

Table 2.15. Cohort studies of benzene and lung cancer

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	
Bond <i>et al.</i> , (1986), USA	19 608 employees of a chemical plant for 1 year or more, 1940-1980. 308 deaths from lung cancer.	Exposure profiles developed by a certified industrial hygienist for each case and control by reviewing each subject's work history record, "blind" to case or control status, listing all agents likely encountered.	LC 162	Benzene	28	(OR)		Nested case-control analysis. Two control series consisting of 308 male subjects individually matched to cases on race, year of birth \pm 5 years, and year of hire, one series living, the other dead within 1 and 5 years of death of case.	
				Ever exposed		0.8 (0.5-1.3)			
				Unexposed		1.0			
				Low		0.9 (0.3-2.3)			
				Moderate		0.7 (0.3-1.6)			
High	0.9 (0.5-1.8)								
Wong (1987), USA	4602 male chemical workers from 7 plants occupationally exposed to benzene for at least 6 months 1947-1975, and 3074 workers from the same plants not exposed to benzene	Jobs with exposure to benzene classified as continuous and intermittent exposure. Tasks classified by occupational hygienists, with level of exposure assigned from exposure measurements.	LC 162, 163	Benzene		(SMR)		SMR for maximum peak exposure >100ppm 1.2 (based on 29 deaths)	
				Continually exposed					
				<180 ppm-months		22			1.3
				180-719 ppm-months		19			1.7
\geq 720 ppm-months	6	0.7							

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Dagg <i>et al.</i> , (1992), USA	Cohort study of 14 074 employees of two petroleum refineries who worked at least a year 1950–1980, followed through 1986.	Only first and last jobs coded. No exposure determination performed	LC 162, 163	None	200	(SMR) 0.8 (0.6-0.9)		Non-significant elevated risks for <15 years employment in the two refineries, but reduced risk for employment > 15 years.
Tsai <i>et al.</i> , (1993), USA	Cohort 4585 workers at two refinery and petrochemical plants who worked more than 6 months before or after January 1 1973 and followed through 1989.	No exposure determination performed	LC 162	None	64	(SMR) 0.7 (0.6-0.9)		

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Wong <i>et al.</i> (1993), USA	18 135 distribution employees with potential exposure to gasoline for at least 1 year between 1946–1985, followed through June 1989.	8hr TWA total hydrocarbon exposure in ppm estimated for job categories based on industrial hygiene data and expert judgment. Cumulative exposure defined as the sum of products of TWA exposure and duration of exposure of each job in an employee's work history.	LC 162, 163	Land-based employees exposed to gasoline	165	(SMR) 0.7 (0.6-0.8)		No indication of increase in LC risk by duration of employment or intensity of exposure to benzene.
				Marine based employees exposed to gasoline	215	1.0 (0.9-1.2)		
Honda <i>et al.</i> , (1995), USA	Cohort of 9796 white males who had worked at a petroleum manufacturing plant for 6 months 1942–1989 and followed to January 1 1990.	No exposure determination performed	LC 162	None	280	(SMR) 0.9 (0.8-1.0)		

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Collingwood <i>et al.</i> , (1996), USA	Cohort of 4855 refinery workers employed for a minimum of 1 year 1946–1979, and followed through 1987.	No exposure determination performed	LC 162, 163		99	(SMR) 0.8 (0.6-1.0)		

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Hayes <i>et al.</i> , (1996), PR China	74 828 exposed and 35 805 unexposed workers employed 1972–1987 in 12 cities in China, followed through 1987	Average occupational benzene exposure was estimated by local industrial hygienists and other occupational health personnel, using available ambient benzene exposure measurements and production and related process information for seven calendar periods for study specific job titles in each factory. Work histories were linked to benzene-exposure data to provide individual time-specific benzene-exposure estimates	LC 162	Benzene cumulative ppm-years None <10 10-39 40-99 100-400 ≥ 400 p for trend	41 10 13 19 38 41	(SMR) 1.0 1.2 1.0 1.4 1.4 1.7 0.01	Age and sex	NCI-CAPM cohort

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Satin <i>et al.</i> , (1996), USA	Cohort of 17 844 petroleum refinery workers, employed 1937-1983, followed through 1987	No exposure determination performed	LC 162		423	(SMR) 0.9 (0.8-1.0)		
Tsai <i>et al.</i> , (1996), USA	9720 employees who had worked at least 3 months 1948–1989 in a petrochemical refinery and chemical plant complex	Workers assigned to refinery (5019) or chemical plant (3988) according to longest duration job. No benzene exposure determination performed	LC 162	Refinery	107	(SMR) 0.8 (0.6-0.9)		
				Chemical plant	56	0.7 (0.5-0.9)		
Lynge <i>et al.</i> , (1997), Denmark, Norway, Sweden, Finland	Cohort of gasoline service station workers (16 524 male, 2445 female), followed through 20 years by linkage to national cancer registries	Service station occupation identified from the 1970 censuses of each country	LC 162	Males Females	208 11	(SIR) 1.3 (1.1-1.4) 1.1 (0.5-1.9)		Estimated average level of exposure to benzene below 1 mg/m ³

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Pukkala (1998), Finland	Cohort of 7512 men and 1942 women employed in one group including oil refinery, and chemical manufacturing; follow-up by linkage with the Finnish cancer registry 1971–1994.	No estimate of exposure to benzene	LC 162	Employed at least 3 months during 1967-1982	50	(SIR) 0.9 (0.6-1.2)		
Consonni <i>et al.</i> , (1999), Italy	Cohort of 1583 workers employed 1949–1982 in an oil refinery and followed through May 1991.	No estimate of exposure to benzene	LC 162		46	(SMR) 1.1 (0.8-1.4)		
Divine <i>et al.</i> (1999a) USA	White men (24 604) 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 years; still employed on the end date of the study	Complete work history of all jobs held at the participating factories	LC 162	Employed: Ever before 1950 1950 and after	537 449 88	(SMR) 0.7 (0.6-0.7) 0.7 (0.6-0.8) 0.5 (0.4-0.6)		No estimates of exposure to benzene

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Wong <i>et al.</i> , (2001a) USA	Cohort of 7543 petroleum refinery workers (91% male) employed for at least 1 year, 1945-1996, followed to 1996	No exposure determination performed	LC 162	Male workers Female workers	195 6	(SMR) 0.8 (0.7-1.0) 1.1 (0.4-2.4)		No estimates of exposure to benzene
Wong <i>et al.</i> , (2001b) USA	Cohort of 3328 petroleum refinery workers employed for at least 1 year, 1959-1997, followed to 1997	No exposure determination performed	LC 162	All workers	52	(SMR) 0.8 (0.6-1.0)		No estimates of exposure to benzene

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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 year, followed 1951-1998 by linkage with national files	No exposure determination performed	LC 162	Refinery workers	959	(SMR) 0.9 (0.8-0.9)		
				Distribution workers	686	1.0 (0.9-1.1)		
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 to 1997	Work histories, sampling measurements and industrial hygienists assessments	LC 162	Benzene cumulative exposure ppm-years		(SMR)		The SMR for peak benzene exposure >40 ppm was 1.6 (95%CI 1.1-2.3) based on 28 deaths.
				0	126	1.3 (1.1-1.5)		
				<1	32	1.1 (0.7-1.5)		
				1-6	39	1.3 (1.0-1.8)		
>6	55	1.6 (1.2-2.1)						

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Lewis <i>et al.</i> , (2003), Canada	Cohort of 17230 males and 8062 females employed for at least a year 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	LC 162	Males	44	(SIR) 0.7 (0.5-0.9)	Smoking	No specific estimates of benzene exposure
				Females	9	0.6 (0.3-1.1)		
				Hydrocarbons/solvents/fuels (Males) (ppm-years)				
				Unexposed	18	1.0		
				<2.5	7	0.8 (0.3-1.8)		
≥2.5-<30	6	0.7 (0.3-1.8)						
≥30	13	1.2 (0.6-2.4)						
Tsai <i>et al.</i> , (2003), USA	Cohort of 3579 male employees of a chemical and refinery facility during 1973-1999 followed 1979-1999	No exposure determination performed	LC 162	All male workers	46	(SMR) 0.7 (0.5-1.0)		
Bloemen <i>et al.</i> , (2004), USA	Workers exposed to benzene at a chemical plant; 2266 workers (94% male) Followed for up to 30 years.	Job-titles were assigned to exposure categories by an industrial hygienist, based on industrial hygiene measurements.	LC 162	Benzene exposed workers	97	(SMR) 1.0 (0.8-1.2)		

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Huebner <i>et al.</i> , (2004), USA	All employees of two refinery/petrochemical plants (Baton Rouge 6941 males, Baytown 6241 males) active in 1970 or hired between 1970-1982 with at least 1 month of employment at the facility and followed through 1997	No exposure determination performed	LC 162	Hired before 1950		(SMR)		
				Baton Rouge	170	0.8 (0.7-0.9)		
				Baytown	122	0.7 (0.6-0.9)		
				Hired in 1950 or later				
				Baton Rouge	23	0.5 (0.3-0.7)		
				Baytown	18	0.5 (0.3-0.8)		
Sorahan <i>et al.</i> , (2005), United Kingdom	Cohort of 5130 males and 384 females 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	LC 162	All benzene exposed workers	294	(SMR) 1.2 (1.1-1.4)		
					293	(SIR) 1.2 (1.1-1.3)		
Gun <i>et al.</i> (2006), Australia	Australian petroleum workers cohort, 16547 men and 1356 women, followed 1981-1999	None	LC 162		113	(SIR) 0.7 (0.6-0.8)		