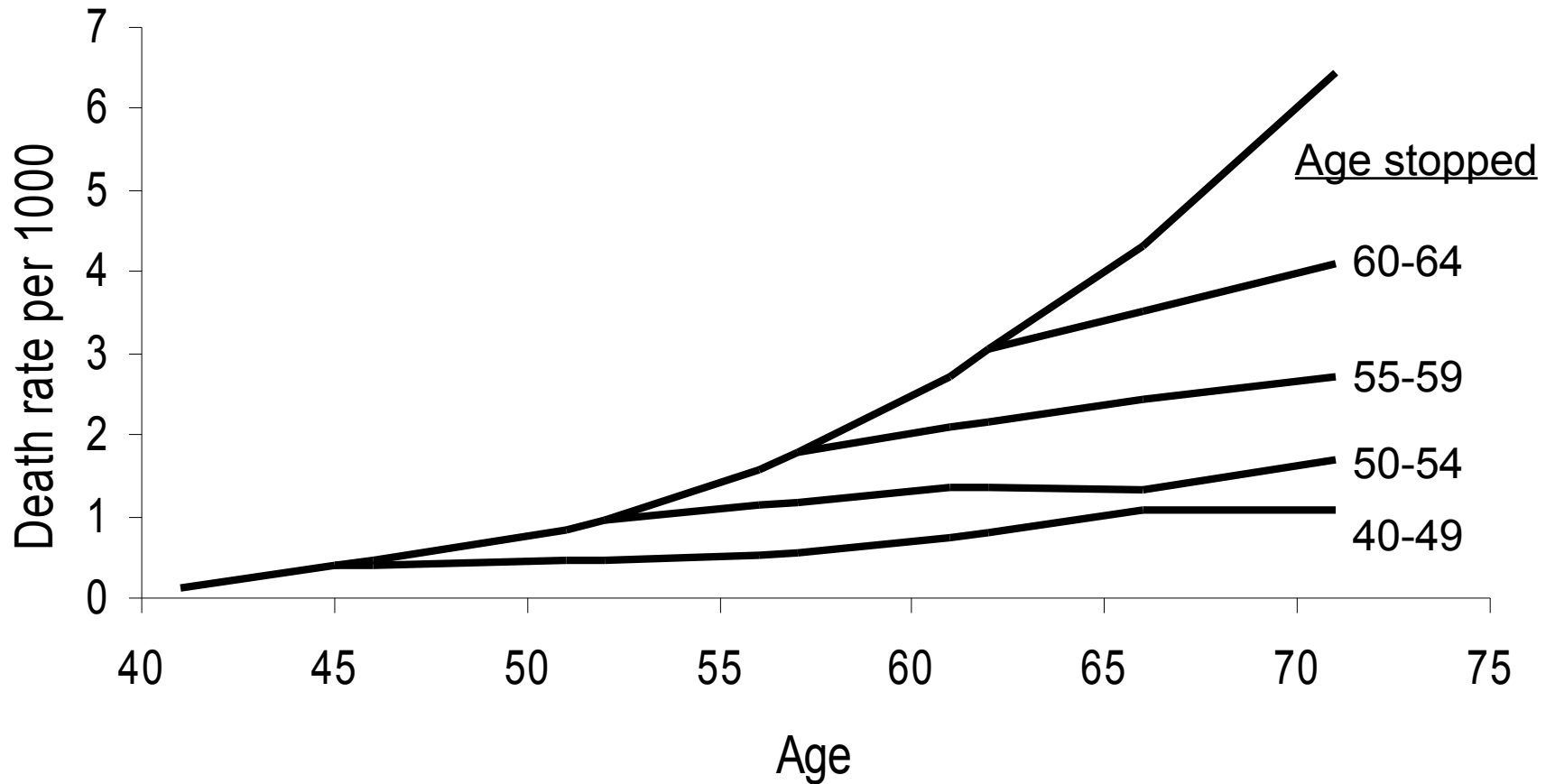
Langer and Nolan Monaldi Arch Chest Dis 1998 53:168-80

Among the 83 causes of death were 33 mesotheliomas, 35 lung cancers, 12 asbestosis and 3 from other cancers. Of the three major commercial asbestos fibre types, amosite was found to be the most prevalent fibre... Amosite was present in all of the insulation workers' lungs studied and was found in the highest concentration in this exposure category

Why should amphiboles (brown and blue asbestos) be so much more dangerous than chrysotile (white asbestos)?

They persist in the lung.

Lung cancer mortality is almost constant in ex-smokers. Halpern et al (1993) JNCI 85, 457



Epidemiology of lung cancer and smoking

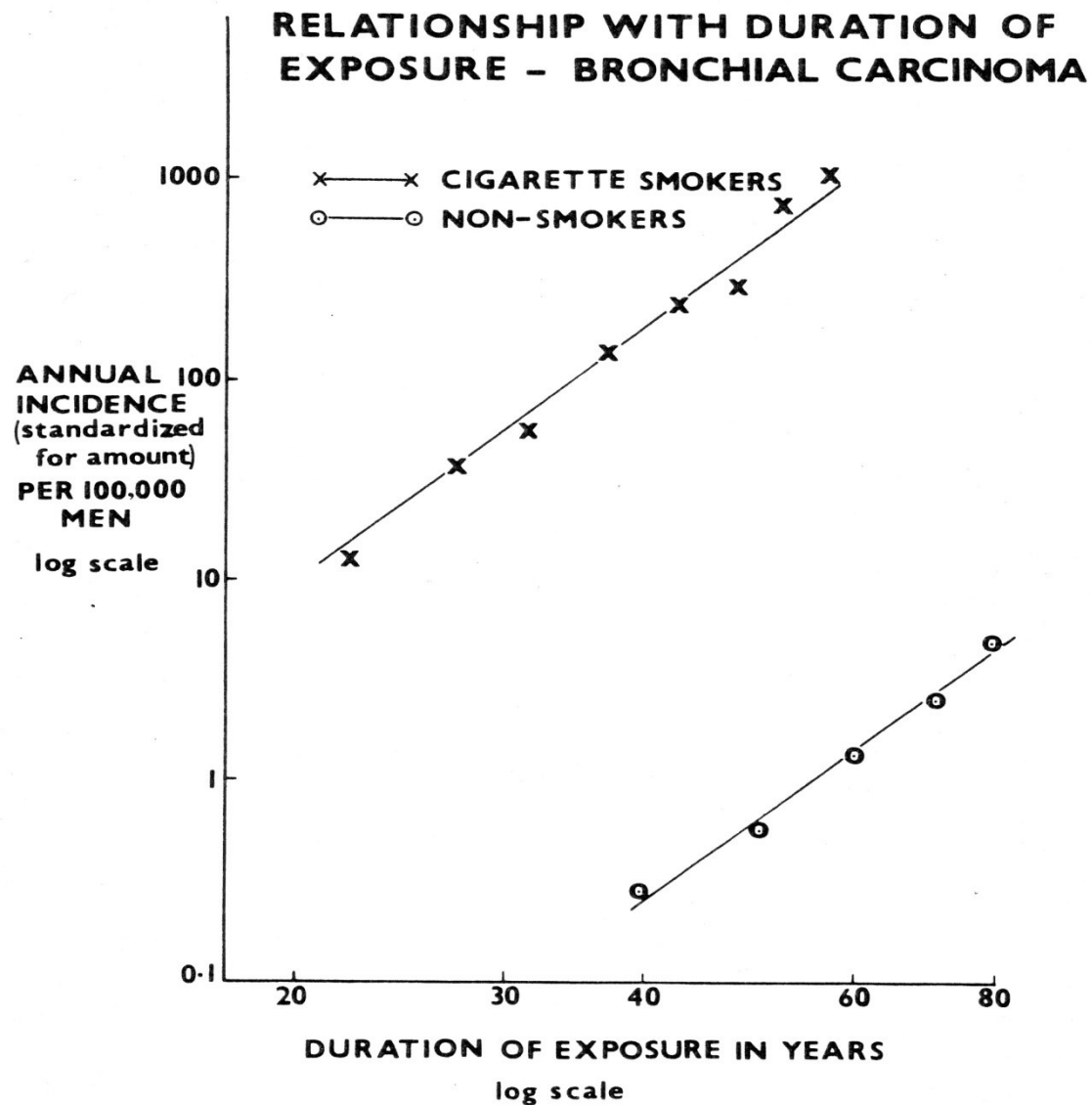
Lung cancer in cigarette smokers:

Incidence rate \propto (years of smoking)⁴

Lung cancer in non-smokers:

Incidence rate \propto (age)⁴

Lung cancer incidence in non-smokers is proportional to the fourth power of age. In smokers it is proportional to the fourth power of duration of smoking, independent of age. (Doll 1978: Cancer Research 38: 3573-83)



Epidemiology of mesothelioma and asbestos

Mesothelioma in asbestos workers:

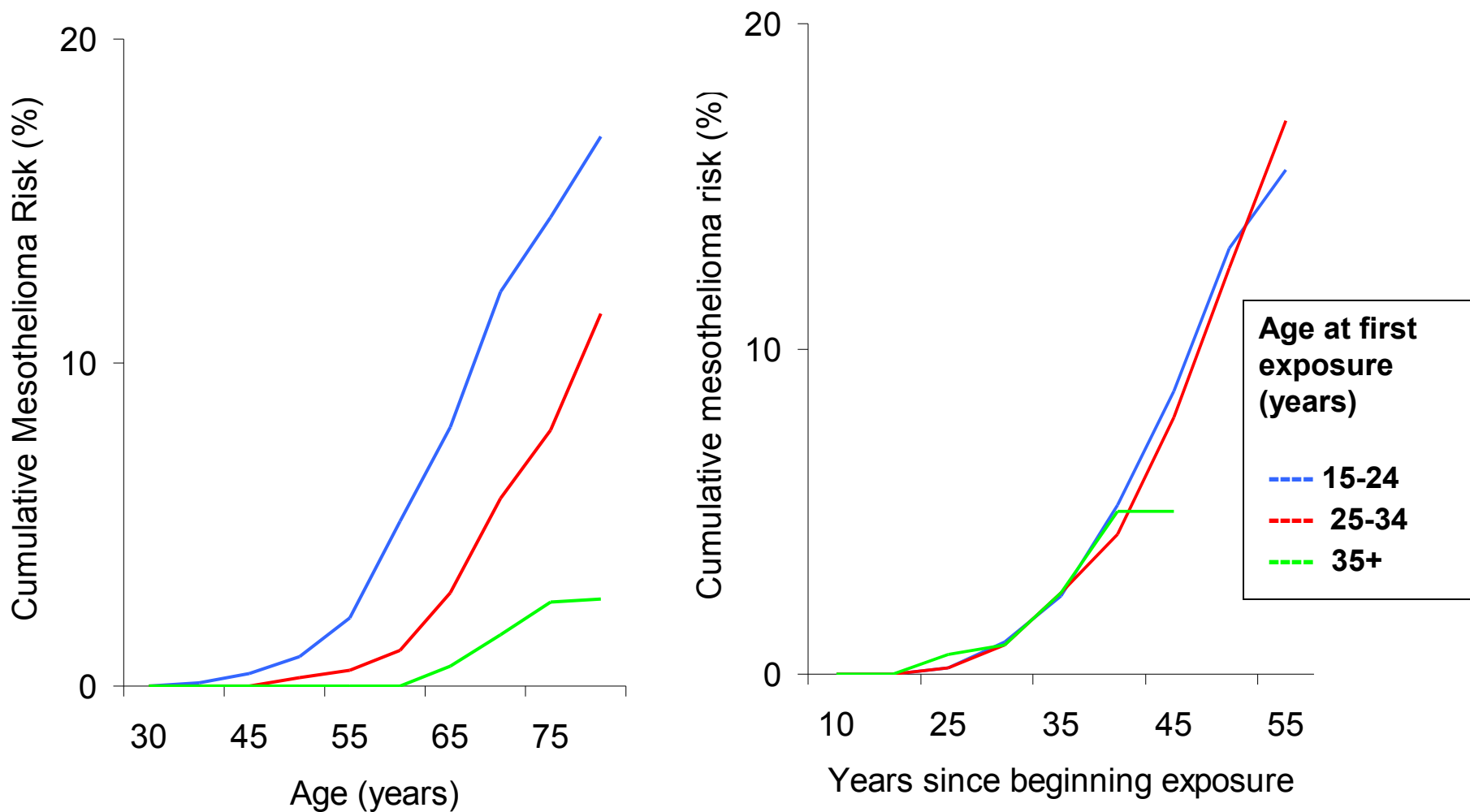
Incidence rate \propto (years since first asbestos exposure)³

Mesothelioma in the 'unexposed' population:

Incidence rate \propto (age)³

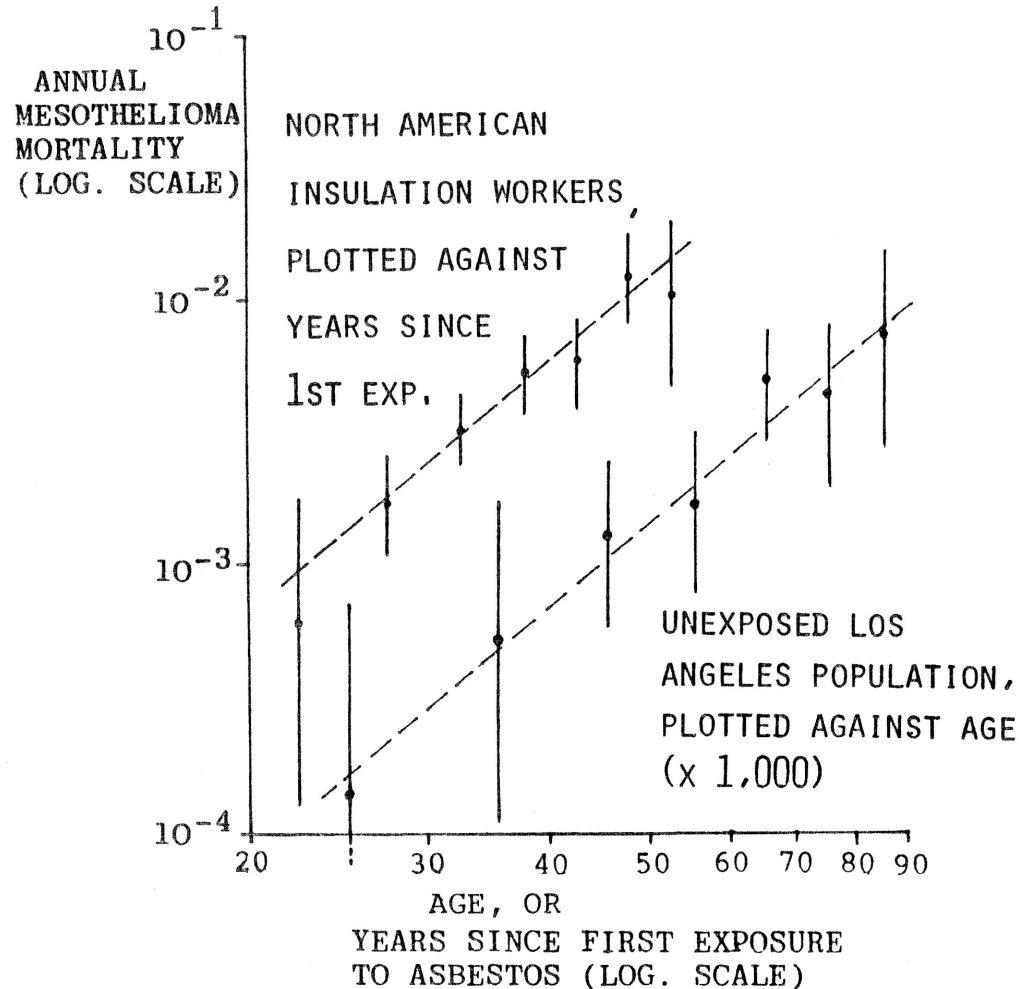
Mesothelioma mortality in North American insulation workers is independent of age

(Peto et al 1982: Br J Cancer 45: 124-135)



Mesothelioma incidence is proportional to the third power of time since first asbestos exposure, independent of age. In unexposed people it is proportional to the third power of age.

(Peto et al 1981: Banbury Report 9, Cold Spring Harbor Laboratory
Peto et al 1982: Br J Cancer 45: 124-135)



UK national case-control study of 622 mesotheliomas (512 men, 110 women) and 1420 controls interviewed 2001-2005

65% aged < 65 years at diagnosis

Rake et al (2009) Br J Cancer 100: 1175-83

Male mesotheliomas: Duration of asbestos exposure before and after age 30. Odds ratios are relative to 38 cases and 413 controls with no asbestos exposure at work (reference group)

Duration before age 30	Duration after age 30					
	none		<10 years		≥10 years	
	Cases/ controls	OR (95% CI)	Cases/ controls	OR (95% CI)	Cases/ controls	OR (95% CI)
None	38/413	1.0 (ref)	5/21	2.4 (0.9, 6.9)	3/28	1.1 (0.3, 3.7)
<10 yrs	59/163	3.9 (2.5, 6.1)	27/76	3.9 (2.2, 6.7)	47/104	4.6 (2.8, 7.5)
≥10 yrs	19/31	6.5 (3.3, 12.8)	54/53	10.7 (6.4, 17.9)	260/223	12.7 (8.6, 18.6)

Case control study: 512 male mesotheliomas and 1112 male controls.
 Odds ratios by duration in job category before age 30 compared to 38 cases
 and 413 controls who only worked in low risk jobs (lifetime risk 0.12%)

	Non- construction high risk	Carpenters	Plumbers, electricians & painters	Other construction	Medium risk industrial
None	2.6	3.0	5.4	3.0	1.5
<5 years	9.4	8.1	4.0	3.3	2.1
5-9 years	17.6	24.1	12.1	4.3	1.2
≥10 years	15.1	49.3	16.5	6.7	5.0
Lifetime risk for ≥10 yrs in category	1.8%	5.9%	2.0%	0.8%	0.6%

Lifetime exposure histories of 512 male mesothelioma cases diagnosed 2000-2004 and 1,112 male controls

Highest exposure category	Cases			Controls	OR (95% CI)
	Caused by this exposure				
	Yes	No*	Total		
Occupational exposure					
Non-construction high risk jobs	144.1	8.9	153	138	17.2(10.1,29.3)
Carpenters	86.4	2.6	89	42	33.9(18.5,62.1)
Plumbers, electricians & painters	104.8	7.2	112	114	15.6 (9.1,27.0)
Other construction	43.0	9.0	52	142	5.8 (3.3, 10.4)
Medium risk industrial	51.4	16.6	68	263	4.1 (2.4, 7.1)
Other substantial exposure	5.3	1.7	7	27	4.1 (1.6, 10.6)
Non-occupational exposure					
Father exposed	6.8	6.2	13	98	2.1 (1.0, 4.5)
None of the above (ref group)	-	18.0	18	288	1.0
Total population	441.8	70.2*	512	1112	

* Number of cases not caused by exposure = Total/ OR = 512/70.2 = 70.2 'environmental' cases

Lifetime exposure histories of 110 female mesothelioma cases diagnosed 2000-2004 and 308 female controls

Highest exposure category	Cases			Controls	OR (95% CI)
	Caused by this exposure				
	Yes	No*	Total		
Occupational exposure					
Non-construction high risk	4.0	1.0	5	5	5.1 (1.4, 19.2)
Carpenters	-	-	0	0	-
Plumbers, electricians & painters	-	-	0	2	-
Other construction	-	-	0	1	-
Medium risk industrial	18.7	13.3	32	63	2.4 (1.4, 4.4)
Other substantial exposure	1.8	0.2	2	1	8.8(0.7,103.0)
Non-occupational exposure					
Father or husband exposed	17.5	19.5	37	86	1.9 (1.1, 3.3)
None of the above (ref group)	-	34.0	34	150	1.0
Total population	42.0	67.8*	110	308	

* Number of cases not caused by exposure = Total/OR

*67.8 'environmental' cases

Asbestos lung burdens (fibres > 5 μ) in patients with mesothelioma, lung cancer and pneumothorax

Million fibres per gram (TEM)	Mesothelioma patients	Lung cancer patients	Pneumothorax patients	
			Born <1970	Born \geq 1970
	n (%)	n (%)	n (%)	n (%)
<0.025	12 (29.3%)	28 (65.1%)	21 (70.0%)	20 (95.2%)
0.025-0.200	13 (31.7%)	13 (30.2%)	9 (30.0%)	1 (4.8%)
\geq 0.200	16 (39.0%)	2 (4.7%)	0	0
Total	41	43	30	21

Why have female rates increased about five-fold in the UK since 1970?

Could environmental exposure (~ 0.0001 fibre/ml) account for the 'background' mesothelioma risk in unexposed men and women, whose lifetime risk is about 0.1%?

1. Exposure from birth or age 20: Risk x 5
2. Continuous exposure (168 hours/week) or at work (10 – 20 hours/week):
Risk >10 times greater

HSE case-control study: Lung cancer risk by duration in high-risk jobs (mainly construction) identified from mesothelioma analysis

Duration worked before age 35	Lung cancers		Controls		Relative Risk [†]	(95% CI)
	N	(%)	N	(%)		
Carpenters only						
0 yrs	273	(92.9%)	800	(96.6%)	1.0	
<10 yrs	13	(4.4%)	15	(1.8%)	1.7	(0.7 – 4.2)
10+ yrs	8	(2.7%)	13	(1.6%)	3.0	(1.0 – 9.4)
All high-risk jobs						
0 yrs	125	(42.5%)	508	(61.4%)	1.0	
<10 yrs	84	(28.6%)	172	(20.8%)	1.6	(1.1 – 2.4)
10+ yrs	85	(28.9%)	148	(17.8%)	2.0	(1.3 – 2.9)
Total	294	(100%)	828	(100%)	-	-

[†] OR adjusted for year of birth, SES and smoking

Attributable fraction for all high-risk jobs = 23%. Are one in 4 of all lung cancers in British men caused by asbestos?

World asbestos production

1975 5 million tons

1991 4 million tons

2003 2 million tons

What will future death rates be

1. For mesothelioma?

2. For lung cancer?

Who knew what was happening? Why did amosite use continue in Britain and Australia for about 15 years after crocidolite had been abandoned?

S.F. McCullagh, Principal Occupational Physician, James Hardie Industries, Australia
J Soc Occup Med` 1980 30: 153-6

The Advisory Committee on Asbestos has lately recommended that the hygiene standard ... for amosite should be 0.5 f/ml, half the limit recommended for chrysotile. The evidencedoes not suffice to justify different limits.

Lancet editorial Dec 6th 2008

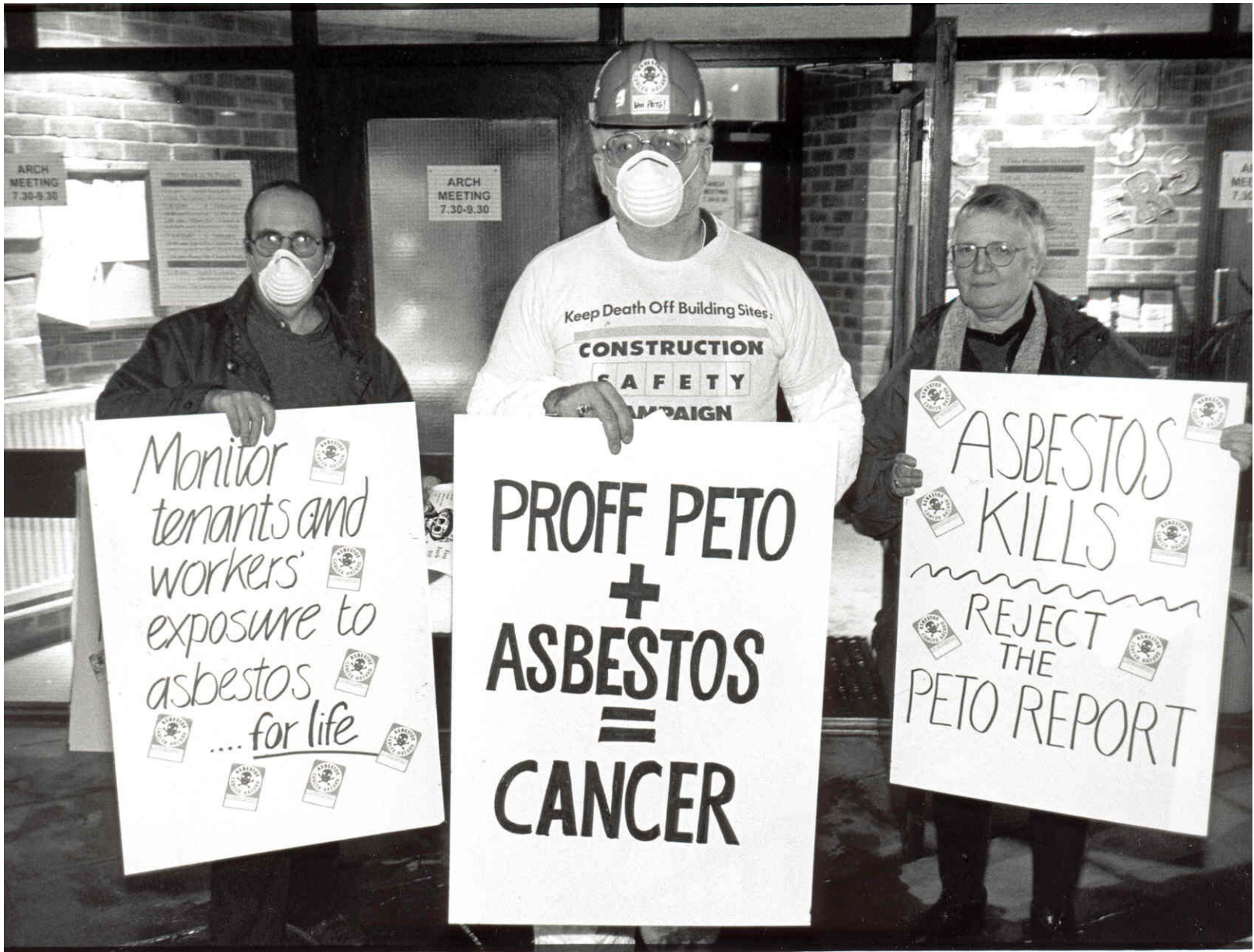
Asbestos is a combination of naturally occurring minerals with two primary varieties: chrysotile and crocidolite

All forms of asbestos are carcinogenic. Mesothelioma, the most common asbestos-related disease, is...caused by inhalation of asbestos fibres

In the UK alone, 2,000 people annually die from asbestos exposure.... A similar epidemic is likely to arise in developing countries where asbestos is still widely used

Despite [Canada's] claims that chrysotile poses a lower health risk than other types of asbestos, it acknowledges that chrysotile is a carcinogen

The only way to eliminate asbestos-related disease is to stop the use of all types of asbestos



Keep Death Off Building Sites

**CONSTRUCTION
SAFETY
CAMPAIGN**

Monitor
tenants and
workers'
exposure to
asbestos
.... for life

**PROFF PETO
+
ASBESTOS
=
CANCER**

**ASBESTOS
KILLS
REJECT
THE
PETO REPORT**

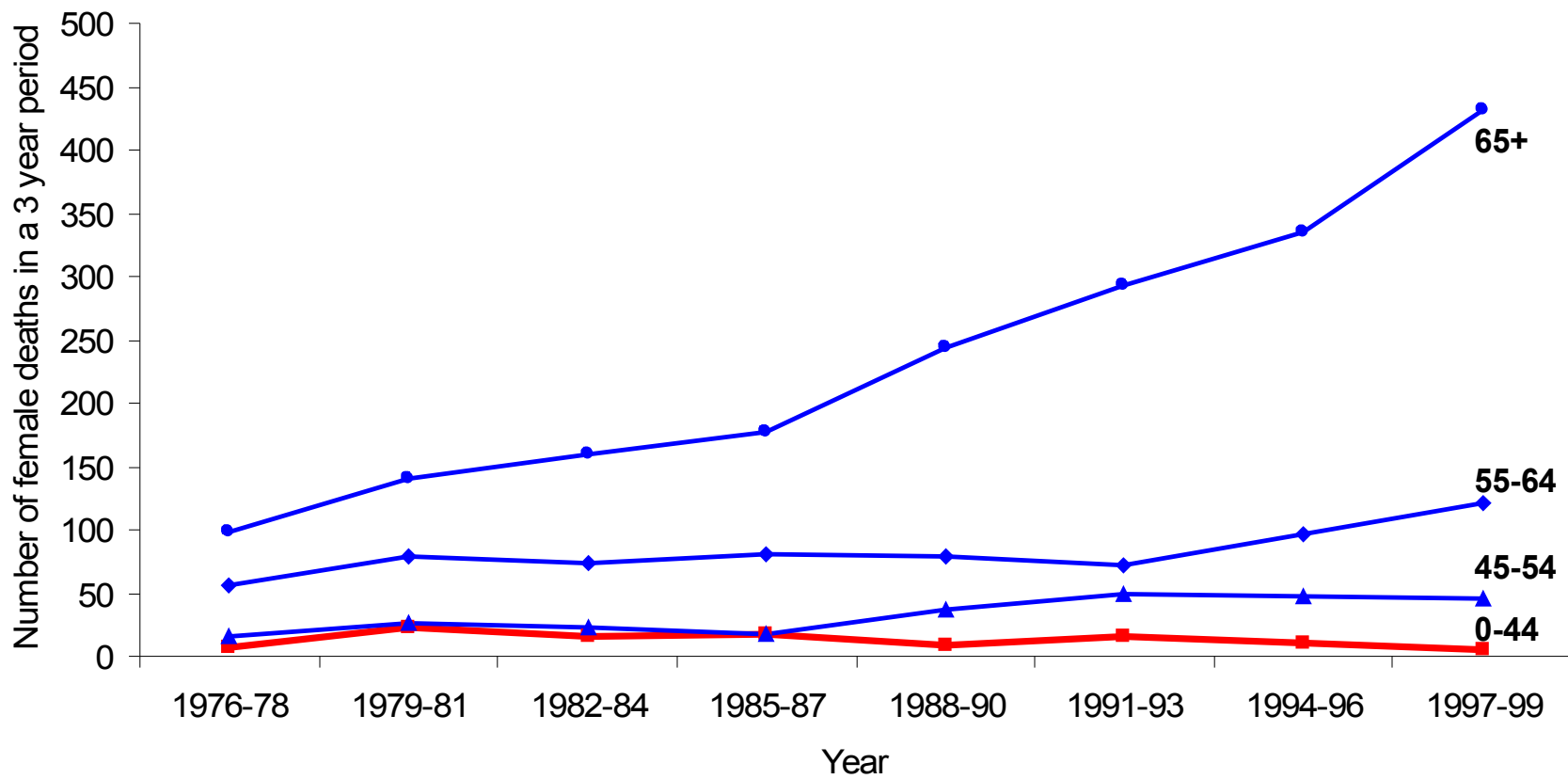
Christine Rake and Clare Gilham (Institute of Cancer Research)
John Hodgson and Andrew Darnton (Health and Safety
Executive)



Asbestos regulation and consumption in Asia
 Takahashi and Karjalainen IJOEH (2003)

	Imports (\$M)	Ban			Trend
		blue	brown	white	
China	1,275	yes	no	no	up
Indonesia	211	?	?	no	up
Korea	42	yes	yes	no	down
Malaysia	23	yes	no	no	flat
Philippines	76	yes	yes	no	up
Taiwan	22	yes	yes	no	down
Thailand	62	yes	yes	no	up
Vietnam	78	no	no	no	up

British female mesothelioma deaths



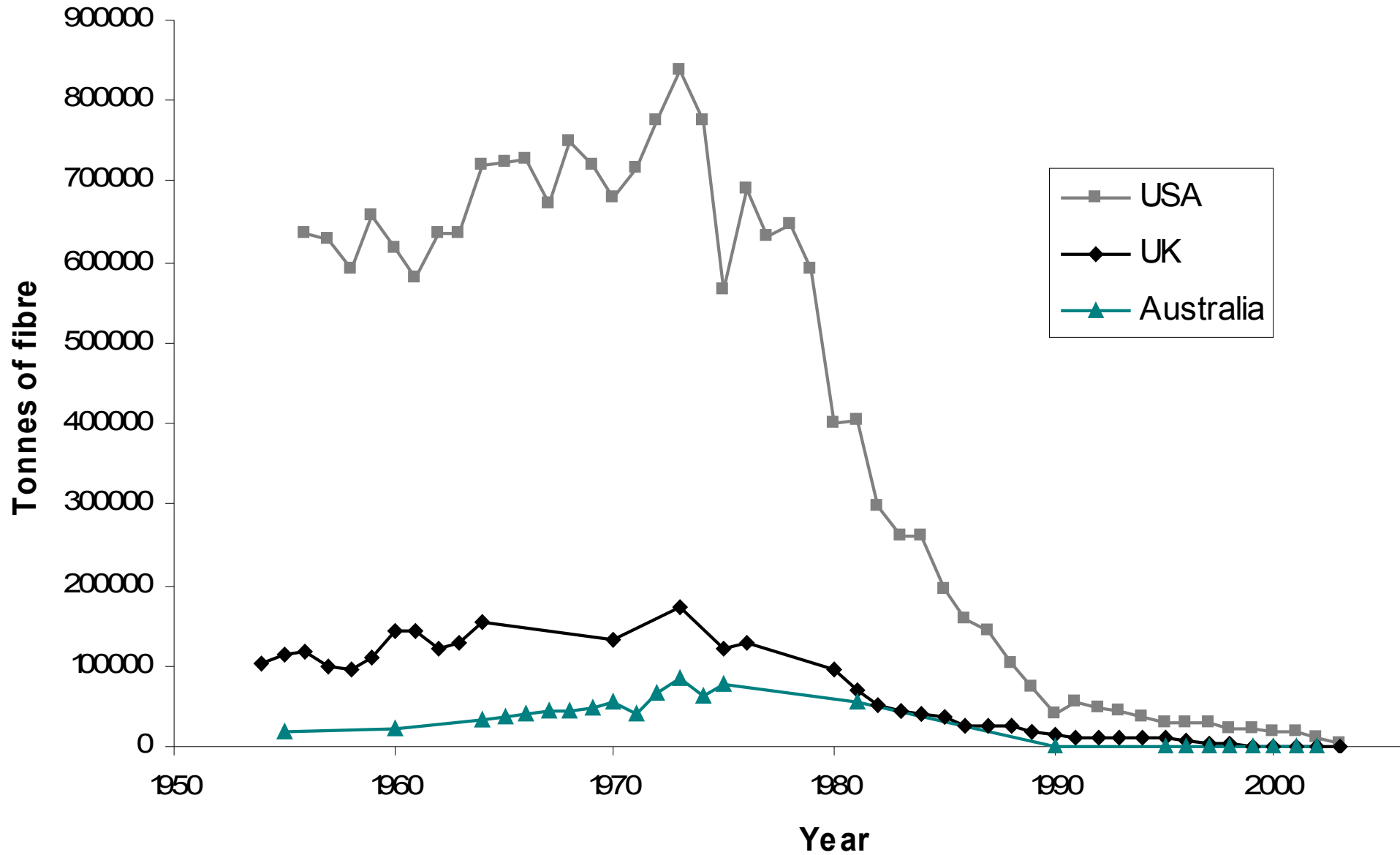
Lifetime mesothelioma risks in British men

deaths	PMR	Percent of all in 2005 at age 40-79
All British men:	100	0.9%
Construction: Plumbers	413	3.7%
Carpenters	388	3.4%
Electricians	279	2.5%
Manufacture: Metal plate workers	503	4.5%
Vehicle body makers	526	4.7%
Low risk: Farmers	26	0.2%
Doctors	28	0.2%
Motor mechanics	48	0.4%

UK national case-control study of mesotheliomas (512 men, 110 women) interviewed 2001-2005

Year of birth	Unexposed cases		Asbestos-exposed cases	
	Male	Female	Male	Female
≥ 1965	1	2	1	0
1960-64	0	1	4	0
1955-59	2	7	11	1
1950-54	2	5	42	2
1945-49	14	11	105	6
1940-44	10	21	145	13
1935-39	7	17	82	8
1930-34	1	7	48	5
1925-30	1	2	36	2
Total	38	73	474	37

Chrysotile production + imports



Average asbestos consumption (1,000 tonnes p.a.)

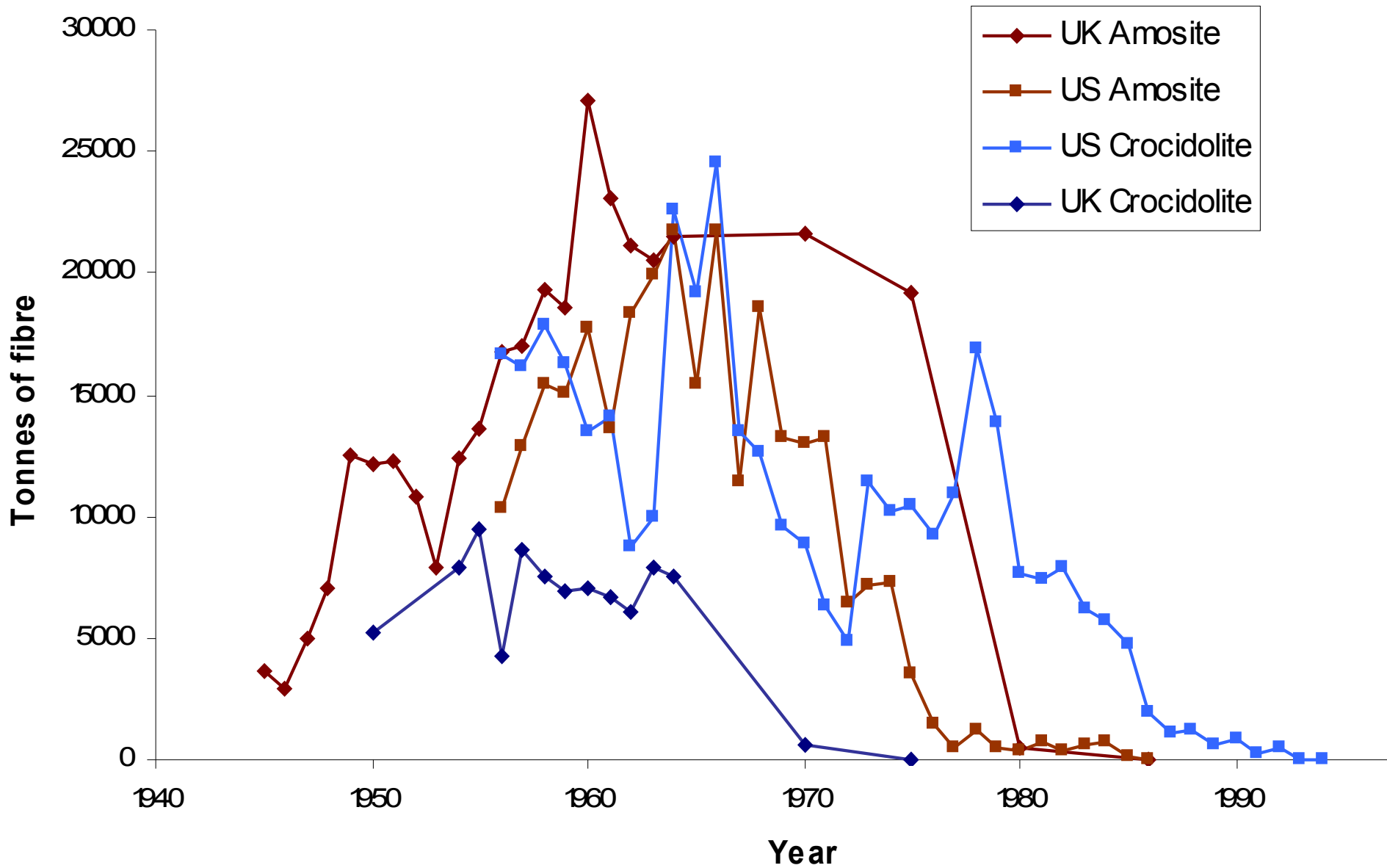
consumption=production+imports – exports (% shown in table)

		1950s	1960s	1970s	1980s
Australia	Blue	6	8	0	0
	Brown	9	7	8	<1
	White	17	31	74	12
	% exported	14%	9%	5%	47%
USA	Blue	17	14	10	4
	Brown	13	17	5	<1
	White	626	655	646	182
	% exported	<1%	3%	6%	24%
UK	Blue	7	7	0	0
	Brown	14	21	~15	~1
	White	107	131	136	43
	% exported	NK	3%	2%	2%

Average asbestos consumption (1,000 tonnes p.a.)

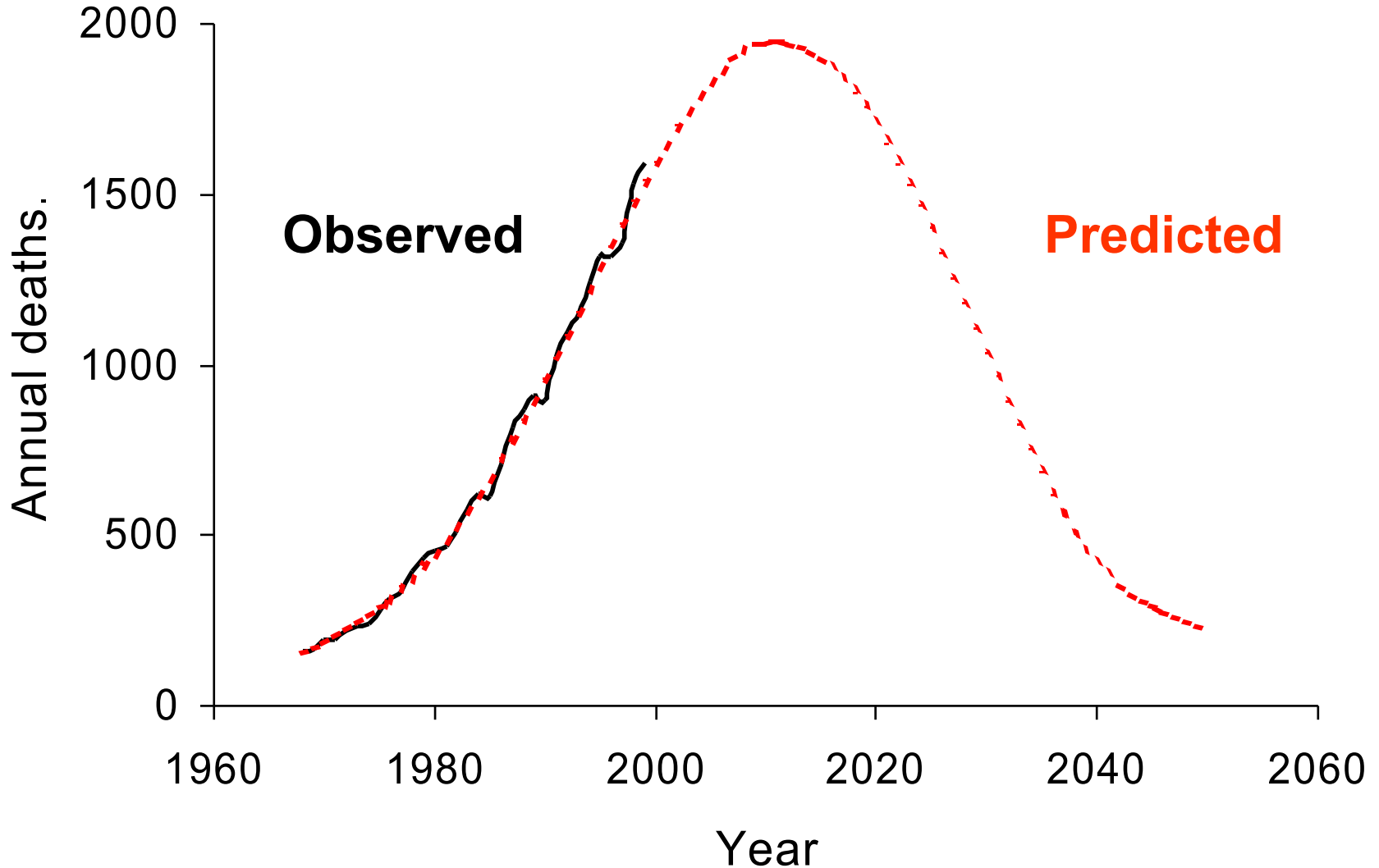
		1950s	1960s	1970s	1980s
Australia	Blue	6	8	0	0
	Brown	9	7	8	<1
	White	17	31	74	12
USA	Blue	17	14	10	4
	Brown	13	17	5	<1
	White	626	655	646	182
UK	Blue	7	7	0	0
	Brown	14	21	~15	~1
	White	107	131	136	43

Amphibole imports into UK and US



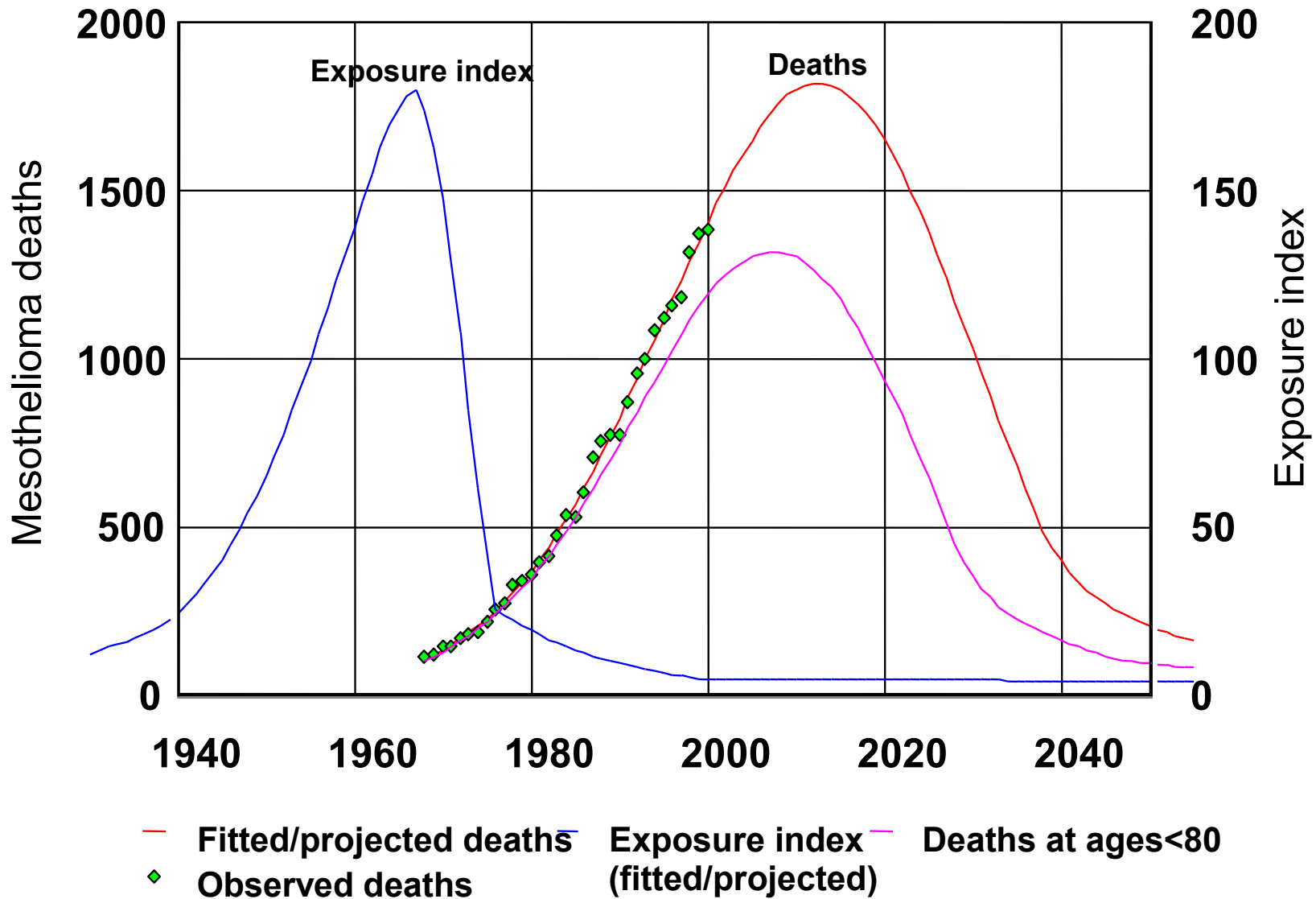
Mesothelioma deaths in Britain and predicted numbers based on new HSE model

Hodgson et al (2005) Br J Cancer 92: 587-93



Projected British male mesothelioma deaths – all deaths (red) and deaths below age 80 (purple)

Hodgson et al (2005) Br J Cancer 92: 587-93



Most Western countries

Most or all asbestos products are now banned.

Mesothelioma rates are still rising in old age, but are level or falling at younger ages in countries that have stopped using asbestos products.

Rest of the world

Asbestos use is continuing and in some cases increasing. Leading consumers include Russia, India and most other Asian countries except Japan.

Crocidolite imports + production

