

Table 2.7. Cohort studies of exposure to benzene and the risk for chronic lymphocytic leukaemia (CLL)

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
McCraw <i>et al.</i> (1985) USA	All white male employees at an oil refinery for at least one day between 1973–1982, and retirees alive as of 1973; total 3976	No exposure assessment was performed	CLL 204.1	None	1	(SMR) 0.7 (0.0–4.3)		Comparison population Surveillance, Epidemiology and End Results, white men.
Rushton (1993) United Kingdom.	Cohort of men who worked for at least a yr at 8 oil refineries (35 569) and 750 distribution centres (23 306) in the United Kingdom and followed for 39 yr	No exposure assessment was performed	CLL 204.1	Distribution workers Refinery workers	16 12	(SMR) 1.2 (0.7–1.9) 0.8 (0.4–1.3)		

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Wong <i>et al.</i> (1993), USA	18135 distribution employees with potential exposure to gasoline for at least 1 yr between 1946–1985, followed up to 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.	CLL 204.1	Land-based employees exposed to gasoline	2	(SMR) 0.3 (0.0–1.3)		Detailed exposure measurements not applied to analyses of leukaemia subtypes
				Marine based employees exposed to gasoline	4	0.9 (0.3–2.4)		
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	CLL 204.1		3	(SMR) 0.3 (0.1–0.9)		

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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	CLL 204.1	Men Women	8 2	(SIR) 0.8 (0.3–1.6) 2.7 (0.3–9.6)		Estimated average level of exposure to benzene below 1 mg/m ³
Rushton & Romaniuk (1997) United Kingdom	Cohort of petroleum industry distribution workers in which 91 cases of leukaemia were identified (31 CLL)	Work histories and occupational hygiene measurements of benzene	CLL 204.1	Benzene cumulative exposure ppm-yr				Nested case-control analysis; 4 controls selected per case matched by age. Cumulative exposure analysed as a continuous variable showed no association with CLL (OR1.0, 95% CI: 0.9–1.0)
				< 0.26	1	1.0		
				0.26–0.59	12	10.6 (1.3–87.9)		
				0.60–1.64	9	11.2 (1.2–104.4)		
				1.65–4.78	2	1.3 (0.1–16.5)		
				≥ 4.79	7	5.6 (0.6–49.6)		

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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)	CLL 204.1	Employed: before 1950	13	(SMR) 0.8 (0.4–1.4)		No estimates of exposure to benzene
				after 1950	2	0.7 (0.1–2.6)		
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	CLL 204.1	Men workers hired before 1950	1	(SMR) 0.2 (0.0–1.0)		No estimates of exposure to benzene
				Hired 1950 or later	0	-		

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Guénel <i>et al.</i> (2002) France	Cohort of 170000 men employed at an electric utility company for at least one yr, 1978–1989	Time weighted average exposure to benzene was estimated based on expert judgement (expressed in units of exposure). Estimates were included in a JEM. Cumulative exposure was calculated by summing yearly exposure estimates of all the consecutive jobs in the individual's work history.	CLL 204.1	Benzene unit exposure-yr 0 < 5.5 ≥ 5.5 p for trend	9 3 1	(OR) 1.0 1.3 (0.3–6.3) 4.4 (0.3–77.1) 0.75		Nested case-control analysis.
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	CLL 204.1	Benzene cumulative exposure ppm-yr 0 < 1 1–6 > 6	2 1 0 1	(SMR) 0.9 (0.1–3.1) 1.6 (0.0–8.9) 0.0 (0.0–5.9) 1.3 (0.0–7.2)		The SMR for peak benzene exposure > 40 ppm was 2.5 (95%CI: 0.0–13.8) based on 1 death.

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Glass <i>et al.</i> (2003) Australia	Australian petroleum workers cohort in which 11 cases of CLL were identified.	Benzene exposure based on task-based algorithm involving the subject's occupational history; previously measured exposures for particular tasks in the Australian petroleum industry; and task-, site-, and period-specific data.	CLL 204.1	Cumulative lifetime Benzene exposure (ppm-yr) ≤ 4 > 4–8 > 8	NA	1.0 2.8 (0.4–18.1) 4.5 (0.9–22.9)		Nested case-control analysis 5 controls per case randomly selected and matched by age and availability at time of diagnosis of the case
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.	Estimates of similar exposure groups based upon job title and location by industrial hygienists	CLL 204.1	Men Women	6 0	(SIR) 1.8 (0.7–3.9) -		

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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.	CLL 204.1	Benzene exposed workers	1	(SMR) 0.4 (0.0–2.4)		
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	CLL 204.1	Hired before 1950 Baton Rouge Baytown Hired in 1950 or later Baton Rouge Baytown	10 3 0 2	(SMR) 2.8 (1.4–5.2) 0.8 (0.2–2.5) - 0.6		
Sorahan <i>et al.</i> , (2005) United Kingdom	Cohort of 5130 men and 384 women followed for mortality, 1968–2002	Occupational exposure to benzene 1966/67 or earlier as reported by 233 employers	CLL 204.1	All benzene exposed workers	5	(SMR) 1.2 (0.4–2.9)		

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Gun <i>et al.</i> (2006) Australia	Australian petroleum workers cohort, 16547 men and 1356 women, followed 1981–1999	No exposure assessment was performed	CLL 204.1		12	(SIR) 1.0 (0.5–1.8)		Overlap with Glass <i>et al.</i> (2003)
Kirkeleit <i>et al.</i> (2008) Norway	Cohort of 27919 offshore petroleum workers registered to the Norwegian registry of employers and employees and 366114 matched referents from the general working population	Location of work and job category	CLL 204.1	Exposed upstream offshore workers	3	1.6 (0.5–5.2)	Sex, age, yr of first exposure and education	Cases identified by linkage to the Norwegian cancer registry.

CLL, chronic lymphocytic leukaemia; hr, hour or hours; ppm, parts per million; yr, year or years