Table 2.1. Cohort studies of Aluminum production workers and cancer

Reference, location, name of study	Cohort description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	Relative risk, OR, or SMR (95% CI)*	Adjustment for potential confounders	Comments
Gibbs *et al*. (2007), Canada	All men on company payroll on January 1950 (A and C) or January 1951 (C). A: 5285; B:529; C: 163. Followed for mortality from 1950 (1951) up to 1999	JEM: BSM and B[a]P applied to work histories, lifetime B[a]P and BSM-years calculated Smoking data (individual but incomplete) collected in the 1990's from medical records and "previous research"	Lung	All	538	SMR 136 (125-148)	Smoking adjustment had only a small influence on the SMRs both for cancer of the lung and bladder	Reference rates obtained from Quebec mortality statistics. All plants predominately used Söderberg process
				0 B[a]P-years	28	61 (41-81)		
				0-	196	106 (92-123)		
				20-	49	188 (139-248)		
				40-	46	142 (104-189)		
				80-	96	219 (177-268)		
				160-	104	183 (150-222)		
				320-	19	270 (163-422) p trend < 0.001		
			Bladder	All	78	223 (177-279)		
				0 B[a]P-years	3	73 (15-213)		
				0-	14	82 (45-138)		
				20-	3	136 (28-398)		
				40-	1	35 (1-194)		
				80-	15	421 (235-694)		
				160-	30	643 (434-918)		
				320-	12	2385 (1232-4166) p trend < 0.001		
			Stomach	All	126	148 (124-177) No trend with increasing exposure to B[a]P		
				6 strata of increasing B[a]P-years				

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Gibbs and Sevigny (2007a) Canada	Same plants as in Gibbs *et al*. (2007), but includes all workers first hired between 1950 (1951) and 1999 and employed > 1 year. A: 6697 men and 588 women B: 1082 men and 56 women C: 1379 men and 42 women	As in Gibbs *et al*. (2007)	Lung	First hired (latency 20y) 1950-59 1960-69 1970-79 No trend with increasing B[a]P-years	 105 10 5	 133 (109-161) 74 (37-137) 86 (28-200)		
			Bladder	All	5	85 (28-198)		
Gibbs and Sevigny (2007b) Canada	Study groups combined from Gibbs *et al*. (2007) and Gibbs & Sevigny (2007a), and a small plant (D) using the prebake process, adding 568 men and 42 women. Cancer incidence from 1980 to [not stated] was obtained from Quebec cancer registry, which was also used to calculate expected numbers.	As in Gibbs *et al*. (2007)	Lung	All pre-1950 post-1950	519 [378] [140]	120 [110-131] [135 (122-150)] [106 (89-124)]		Dose-response from mortality studies replicated. For post-1950 cohort trend to diminishing risks.
			Bladder	All pre1950 post1950	230 [177] [52]	181 [159-207] [199 (171-231)] [141 (105-184)]		

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Giovanazzi & D'Andrea (1981), Italy	494 workers in an aluminum production plant, using the Söderberg process, during 1965–79 followed up to 1979		Lung	Pot-room workers	4	1.74 [0.47–4.46]		
Spinelli *et al*. (2006), Friesen *et al*. (2007). Canada	6423 male workers employed > 3 years from 1954, when plant started, up to 1907. The cohort was followed for mortality from employment up to 1999 (, and for cancer in the national cancer register from 1970 to 1999. 3 years of latency applied. The Söderberg process was used at the plant.	JEMs were developed to assess exposure to BSM and B[a]P, used to calculate cumulative exposure	Lung	All B[a]P-years 0-0.5 0.5-20 20-40 40-80 80+	147 23 42 23 25 32	SIR 1.10 (0.93-1.30) RR 1.0 1.20 (0.73-1.98) 1.41 (0.79-2.49) 1.46 (0.83-2.55) 1.97 (1.16-3.34) p trend <0.001		Adjustment for smoking gave lower numbers but still significant trends for both bladder and lung cancer.
			Bladder	All B[a]P-years 0-0.5 0.5-20 20-40 40-80 80+	90 17 20 13 18 22	SIR 1.80 (1.45-2.21) RR 1.0 0.83 (0.43-1.59 1.16 (0.56-2.39 1.50 (0.77-2.94 1.92 (1.02-3.65 p trend <0.001		

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Rockette & Arena (1983), USA	21829 male workers with > 5 years employment in 14 plants between 1946 and 1977 were followed up for mortality to 1977	Job histories and process Pre-bake process (2 plants) and Söderberg process (6 plants)	Lung	Entire cohort	272	0.96 [0.85–1.06]	Age, sex, race, calendar period	Milham (1979) study (plant 11) included.
				Pre-bake process	161	1.00 [0.82–1.13]		
				Söderberg process	64	0.87 [0.67–1.11]		
				Entire cohort	19	0.78 [0.46–1.18]		
			Urinary bladder	Pre-bake process	11	0.73 [0.35–1.26]		
				Söderberg process	8	1.62 [0.69–3.15]		
				> 5 years of employment	6	2.36 (0.46–2.73)		
			Hemto-lymphatic system	Entire cohort	94	1.09 [0.86–1.30]		
			Pancreas	Entire cohort	63	1.25 [0.96–1.60]		
				Employed >15 years				
				Pre-bake process	12	2.22 [1.15–3.88]		
				Söderberg process	17	2.30 [0.92–4.73]		
Mur *et al.* (1987), France	6455 workers who worked > 1 year in one of 11 plants between 1950 and 1976 followed up for mortality to 1976; follow-up 95% complete, cause of deaths known for 71.3%		Lung	Entire cohort	37	1.14 (0.85–1.48)	Tobacco smoking for workers still employed in 1976 similar between work areas and length of employment	
				Söderberg process	4	1.36 (0.39–3.46)*		
				Pre-bake process	0	0 (0–5.27)*		
			Urinary bladder	Entire cohort	7	2.09 (0.96–3.68)		

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Moulin *et al.* (2000), France	2 133 men employed > 1 year in 1950–94 followed for mortality 1968–94. The plant used both Söderberg and pre-bake processes, but only pre-bake process since 1982	Ever employment in potroom and other departments with PAH exposure	Lung	Entire cohort	19	0.63 (0.38–0.98)		Extended follow-up of one of the 11 plants studied by Muir *et al.* (1987). Analyses by time since first, or duration of employment did not indicate any trend.
				Workers with probable PAH exposure	15	0.69 (0.39–1.15)		
			Urinary bladder	Entire cohort	7	1.77 (0.71–3.64)		
				Workers with probable PAH exposure	6	2.15 (0.79–4.68)		
Carta *et al.* (2004), Italy	1 152 men employed for > 1 year between 1972 and 1980 in a pre-bake aluminum smelter and followed up to 2001	Job history and PAH measurements by task and department	Lung		11	0.70 (0.39–1.26)	Increased smoking-adjusted risk for pancreatic cancer and employment in anodes factory (4 exposed deaths)	
			Bladder		3	0.79 (0.26–2.44)		
			Pancreas		6	2.41 (1.11–5.23)		
			Lymphomas and leukaemias		8	2.03 (1.03–4.00)		

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Romundstad *et al.* (2000), Norway	11 103 men employed > 3 years between 1953 and 1996 in 6 aluminum plants in Norway followed up 1953–96	Job–exposure matrix for PAH and fluorides. Tobacco smoking data available for 3 plants	Lung	Entire cohort	189	**SIR/Rate ratio*** 1.0 (0.9–1.2)	Adjustment for tobacco smoking produced similar results. 20 years lag time and controlled for age and calendar period.	
				PAH-years (µg/m^3-years)				
				0	93	1.0		
				0–499	38	1.4 (0.9–2.0)		
				500–1999	30	0.9 (0.6–1.3)		
				≥ 2000	28	1.0 (0.6–1.5)		
						p for trend > 0.5		
			Urinary Bladder	Entire cohort	130	1.3 (1.1–1.5)		
				PAH-years (µg/m^3-years)				
				0	52	1.0		
				0–499	20	1.3 (0.8–2.1)		
				500–1999	27	1.3 (0.8–1.9)		
				≥ 2000	31	1.8 (1.1–2.8)		
						p for trend = 0.02		

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Björ *et al* (2008), Sweden	2 264 male non-office workers employed > 6 months 1942 (plant start) to 1987 at a primary aluminum smelter in northern Sweden. Both Söderberg and prebake processes were used. Cancer incidence was followed 1958-2005 and mortality 1962-2004. Both national, regional and local population cancer rates were used to calculate expected numbers	Employment duration	Lung (regional reference rates)	Entire cohort	40	1.62 (1.15-2-20)	No smoking data available. Risk of lung cancer decreased with longer latency.	
				0.5-2 years employment	10	1.39 (0.67-2.56)		
				2-10	10	1.33 (0.64-2.45)		
				10+	20	1.99 (1.21-3.07)		
			Urinary organs (ICD7 181) (regional reference rates)	Entire cohort	22	1.11 (0.69-1.68)		
				0.5-2 years employment	9	1.57 (0-72-2.98)		
				2-10	7	1.17 (0.47-2.40)		
				10+	6	0.74 (0.27-1.61)		

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Sim *et al* (2009), Australia	4396 male workers employed for > 90 days between 1983 and 2002 at 2 prebake aluminum smelters, starting to operate in 1962 and 1986. Subjects were identified from company records and health survey records. The cohort was followed in national mortality and cancer registries up to 2002.	Jobs were classified as office, maintenance or production, but could be classified up to 1996 only. Smoking data were obtained from interviews or health records (incomplete)				SIR		Young cohort and short follow-up
			Lung	Entire cohort	39	1.23 (0.90-1.72)		
			Bladder	Entire cohort	13	1.26 (0.73-2.16)		
			Stomach	Entire cohort	23	1.95 (1.16-3.29)		
			Kidney	Entire cohort	14	1.99 (1.12-3.35)		
			Mesothelioma	Entire cohort	5	2.41 (1.00-5.78)		
						No trend with duration of employment in production or maintenance was observed for any cancer site		
Friesen *et al* (2009) Australia	Same cohort as Sim *et al* (2009), including 4316 male workers.	Job exposure matrices were developed for B[a]P, BSF, inhalable dust and fluorides based on measurements and modeling. Indices of cumulative exposures were calculated.	Respiratory cancer	Inhalable dust-years		RR	Adjusted for individual data on tobacco smoking	
				Not exposed	5	1.0		
				Low	9	0.8 (0.3-2.4)		
				Medium	10	1.0 (0.3-3.0)		
				High	12	2.5 (0.9-7.2)		
						p for trend 0.04		
				B[a]P-years				
				Not exposed	18	1.0		
				Low	6	0.8 (0.3-2.1)		
				Medium	6	1.5 (0.6-3.8)		
				High	6	1.7 (0.7-4.4)		
						p for trend 0.21		

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B[a]P: benzo[a]pyrene; BSF: benzene-soluble fraction; BSM: benzene soluble materials; JEM: job exposure matrix; PAH: polycyclic aromatic hydrocarbons; RR: relative risk; SIR: standardised incidence ratio; SMR: standardised mortality ratio