Table 2.14. Cohort studies of uranium exposure

Reference, location, name of study	Cohort description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	Relative rate (95% CI)*	Adjustment for potential confounders	Comments
Pinkerton *et al.* (2004) USA	1484 male uranium mill workers, employed on or after January, 1940 in seven uranium mills in Colorado Plateau; mortality ascertainment 1940–1998. [It is likely that this study partly covers the two following studies (Boice *et al.*, 2007, 2008). However, due to different follow-up periods for those studies, it was impossible to quantify the exact extend of overlap]	Comparisons to general population; trends by duration of employment and hire cohort	All cancers (ICD8-140-209), with particular emphasis on lung (ICD8 162)	None	*Mortality* All cancer, 184 Lung cancer, 78 Lymphatic and haematopoietic cancers other than leukaemia, 16	SMR 0.90 (0.78–1.04) 1.13 (0.89–1.41) 1.44 (0.83–2.35)	Year of birth, sex, race, age	No assessment of radiation exposure potential for healthy worker bias. Using state rates the lung cancer SMR=1.51 (95%CI: 1.19, 1.89). No trend with duration of employment. The SMR (95% CI) for all causes mortality was 0.92 (0.86, 0.99)
Boice *et al.* (2007) USA	450 uranium mill workers who were residents of Uravan, Colorado during the period 1936-1984 and survived until 1979; mortality ascertainment 1979-2004.	Comparisons to general population; trends by duration of employment.	All cancers (ICD8-140-209), with particular emphasis on lung (ICD8 162)	None	*Mortality* All cancer, 48 Lung cancer, 24	SMR 0.83 (0.62–1.11) 1.26 (0.81–1.87)	Year of birth, sex, race, age	No assessment of radiation exposure potential for healthy worker bias. The SMR (95% CI) for all causes mortality was 0.80 (0.69, 0.92)
Boice *et al.* (2008) USA	718 uranium mill workers at Grants, Colorado, employed during the period 1955-1990; mortality ascertainment 1979-2005.	Comparisons to general population; trends by duration of employment.	All cancers (ICD8-140-209), with particular emphasis on lung (ICD8 162)	None	*Mortality* All cancer, 56 Lung cancer, 18	SMR 0.94 (0.71–1.22) 0.88 (0.52–1.38)	Year of birth, sex, race, age	No assessment of radiation exposure potential for healthy worker bias. The SMR for lung cancer for the 209 persons who worked more than 5 years (SMR=0.56, n=5) was lower than for all 718 millers.

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Dupree-Ellis et al. (2000) USA	2514 white male uranium processing workers at the Malincrodt, Missouri plant employed during the period 1942-1966; mortality ascertainment 1942-1993.	External radiation dose based on film badges.	All cancers (ICD9-140-209), including lung cancer (ICD9 162) and kidney cancer (ICD9 189).	Mean external dose (47.8 mSv).	Mortality All cancer, 283 Lung cancer, 98 Leukaemia, 11 Kidney cancer, 10	SMR 1.05 (0.93–1.17) 1.02 (0.83–1.24) 1.11 (0.57–1.89) 1.17 (0.54–2.18) ERR per Sv (10-year lag)= 10.5 (90% CI: 0.6–57.4)	Age, calendar period	The SMR (95% CI) for all causes mortality was 0.90 (0.85, 0.96)
Richardson & Wing (2006) USA	3864 workers at the Y-12, Tennessee nuclear materials fabrication plant employed during the period 1947-1974; mortality ascertainment 1947-1990.	External radiation dose based on film badges. Internal radiation dose based on urinalysis and in vivo monitoring.	Lung cancer (ICD8 162)	Mean external dose (10.1 mSv). Mean internal dose (44.7 mSv)	Lung cancer deaths 111.	External radiation dose (5-year lag) was associated with 0.54% increase in lung cancer mortality per 10 mSv (SE= 0.16; likelihood ratio test= 6.35, 1 df).	Age, year of birth, sex, race, pay type, employment status, and length of employment (<1 year vs 1+ year).	Effects were most pronounced for exposures at ages 35+ years and in the period 5-14 years after exposure. Cumulative internal radiation dose exhibited a highly-imprecise negative association with lung cancer mortality.
Ahrenholz et al. (2001) USA	8877 workers at the Portsmouth gaseous diffusion plant (a uranium enrichment facility) employed during the period 1954-1991; mortality ascertainment 1954-1991.	External radiation dose based on film badges. Internal radiation dose based on urinalysis monitoring	All cancers, with particular emphasis on lung cancer (ICD8: 162, 163) and leukaemia (ICD8: 204-207)		Mortality All cancer, 313 Lung cancer deaths, 112.	0.82 (0.73–0.92) For specific sites, few positive associations observed.	Age, sex, calendar year, industrial status, worker status, and length of employment.	

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McGeoghegan & Binks (2000b) UK	19454 workers (13960 radiation workers) at the Springfields uranium plant employed during the period 1946-1995; mortality ascertainment 1946-1995; cancer incidence data 1971-1995.	External radiation dose based on film badges.	All cancers, with particular emphasis on lung cancer (ICD8 162) and leukemia (ICD)	Mean cumulative whole body dose (22.8 mSv).	*Mortality* All cancer, 971 Lung cancer, 360. *Incidence* All cancer, 923 Lung cancer, 225 Non-Hodgkin's lymphoma, 20.	All cancer mortality was positively associated with cumulative dose (20-year lag). Statistically significant positive trends with cumulative dose for incidence of all cancers and lung cancer (20-year lag) and for non-Hodgkin's lymphoma (under all lags).	Age, sex, calendar year, industrial status, worker status, and length of employment.	The significant positive association for lung cancer was observed when cancer of pleura was also included. When they were separated, cancer of pleura had positive trends under all lags, while only unspecified histological types of lung cancer had significant trend with 10- and 20- year lag
McGeoghegan & Binks (2000a) UK	12540 workers (3244 radiation workers) at the Capenhurst uranium enrichment facility employed during the period 1946-1995; mortality ascertainment 1946-1995; cancer incidence data 1971-1995.	External radiation dose based on film badges.	All cancers, with particular emphasis on lung cancer (ICD8 162) and leukemia (ICD)	Mean cumulative whole body dose (9.85 mSv).	*Mortality* All cancer, 178. Lung cancer, 67. Leukemia, 4. *Incidence* All cancer, 181. Lung cancer, 49. Bladder cancer, 14. Leukemia, 4.	Few positive associations observed with cancer mortality or morbidity; estimates tended to be highly-imprecise. A positive association between bladder cancer incidence and cumulative external radiation exposure under a 20 year lag (trend statistic=1.95, p=0.035)	Age, sex, calendar year, industrial status, worker status, and length of employment.	
Baysson et al. (2000) France	356 workers at the metallurgy department of the French Atomic Energy Commissariat employed during the period 1950-1968; mortality ascertainment 1950-1990.	External radiation dose based on film badges. Job and hazard forms. Qualitative hazard assessment for 30 products.	All cancers (ICD9: 140-208), respiratory cancer (ICD9 160-164).	0, 1-4, 5-9, 10-14, 15-19, 20+ years of exposure. no dose, 0.35–1.40 mSv, 1.41–3.95 mSv, 3.96–10.25 mSv, and >10.26 mSv	*Mortality* All cancer, 22. Respiratory cancer, 9	The risk of death from all cancer sites increased with the duration of exposure to radionuclides and chemicals.	Age, sex, calendar year.	

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Gustavsson et al. (2004) Swedish soldiers deployed to the Balkans	9188 military (n= 8780) and rescue service (n= 408) personnel involved in UN missions in Bosnia and Kosovo from 1989 to 1999; end of follow-up 31 Decembre 1999. Duration of missions was normally six months.	Comparisons to general population.	All cancer (ICD7: 140-209); including cancers of the lung (ICD7: 162.1), testis (ICD7: 178), oral cavity, rectum, liver, cervix, bladder, melanoma, brain, and haematolymphatic organs	None	*Incidence* *All cancers: 34* Military men: 26 Military women: 4 Civil personnel: 4 *Testis cancer: 8* (military men only) *Lung cancer: 3* Military men: 1 Military women: 1 Civil personnel: 1	SIR 1.2 (0.8–1.8) 1.5 (0.4–3.9) 1.1 (0.3–2.07) 1.9 (0.8–3.7) Expected: 0.8 Expected: 0.1 Expected: 0.3	Age, gender, calendar period	Similar to lung cancer, there were very few cases with cancers of the other sites, with no significant associations.
Storm et al. (2006) Danish soldiers deployed to the Balkans	14012 military personnel (13552 men and 460 women) deployed to Albania, Bosnia, Kosovo, Croatia, and Macedonia. Most persons were only deployed once and for 6 months.	Comparisons to general population.	All cancer (ICD7: 140-209); including bone cancers (ICD7: 196) and several other cancer sites.	None	*Mortality* *All cancers: 96* Men: 84 Women: 12 *Bone cancer: 4* (all were men) *Testis cancer: 24*	SIR 0.9 (0.7–1.1) 1.7 (0.9–3.0) 6.0 (1.6–15.3) 1.2 (0.8–1.8)	Age, gender, calendar period	The number of other cancers were generally smal; no significant association was observed.
Kang & Bullman (2001) US Gulf veterans	621902 Gulf War veterans with those of 746248 non-Gulf veterans; mortality ascertainment from exit from the Persian Gulf theater (Gulf veterans) or 1 May 1991 (control veterans) – 31 December 1997	Comparisons between Gulf veterans and control veterans.	All cancers (ICD9: 140-209)	None	*All causes* Men: Gulf, 4132; non-Gulf, 5542 Women: Gulf, 194; non-Gulf, 376 *All cancers* Men: Gulf, 477; non-Gulf, 860 Women: Gulf, 49; non-Gulf, 103	 0.95 (0.92–0.99) 1.16 (0.97–1.38) 0.90 (0.81–1.01) 1.11 (0.78–1.57)	Age, race, marital status, branch of service, and type of unit	

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Reference, location, name of study	Cohort description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	Relative rate (95% CI)*	Adjustment for potential confounders	Comments
Macfarlane et al. (2003) British soldiers (Gulf and Era cohorts)	51721 UK Gulf war veterans and 50755 members of the armed force matched for age, sex, rank, service, and level of fitness who were not deployed in the Gulf (Era cohort). Cancer incidence ascertainment 1 April 1991 – 31 July 2002. From a subset of the cohorts (28518 in Gulf cohort and 20828 in Era cohort) data on smoking and alcohol use were collected.	Self-reported exposure to depleted uranium in the Gulf cohort. Comparisons between Gulf cohort and Era cohort.	All cancers (ICD10: C00-97) and several cancer sites, including upper digestive tract (ICD10: C15-17), urinary tract (ICD10: C64-68), and Lymphoid and haematopoietic (ICD10: C81-96) cancers.	Exposed and non-exposed to depleted uranium (self-reported)	*Overall* All cancers (268 Gulf, 265 Era) Upper digestive tract (9 Gulf, 6 Era) Urinary tract (13 Gulf, 9 Era) Lymphoid and haematopoietic (45 Gulf, 34 Era) All cancers in those with self-reported exposure to DU, 7 *Subset of participants with smoking and alcohol use data* All cancers (144 Gulf, 95 Era) Upper digestive tract (4 Gulf, 5 Era) Urinary tract (7 Gulf, 4 Era) Lymphoid and haematopoietic (24 Gulf, 11 Era)	0.98 (0.82–1.18) 1.47 (0.53–4.14) 1.42 (0.61–3.32) 1.30 (0.83–2.03) 0.63 (0.30–1.36) 1.12 (0.86–1.45) 0.69 (0.10–4.93) 1.29 (0.38–4.41) 1.60 (0.79–3.28)	Overall results were adjusted for age, gender, service branch and rank. For a subset of analyses. For a subset of participants, results were further adjusted of smoking and alcohol use.	Other cancer sites generally showed weaker associations.

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Macfarlane et al. (2005) British soldiers (Gulf and Era cohorts)	Same study as Macfarlane et al. (2003) but on cancer mortality. 51753 Gulf war veterans and 50808 members of the armed force who were not deployed in the Gulf; mortality ascertainment 1 April 1991 – 30 June 2004. From a subset of the cohorts (28518 in Gulf cohort and 20828 in Era cohort) data on smoking and alcohol use were collected.	Self-reported exposure to depleted uranium in the Gulf cohort. Comparisons between Gulf cohort and Era cohort.	All cancers (ICD10: C)	Exposed and non-exposed to depleted uranium (self-reported)	*Mortality* All cancers, 253 (Era cohort, 130; Gulf cohort, 123)	MRR 1.01 (0.79–1.30)	Results for all cancers were adjusted for age. Results for death from non-external causes were adjusted for age, gender, service and service branch, smoking and alcohol use.	Exposure to depleted uranium was reported by 7% of those deployed. MRR (95% CI) was 1.48 (0.83–2.64) among those with self-reported exposure to DU and 1.99 (0.98, 4.04) for disease-related (non-external causes of) deaths

ERR, excess relative risk; MRR, mortality rate ratio; SIR, standardised incidence ratio; SMR, standardised mortality ratio