# SUPPLEMENTARY TABLES

Supplementary Table S1. Cohort-specific results. Study characteristics among males: count and proportion of lung cancer deaths and person-years of follow-up by categories of covariates of interest, and 5-year lagged cumulative radon exposure in WLM

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Colorado Plateau (US)** | | | | | **Czech (CR)** | | | | | **Eldorado (CAN)** | | | | | **French (FR)** | | | | | **Ontario (CAN)** | | | | | **Wismut (GER)** | | | | | **New Mexico (US)** | | | |
| Period of follow-up | 1960–2005 | | | | | 1952–2014 | | | | | 1950–1999 | | | | | 1946–2007 | | | | | 1954–2007 | | | | | 1946–2013 | | | | | 1957–2012 | | | |
| Period of first hire | 1953–1968 | | | | | 1948–1995 | | | | | 1942–1980 | | | | | 1946–1990 | | | | | 1954–1996 | | | | | 1946–1989 | | | | | 1956–1982 | | | |
| Minimum duration of employment | 1 month | | | | | 1 year | | | | | None | | | | | 1 year | | | | | 1 week | | | | | 6 months | | | | | 1 year | | | |
|  | **n** | **%** | **pya** | **%** | **n** | | **%** | **py** | **%** | **n** | | **%** | **py** | **%** | **n** | | **%** | **py** | **%** | **n** | | **%** | **py** | **%** | **n** | | **%** | **py** | **%** | **n** | | **%** | **py** | **%** |
| Attained age (years) |  |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |
| <55 | 130 | 21 | 65 | 54 | 343 | | 29 | 229 | 71 | 97 | | 19 | 309 | 73 | 35 | | 16 | 124 | 69 | 176 | | 14 | 704 | 70 | 569 | | 15 | 1,532 | 71 | 30 | | 13 | 85 | 67 |
| 55–<65 | 194 | 32 | 29 | 24 | 437 | | 37 | 64 | 20 | 205 | | 40 | 70 | 16 | 64 | | 30 | 30 | 16 | 435 | | 35 | 165 | 16 | 1158 | | 31 | 340 | 16 | 75 | | 32 | 24 | 19 |
| 65–<75 | 195 | 32 | 19 | 16 | 299 | | 25 | 23 | 7 | 172 | | 33 | 34 | 8 | 74 | | 35 | 19 | 11 | 463 | | 37 | 98 | 10 | 1349 | | 36 | 207 | 10 | 88 | | 38 | 13 | 10 |
| 75+ | 93 | 15 | 8 | 6 | 97 | | 8 | 8 | 2 | 43 | | 8 | 11 | 3 | 40 | | 19 | 7 | 4 | 172 | | 14 | 38 | 4 | 683 | | 18 | 83 | 4 | 38 | | 16 | 4 | 3 |
| Duration of employment (years) |  |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |
| 0-5 | 153 | 25 | 66 | 55 | 208 | | 18 | 146 | 45 | 384 | | 74 | 373 | 88 | 31 | | 15 | 51 | 28 | 678 | | 54 | 659 | 66 | 619 | | 16 | 777 | 36 | 51 | | 22 | 43 | 34 |
| 5-10 | 209 | 34 | 36 | 30 | 433 | | 37 | 91 | 28 | 60 | | 12 | 32 | 8 | 16 | | 8 | 33 | 19 | 264 | | 21 | 182 | 18 | 640 | | 17 | 495 | 23 | 44 | | 19 | 36 | 29 |
| 10+ | 250 | 41 | 18 | 15 | 535 | | 45 | 87 | 27 | 73 | | 14 | 19 | 5 | 166 | | 78 | 96 | 53 | 304 | | 24 | 165 | 16 | 2500 | | 67 | 891 | 41 | 136 | | 59 | 47 | 37 |
| Cumulative radon exposure (WLM) |  |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |
| 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 89 | | 17 | 102 | 24 | 33 | | 15 | 41 | 23 | 54 | | 4 | 64 | 6 | 323 | | 9 | 335 | 16 | 0 | | 0 | 2 | 1 |
| >0 – 50 | 19 | 3 | 13 | 11 | 296 | | 25 | 214 | 66 | 176 | | 34 | 240 | 56 | 96 | | 45 | 109 | 61 | 856 | | 69 | 818 | 81 | 538 | | 14 | 887 | 41 | 60 | | 26 | 78 | 62 |
| >50 – 250 | 61 | 10 | 34 | 28 | 647 | | 55 | 92 | 28 | 116 | | 22 | 55 | 13 | 75 | | 35 | 28 | 15 | 311 | | 25 | 119 | 12 | 614 | | 16 | 353 | 16 | 102 | | 44 | 39 | 30 |
| >250 – 750 | 181 | 30 | 38 | 32 | 228 | | 19 | 17 | 5 | 73 | | 14 | 21 | 5 | 8 | | 4 | 2 | 1 | 23 | | 2 | 4 | 0 | 881 | | 23 | 321 | 15 | 64 | | 28 | 8 | 6 |
| >750 | 351 | 57 | 34 | 28 | 5 | | 0 | 0 | 0 | 63 | | 12 | 7 | 2 | 1 | | 0 | 0 | 0 | 2 | | 0 | 0 | 0 | 1403 | | 37 | 266 | 12 | 5 | | 2 | 1 | 0 |

**a**per 1,000 person-years of follow-up

Supplementary Table S2. Model for the association between cumulative radon exposure and lung cancer mortality with effect modification by time since exposure, attained age and exposure rate with 95% confidence intervals, removing each cohort. PUMA study of male uranium miners.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Cohort removed** | | | | | | |
|  | **Colorado Plateau (US)** | **Czech (CR)** | **Eldorado (CAN)** | **French (FR)** | **Ontario (CAN)** | **Wismut (GER)** | **New Mexico (US)** |
| Lung cancer deaths | 7142 | 6578 | 7237 | 7541 | 6508 | 3995 | 7523 |
| Person timea | 42.2 | 40.2 | 39.2 | 41.6 | 33.3 | 21.8 | 42.1 |
| ERR/100 WLMb | 3.82 (2.14, 5.73) | 4.41 (2.70, 6.62) | 4.89 (2.89, 7.42) | 4.73 (2.67, 7.08) | 4.55 (2.56, 6.86) | 6.91 (3.82, 11.3) | 4.67 (2.8, 6.98) |
| **Time since exposure** | |  |  |  |  |  |  |
| 5-<15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15-<25 | 0.8 (0.57, 1.15) | 0.82 (0.57, 1.16) | 0.78 (0.56, 1.10) | 0.76 (0.56, 1.06) | 0.77 (0.57, 1.10) | 0.70 (0.47, 0.98) | 0.75 (0.56, 1.06) |
| 25-<35 | 0.54 (0.37, 0.80) | 0.62 (0.42, 0.9) | 0.56 (0.38, 0.81) | 0.52 (0.36, 0.75) | 0.55 (0.38, 0.81) | 0.45 (0.27, 0.66) | 0.52 (0.37, 0.76) |
| 35+ | 0.38 (0.25, 0.59) | 0.44 (0.28, 0.67) | 0.42 (0.27, 0.64) | 0.38 (0.25, 0.58) | 0.44 (0.28, 0.66) | 0.27 (0.14, 0.45) | 0.37 (0.25, 0.58) |
| **Attained age** | |  |  |  |  |  |  |
| <55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 55-<65 | 0.52 (0.35, 0.78) | 0.64 (0.43, 0.96) | 0.44 (0.29, 0.68) | 0.55 (0.37, 0.82) | 0.48 (0.33, 0.76) | 0.81 (0.49, 1.48) | 0.57 (0.38, 0.84) |
| 65-<75 | 0.37 (0.24, 0.57) | 0.42 (0.27, 0.65) | 0.32 (0.21, 0.5) | 0.38 (0.25, 0.58) | 0.34 (0.22, 0.55) | 0.51 (0.29, 1.02) | 0.38 (0.25, 0.58) |
| 75+ | 0.40 (0.24, 0.68) | 0.46 (0.27, 0.76) | 0.37 (0.21, 0.63) | 0.38 (0.22, 0.63) | 0.34 (0.20, 0.61) | 0.5 (0.20, 1.16) | 0.42 (0.24, 0.70) |
| **Exposure rate** | |  |  |  |  |  |  |
| 0-<0.5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0.5-<1.0 | 0.74 (0.36, 1.48) | 0.87 (0.49, 1.53) | 0.58 (0.28, 1.10) | 0.56 (0.27, 1.08) | 0.62 (0.30, 1.28) | 0.44 (0.21, 0.83) | 0.57 (0.28, 1.05) |
| 1.0-<5 | 0.51 (0.35, 0.82) | 0.30 (0.2, 0.46) | 0.43 (0.30, 0.67) | 0.43 (0.31, 0.68) | 0.49 (0.33, 0.79) | 0.41 (0.29, 0.64) | 0.41 (0.30, 0.64) |
| 5+ | 0.21 (0.14, 0.33) | 0.14 (0.1, 0.21) | 0.17 (0.12, 0.26) | 0.17 (0.12, 0.26) | 0.18 (0.12, 0.27) | 0.14 (0.09, 0.23) | 0.16 (0.12, 0.24) |

**a**Per 100,000 person-years

**b**Excess relative rate per 100 working level months. Cumulative radon exposure is lagged 5 years. Background stratification for study cohort, attained age, calendar period, and duration of employment in uranium mining.

Supplementary Table S3. Sensitivity analyses examining restriction and adjustment for duration of employment. Model for the association between cumulative radon exposure and lung cancer mortality with effect modification by time since exposure, attained age and exposure rate with 95% profile likelihood confidence intervals. PUMA study of male uranium miners.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Background stratification of duration of employment (Table 2) | No background stratification of duration of employment | Employed 5+ yrs. Background stratification of duration of employment | Employed 5+ yrs. No background stratification of duration of employment | Employed 1+ yrs. Background stratification of duration of employment | Employed 1+ yrs. No background stratification of duration of employment |
| ERR/100WLM**a** | 4.68 (2.88, 6.96) | 3.42 (2.05, 4.82) | 4.72 (2.67, 7.29) | 4.62 (2.68, 7.03) | 5.49 (3.2, 8.27) | 3.78 (2.29, 5.4) |
|  |  |  |  |  |  |  |
| Time since exposure |  |  |  |  |  |  |
| 5-<15 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15-<25 | 0.77 (0.56, 1.05) | 0.63 (0.48, 0.84) | 0.87 (0.62, 1.25) | 0.78 (0.57, 1.11) | 0.77 (0.57, 1.08) | 0.65 (0.5, 0.87) |
| 25-<35 | 0.54 (0.38, 0.76) | 0.44 (0.32, 0.60) | 0.59 (0.39, 0.87) | 0.53 (0.37, 0.76) | 0.54 (0.37, 0.77) | 0.44 (0.32, 0.6) |
| 35+ | 0.39 (0.26, 0.58) | 0.30 (0.21, 0.43) | 0.41 (0.26, 0.65) | 0.34 (0.22, 0.52) | 0.37 (0.24, 0.57) | 0.28 (0.2, 0.41) |
| Attained age |  |  |  |  |  |  |
| <55 | 1 | 1 | 1 | 1 | 1 | 1 |
| 55–<65 | 0.55 (0.38, 0.82) | 0.61 (0.44, 0.83) | 0.42 (0.27, 0.67) | 0.42 (0.27, 0.65) | 0.45 (0.31, 0.70) | 0.53 (0.38, 0.75) |
| 65–<75 | 0.38 (0.25, 0.57) | 0.39 (0.27, 0.55) | 0.32 (0.20, 0.52) | 0.32 (0.20, 0.50) | 0.32 (0.21, 0.51) | 0.36 (0.25, 0.52) |
| 75+ | 0.4 (0.24, 0.66) | 0.39 (0.25, 0.60) | 0.39 (0.22, 0.70) | 0.39 (0.22, 0.67) | 0.35 (0.21, 0.62) | 0.37 (0.23, 0.6) |
| Exposure rate (WL) |  |  |  |  |  |  |
| 0-<0.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0.5-<1.0 | 0.60 (0.31, 1.08) | 0.99 (0.53, 1.92) | 0.67 (0.32, 1.29) | 0.78 (0.38, 1.50) | 0.61 (0.31, 1.11) | 0.99 (0.52, 1.88) |
| 1.0-<5.0 | 0.42 (0.31, 0.64) | 0.70 (0.49, 1.07) | 0.46 (0.32, 0.75) | 0.56 (0.38, 0.88) | 0.44 (0.31, 0.67) | 0.7 (0.48, 1.07) |
| 5.0+ | 0.17 (0.12, 0.25) | 0.28 (0.20, 0.41) | 0.19 (0.13, 0.30) | 0.24 (0.16, 0.37) | 0.17 (0.12, 0.26) | 0.28 (0.2, 0.42) |
| Lung cancer deaths | 7,754 | 7,754 | 5,630 | 5,630 | 7,367 | 7,367 |
| Person-years | 4,343,384 | 4,343,384 | 2,229,211 | 2,229,211 | 3,936,986 | 3,936,986 |

**a**Excess relative rate per 100 working level months. Cumulative radon exposure is lagged 5 years. Background stratification for study cohort, attained age, calendar period, and duration of employment in uranium mining unless otherwise noted

Supplementary Table S4. Comparison of BEIR VI exposure-age-concentration model with PUMA modela for the association between cumulative radon exposure and lung cancer mortality with effect modification by time since exposure, attained age and exposure rate with 95% profile likelihood confidence intervals. PUMA study of male uranium miners and BEIR VI 11 miner study.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PUMA (Table 2) | |  | PUMA removing WISMUT (appendix Table 2) |  | BEIR VI | |
| ERR/100WLMb | 4.68 (2.88, 6.96) |  | 6.91 (3.82, 11.3) |  |  | 7.68 |
| Time since exposure | |  |  |  | Time since exposure |  |
| 5-<15 | 1 |  | 1 |  | 5–14 | 1 |
| 15-<25 | 0.77 (0.56, 1.05) |  | 0.70 (0.47, 0.98) |  | 15–24 | 0.78 |
| 25-<35 | 0.54 (0.38, 0.76) |  | 0.45 (0.27, 0.66) |  | 25+ | 0.51 |
| 35+ | 0.39 (0.26, 0.58) |  | 0.27 (0.14, 0.45) |  |  |  |
| Attained age | |  |  |  | Attained age |  |
| <55 | 1 |  | 1 |  | <55 | 1 |
| 55–<65 | 0.55 (0.38, 0.82) |  | 0.81 (0.49, 1.48) |  | <55–64 | 0.57 |
| 65–<75 | 0.38 (0.25, 0.57) |  | 0.51 (0.29, 1.02) |  | 65–74 | 0.29 |
| 75+ | 0.4 (0.24, 0.66) |  | 0.5 (0.20, 1.16) |  | 75+ | 0.09 |
| Exposure rate (WL) | |  |  |  | Exposure rate (WL) |  |
| 0–<0.5 | 1 |  | 1 |  | < 0.5 | 1 |
| 0.5–<1.0 | 0.60 (0.31, 1.08) |  | 0.44 (0.21, 0.83) |  | 0.5–1.0 | 0.49 |
| 1.0–<5.0 | 0.42 (0.31, 0.64) |  | 0.41 (0.29, 0.64) |  | 1.0–3.0 | 0.37 |
| 5.0+ | 0.17 (0.12, 0.25) |  | 0.14 (0.09, 0.23) |  | 3.0–5.0 | 0.32 |
|  |  |  |  |  | 5.0–15.0 | 0.17 |
|  |  |  |  |  | 15.0+ | 0.11 |
| Lung cancer deaths | 7,754 |  | 3,995 |  | Lung cancer deaths | 2,674 |
| Person-years | 4,343,384 |  | 2,181,211 |  | Person-years | 888,906 |

a Background stratification by study cohort, attained age, calendar period, and duration of employment in uranium mining.

b Excess relative rate per 100 working level months. Cumulative radon exposure is lagged 5 years.