

**Table 2.11. Cohort studies of exposure to benzene and the risk for multiple myeloma**

Reference, location	Cohort description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/deaths	Relative risk (95% CI)	Adjustment for potential confounders	Comments
Wong (1995) USA	Cohort of 1 717 workers in two plants manufacturing Pliofilm (rubber hydrochloride) (Crump, 1994)	Historical records and interviews with former workers (Crump, 1994)	MM 203	Benzene cumulative exposure ppm-yr		(SMR)		
				< 40	3	3.2 (0.7–9.4)		
				40–200	0	0 (0–12.3)		
				200–400	0	0 (0–36.9)		
				> 400	1	25.2 (0.6–139.8)		
Total	4	2.9 (0.8–7.4)						
Satin <i>et al.</i> (1996) USA	Cohort of 17844 petroleum refinery workers, employed 1937–1983, followed up to 1987	No exposure assessment was performed	MM 203		19	(SMR) 1.0 (0.6–1.5)		
Schnatter <i>et al.</i> (1996) Canada	Cases and controls matched 1:4 with cases derived from a cohort of petroleum distribution workers	Industrial hygienists assigned exposure on the basis of work histories from personnel records.	MM 203	Benzene ppm-yr		(OR)		Nested case-control analysis
				0.0–0.49	3	1.0		
				0.50–7.99	1	0.4 (0.0–5.7)		
				8.00–19.99	1	0.6 (0.0–7.8)		
20.0–219.8	2	1.2 (0.1–20.0)						
Yin <i>et al.</i> (1996) PR China	74828 exposed and 35805 unexposed workers employed 1972–1987 in 12 cities in China, followed up to 1987	Benzene exposed jobs determined based upon factory level and job-title specific information.	MM 203	Benzene Unexposed Exposed	1 1	(RR) 1.0 0.4 (0.0–10.7)	Age and sex	NCI-CAPM cohort

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Lynge <i>et al.</i> (1997) Denmark, Norway, Sweden, Finland	Cohort of gasoline service station workers (16524 men, 2445 women), followed for 20 yr by linkage to national cancer registries	Service station occupation identified from the 1970 censuses of each country	MM 203	Men	9	(SIR) 0.6 (0.3–1.1) [1.2]		Estimated average level of exposure to benzene below 1 mg/m <sup>3</sup>
				Women	2			
Nilsson <i>et al.</i> (1998) Sweden	Cohorts of man Swedish seamen, age 20–64, identified through the 1960 (13499) and 1970 (11290) censuses, cases identified by linkage to the Swedish cancer register, 1961–79 and 1971–87, respectively .	Details of service on ships from the Swedish Registry of Seamen. Ship classified as chemical or product tanker, crude oil tanker, other	MM 203	1960 cohort		(OR) - - 4.0 (0.0–161) -		Nested case-control analysis. 3–5 controls per case randomly selected among men in the same 5 yr age stratum classified as seamen in the same national census and confirmed to be alive at the time of the diagnosis of the case
				Chemical or product tanker	0			
				Crude oil tanker	0			
				1970 cohort				
Chemical or product tanker	1							
Crude oil tanker	0							

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Divine <i>et al.</i> (1999b) USA	All (28480) employees who worked at selected refinery, petrochemical, and research establishments at least one day between 1947–1977; employed at these for a cumulative total > 5 yr; still employed on the end date of the study	Complete work history of all jobs held at the participating factories (Divine <i>et al.</i> , 1999a)	MM 203	Employed:		(SMR)		No estimates of exposure to benzene
				Ever	36	1.0 (0.7–1.4)		
				before 1950	30	1.0 (0.7–1.5)		
				1950 and after	6	0.9 (0.3–2.0)		
Wong <i>et al.</i> (2001a) USA	Cohort of 7543 petroleum refinery workers (91% men) employed for at least 1 yr, 1945–1996, followed up to 1996	No exposure assessment was performed	MM 203	Men workers hired before 1950	12	(SMR) 0.9 (0.5–1.7)	No estimates of exposure to benzene	
				Hired 1950 or later	2	1.0 (0.1–3.7)		
Wong <i>et al.</i> (2001b) USA	Cohort of 3328 petroleum refinery workers employed for at least 1 yr, 1959–1997, followed up to 1997	No exposure assessment was performed	MM 203	Length of employment:		(SMR)	No estimates of exposure to benzene	
				< 10 yr	1	1.7 (0.6–9.3)		
				10–29 yr	1	0.5 (0.0–2.8)		
				30+ yr	2	2.8 (0.3–10.0)		

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Rinsky <i>et al.</i> (2002) USA	Cohort of 1291 men employed at one of three rubber hydrochloride plants for at least 1 day 1940- 1976, followed 1960 to 1981.	Job exposure matrices were based on available air sampling data. Cumulative exposures (ppm-yr) were derived from the matrices by summing daily exposure values using detailed work histories.	MM 203	Exposed to at least 1ppm-day of Benzene	5	(SMR) 2.0 (0.7–4.8)		
Sorahan <i>et al.</i> (2002) United Kingdom	Cohorts of 29630 oil refinery and 16480 petroleum distribution workers, first employed after 1 January 1946 who had worked for at least a yr, followed 1951–1998 by linkage with national files	No exposure assessment performed	MM 203	Refinery workers Distribution workers	34 19	(SMR) 0.9 (0.6–1.2) 0.8 (0.5–1.3)		
Collins <i>et al.</i> (2003) USA	Hourly workers (4172 men and 245 women) employed at a chemical manufacturing plant from 1940–1977 and followed up to 1997	Work histories, sampling measurements and industrial hygienists assessments	MM 203	Benzene cumulative exposure ppm-yr 0 < 1 1–6 > 6	5 2 2 4	(SMR) 1.1 (0.3–2.5) 1.4 (0.2–5.1) 1.5 (0.2–5.4) 2.6 (0.7–6.7)		The SMR for peak benzene exposure > 40 ppm was 4.0 (95% CI: 0.8–11.7) based on 3 deaths.

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Lewis <i>et al.</i> (2003) Canada	Cohort of 17230 men and 8062 women employed for at least a yr of a petroleum company hired between 1964 and 1994 linked to national mortality and cancer incidence databases to 1994.	Estimates of similar exposure groups based upon job title and location by industrial hygienists	MM 203	Men Women	3 0	(SIR) [0.8]		No specific estimates of benzene exposure
Bloemen <i>et al.</i> (2004) USA	Workers exposed to benzene at a chemical plant; 2266 workers (94% men) 68% were followed for at least 30 yr.	Job-titles were assigned to exposure categories by an industrial hygienist, based on industrial hygiene measurements.	MM 203	Benzene exposed workers	3	(SMR) 0.7 (0.2–2.1)		
Huebner <i>et al.</i> (2004) USA	All employees of two refinery/petrochemical plants (Baton Rouge 6941 men, Baytown 6241 men) active in 1970 or hired between 1970–1982 with at least 1 mo of employment at the facility and followed up to 1997	No exposure assessment was performed	MM 203	Hired before 1950 Baton Rouge Baytown Hired in 1950 or later Baton Rouge Baytown	12 10 1 1	(SMR) 1.4 (0.8–2.5) 1.3 (0.6–2.4) [0.6] [0.7]		

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Sorahan <i>et al.</i> (2005) United Kingdom	Cohort of 5130 men and 384 women followed for mortality, 1968–2002, and incidence 1971–2001 by linkage to national files.	Occupational exposure to benzene 1966/67 or earlier; details provided by 233 employers	MM 203	All benzene exposed workers	15 8	(SMR) 0.9 (0.5–1.6) (SIR) 0.7 (0.3–1.3)		
Swaan <i>et al.</i> (2005) the Netherlands	Cohort of 311 workers on the production of Caprolactam, 1951–1968 followed up to January 2001	Benzene used in the production of caprolactam (Nylon 6 monomer) indoors, exposure estimates by expert judgement.	MM 203	All workers	1	(SMR) 1.4 (0.0–7.1)		
Gun <i>et al.</i> (2006) Australia	Australian petroleum workers cohort, 16547 men and 1356 women, followed 1981–1999	None	MM 203		16	(SIR) 1.1 (0.6–1.8)		The SMR for MM mortality was 1.4 (0.7–2.4) based on 12 deaths

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Kirkeleit <i>et al.</i> (2008) Norway	Cohort of 27919 offshore petroleum workers registered to the Norwegian registry of employers and employees and 366 114 matched referents from the general working population	Location of work and job category	MM 203	Exposed Offshore workers combined Upstream offshore workers	11 9	1.7 (0.9–3.4) 2.8 (1.4–5.9)	Sex, age, yr of first exposure and education	Cases identified by linkage to the Norwegian cancer registry.

D, day or days; mo, month or months; MM, multiple myeloma; ppm, parts per million; yr, year or years