**Original Research Article**

# Radon and skin cancer in south-west England: an ecological study

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**Running title:** Radon and skin cancer: an ecological study.

**Keywords:** Radon; Skin cancer; Melanoma; Basal Cell Carcinoma; Squamous Cell Carcinoma

**Funding:** The European Centre for Environment and Human Health (part of the Peninsula College of Medicine and Dentistry, which is a joint entity of the University of Exeter, the University of Plymouth and the NHS in the South West) is supported by investment from the European Regional Development Fund and the European Social Fund Convergence Programme for Cornwall and the Isles of Scilly.

**Acknowledgements**: Radon data were provided by the Health Protection Agency. Skin cancer data were supplied by the South West Public Health Observatory. Population data source: 2001 Census (Crown copyright 2004). Digital map boundaries use data provided through EDINA UKBORDERS with support of ESRC and JISC and use boundary material which is copyright of the Crown. Sunshine data adapted from Crown copyright data supplied by the Met Office. Analysis and interpretation of the data are solely the responsibility of the authors and not the data suppliers. We thank two anonymous referees for helpful comments and suggestions for revision of the paper.

**Abstract**

*Background*

Radon, a naturally occurring radioactive gas, is a carcinogen that causes a small proportion of lung cancers amongst exposed populations. Theoretical models suggest that radon may also be a risk factor for skin cancer, but epidemiological evidence for this relationship is weak. In this study we investigated ecological associations between environmental radon concentration and the incidence of different types of skin cancer.

*Methods*

We analysed data for 287 small areas (postcode sectors) in south-west England for the years 2000-2004. Poisson regression was used to compare registration rates of malignant melanoma, basal cell carcinoma and squamous cell carcinoma across mean indoor radon concentrations from household surveys. Analyses were adjusted for potentially confounding factors including age, sex, population socio-economic status and mean hours of bright sunshine.

*Results*

No association was observed between mean postcode sector radon concentration and either malignant melanoma or basal cell carcinoma registration rates. However, sectors with higher radon levels had higher squamous cell carcinoma registration rates, with evidence of an exposure-response relationship. Comparing highest and lowest radon categories, postcode sectors with mean radon ≥230 Bq/m$^3$ had registration rates 1.76 (95% confidence interval 1.46, 2.11) times those with mean radon 0-39 Bq/m$^3$. Associations persisted following adjustment for potential confounders.

*Conclusions*

This ecological study suggests that environmental radon exposure may be a risk factor for squamous cell carcinoma. Further study is warranted to overcome ecological design limitations and to determine whether this relationship is generalisable to national and international settings.

## Introduction

Radon is a radioactive gas produced by decay of radium-226, widely distributed in uranium rich soils and granite bedrock.[1] A key factor affecting population radon exposure is therefore the underlying geology of the environment. The World Health Organisation[2] and the International Agency for Research on Cancer[3] list radon as a human carcinogen with a primary health impact of an increased risk of lung cancer. Radon may be a causal factor in 3.3% of all UK lung cancer deaths, although most of these are due to a combination of radon exposure and smoking.[4] It has also been implicated as a risk factor for other cancers, but studies are limited, and the UK Health Protection Agency concluded in a 2009 review (p.42) that *"Overall there is no epidemiological evidence to suggest that radon exposure contributes directly to excess disease or mortality other than of lung cancer"*.[5]

Despite the lack of strong epidemiological evidence, theoretical dosimetry models indicate that radon at average UK exposure levels could be responsible for a proportion of skin cancers. Also, an earlier UK ecological study suggested an association with non-melanoma skin cancer.[6-8] As radon and its decay products are attracted to water molecules and some atmospheric gases it is possible that the resulting aerosols could adhere to the skin via electrostatic attraction, leading to prolonged irradiation of the skin, even when individuals have left areas of high exposure.[9]

Skin cancers (malignant melanomas and non-melanomas) are by far the most common form of cancer in the UK and other countries. Although less prevalent than non-melanomas, malignant melanoma accounts for the majority of skin cancer mortality in the USA and Europe, with the lifetime risk of an individual developing this disease of approximately 2%.[10,11] A key risk factor for all skin cancer types is exposure to ultraviolet radiation, although different modes and intensities of exposure appear to be significant for different tumour types.[12-14] Ionising radiation has also been implicated as a risk factor in the development of basal cell carcinoma.[12,15,16] South-west England has the highest melanoma incidence and mortality rates, and the highest incidence of non-melanoma skin cancer in the UK.[17,18] The south-west of England also encompasses localities where background levels of radon can far exceed the national average (21 Becquerels per cubic metre, Bq/m$^3$).[4,19] A previous ecological study in the same region found an association between radon concentration and non-melanoma skin cancer registrations from 1989 to 1992.[6] Completeness of non-melanoma skin cancer registration is variable nationally[18] and internationally.[20] However, the South West Public Health Observatory (which hosts the regional cancer registry) leads on skin cancer for the UK Association of Cancer Registries,[21] and is recognised for high quality non-melanoma surveillance.[22] Three key factors make this an ideal region for an updated, improved ecological study to investigate the association between radon exposure and the risk of developing different types of skin cancer: a high quality surveillance system providing more complete detection of non-melanoma skin cancers than is available in many other locations nationally and internationally; the availability of data on skin cancer subtypes; and the wide variation in radon concentrations, permitting comparison of rates from very high to very low radon areas.

## Methods

### *Geography*

The study area comprised the counties of Devon, Cornwall and Isles of Scilly in south-west England. Radon and skin cancer registration data were available by postcode sector and ward. However, ward boundaries change over time and the two datasets were not consistently coded. Postcode sectors, aggregations of unit (full) postcodes, were therefore selected. Sectors could be aggregated into larger spatial units, but represent a useful compromise between smaller units, which can result in very small populations and hence unstable rates, and larger units, which may lack sufficient resolution to detect geographical variation.

*Skin cancer incidence*

Registration data were obtained with appropriate ethical and data protection permissions. These included total counts of new skin cancer cases diagnosed during the 5 years between 2000 and 2004, and recorded at the regional cancer registry. Additional information regarding individuals diagnosed included age at diagnosis, postcode sector and tumour type. The four tumour types were malignant melanoma, and three types of non-melanoma skin cancers; squamous cell carcinoma, basal cell carcinoma and 'other'. Given the potential differential relationship between radon and different skin cancers,[6] we calculated incidence rates separately for the tumour types. Data included only the first instance of a tumour/lesion recorded for each individual for non-melanoma skin cancer, but multiple instances for each individual for malignant melanoma. Due to the mismatch between postal, administrative and census boundaries, and the use of some superseded postcodes, registrations for seven postcode sectors could not be matched with population data, and were excluded. For comparative purposes, we obtained national (England) registration rates for melanoma and non-melanoma skin cancer.[18] National figures also included multiple instances of malignant melanoma per individual, and were therefore comparable with study area data, although national non-melanoma statistics are not sub-divided by tumour type. To calculate incidence rates, postcode sector population estimates for 2000 to 2004 were required. Population counts for postcode sectors were available from 2001 Census Key Statistics tables,[23] but estimates for other years were not available. Annual age-specific population growth rates relative to 2001 were therefore calculated from regional population estimates.[18] These were applied to 2001 postcode sector populations to estimate total person-years at risk from 2000 to 2004. Key Statistics tables did not include population by both age and sex, so incidence rates could not be standardised for both. Consequently, directly age-standardised rates for postcode sectors were calculated, using the total study population as the reference population.

*Radon exposure*

Mean indoor radon concentrations, in $Bq/m^3$, for each postcode sector were obtained from a National Radiological Protection Board (now part of the Health Protection Agency) radon atlas.[24] These data were accumulated between approximately 1980 and 2000 through government funded surveys and measurements requested by householders and landlords. The data result from approximately 400,000 households of around 22 million in England and Wales. However, measurements are not geographically representative, and surveys were targeted at areas where high levels were expected. Householders/landlords in areas with high radon levels would also be more likely to request measurement (often during housing transactions).[24]

Radon measurements were made using standardised methods. Two passive radon detectors were placed, one in the main living area and one in a frequently used bedroom. After 3 months, detectors were returned for analysis, producing an average annual radon concentration for the dwelling.[25] The atlas takes these measurements and summarises them for postcode sectors, and the summary mean radon concentration for each sector forms our small area exposure estimate. Radon measurements within a given area tend to be approximately log-normally distributed and it has been estimated that the coefficient of variation (standard deviation/mean) within any given small area is 19%.[5] This suggests that the mean observed within each sector can be considered to be reasonably representative of households within that area.

Mean radon concentrations across postcode sectors derived from atlas data were classified and analysed categorically to allow for non-linear association with skin cancer incidence. A classification was adopted to maintain consistency with previous work,[6] breaking the range of values into ten classes.

*Statistical methods*

Age-specific malignant melanoma and non-melanoma skin cancer registration rates for the study area were compared to national rates. Radon concentrations and directly age-standardised skin cancer incidence rates were mapped for visual inspection of geographical variation. Poisson regression models were used to calculate age/sex adjusted rate ratios across categories of radon concentrations before and after adjustment for the effects of other potential confounders as follows.

Ultraviolet (UV) radiation from sunlight is a potential confounder if it is independently related to radon exposure. No data were available on actual population exposure, but as a proxy, small-area estimates of daily hours of bright sunshine were obtained from the UK Met Office.[26,27] These estimates were available for 5 km grid-squares for 1961-1990. Mean daily hours of bright sunshine from April to September during this period were calculated for postcode sectors using a Geographic Information System (GIS).

The following potential socio-demographic confounding variables were derived from 2001 Census tables.[23] Given the lack of population denominators by both age and sex, models were constructed using age-specific registration count as the outcome variable, with population as the offset. To allow for variation in sex distribution, the percentage of the postcode sector population that was male was included as an independent variable. Three socio-economic variables were also included: low socio-economic status (percentage of people aged 16–74 in National Statistics

Socio-economic Classifications 5–7), unemployment (percentage of the economically active population that was unemployed), and low educational attainment (percentage of people aged 16–74 without qualifications). To assess effects of occupational sun exposure, the percentage of the employed population aged 16–74 working in primarily outdoor industries (agriculture, hunting, forestry, fishing and construction) was also included. Coastal residence may be associated with an increased risk of skin cancer due to increased time spent on beaches and consequent increase in sun exposure.[28] Given the extensive coastal zone in the study area, this was an important consideration. The GIS was used to calculate whether or not each postcode sector was wholly or partially within 2 km of the coast, and this binary indicator was included in regression models. Population density (from 2001 Census) was included to allow for potential confounding effects of urban-rural status.

Poisson regression models were constructed using Stata version 10 (Stata Corp, TX). Robust standard errors (and hence confidence intervals) for rate ratios were calculated to allow for clustering of age group-level observations within postcode sectors.

**Results**

Exclusion of seven study area postcode sectors meant that 44 of 18,350 skin cancer registrations were not considered. The remaining 287 postcode sectors had a mean population 4,610 in 2001. Age-specific registration rates of malignant melanoma and non-melanoma skin cancer for the study area and the whole of England are presented in Table 1. These data demonstrate high registration rates of malignant melanoma and non-melanoma skin cancer in the study area relative to England across all ages. In the study area, 70% of non-melanomas were basal cell carcinomas, 24% squamous cell carcinomas and 6% other non-melanomas. Supplemental Digital Content eTables 1 and 2 describe age-specific rates and registration counts for non-melanoma sub-types. Due to low numbers, and the inclusion of tumours of mixed pathology, ‘other’ non-melanomas were not considered further.

Given the high radon levels in parts of the study area, dwellings here have been subject to greater measurement than elsewhere. Of an estimated 688,389 dwellings across the 287 postcode sectors, 162,634 (23.6%) had contributed a measurement (compared to 1.8% nationally). The proportion of dwellings contributing a measurement within study area sectors varied between 3.1% and 60.5%. The minimum number of dwelling measurements for a single postcode sector was 14 and the maximum 1700, with only 9 sectors having fewer than 50 measurements. Mean radon concentration across all sectors was 98.1 $Bq/m^3$ (standard deviation 73.1 $Bq/m^3$). Within the study area, sectors with high radon levels tended to have a higher proportion of dwellings measured (correlation coefficient 0.63).

Radon concentrations across the study area were mapped using the Etherington *et al.* classification[6] (Figure 1). Substantial variation in mean radon concentrations can be observed, with lower values in eastern, northern and southwest Devon, and high concentrations through central Devon and Cornwall and in western Cornwall. The highest mean postcode sector household radon concentration was 475 $Bq/m^3$. The UK Government ‘action level’, above which remedial action is recommended, is 200 $Bq/m^3$.[29]

Age-standardised rates of malignant melanoma, basal cell carcinoma and squamous cell carcinoma are shown in Figure 2. Melanoma rates appeared higher in coastal areas, basal cell carcinoma rates were higher in eastern Cornwall and southern Devon, and squamous cell carcinoma rates were higher in central/western Cornwall. The distributions were all quite different, with only weak correlation coefficients between standardised rates (melanoma vs. basal cell carcinoma=-0.10, p=0.11; melanoma vs. squamous cell carcinoma=-0.10, p=0.08;

basal vs. squamous cell carcinoma=-0.03, p=0.57). The variation in geographical patterns supported our decision to analyse the three tumour types separately.

Poisson regression results for the association between malignant melanoma registration rate, and mean radon concentration and potential confounders, before and after mutual adjustment, are presented in Table 2. No evidence of an association between radon concentration and melanoma incidence was found, nor evidence of an association with mean daily sunshine exposure. There was some indication of a higher melanoma risk with proximity to the coast, although statistical evidence was weakened following adjustment for other variables (rate ratio = 1.14, 95% Confidence Interval 0.99–1.31). There was also evidence of inverse associations between melanoma incidence and the proportions of the population in low socio-economic classes and those working in outdoor industries.

Equivalent regression results for basal cell carcinoma incidence are presented in Table 3. Unadjusted and adjusted rate ratios fluctuated around the null (1), providing no evidence of an association with radon. Again, there was no suggestion of an association between mean daily sunshine and incidence of basal cell carcinoma. Results from the fully adjusted model indicated inverse associations between basal cell carcinoma incidence and both population density and the proportion of population in primarily outdoor occupations.

Finally, regression model results for squamous cell carcinoma incidence are presented in Table 4. Rate ratios demonstrated a clear association between increasing radon concentration and squamous cell carcinoma registration rate, which was almost unchanged following adjustment for potential confounders. Incidence rates in areas with the highest radon concentrations (>230 $Bq/m^3$) were 1.76 (95% Confidence Interval 1.46–2.11) times those in areas with the lowest radon concentrations (0-39 $Bq/m^3$). An association was also observed between squamous cell carcinoma and coastal proximity, but not with mean daily sunshine or any of the socio-economic factors.

Rate ratios and associated 95% confidence intervals across radon categories for each of the three tumour types are shown graphically in Figure 3. This is suggestive of an exposure-response gradient for the association with squamous cell carcinoma. Expanded regression results including stratum-specific absolute rates and p-values for trend are provided in Supplemental Digital Content eTables 3-5.

**Discussion**

Comparison of data from the study area and national data supported the assertion that rates of melanoma and non-melanoma skin cancer are high in south-west England, with crude incidence rates in the study area of almost double the national rates. Rates exhibited strong age gradients, and the older population demographic of the study area may to some extent explain this difference in crude rates.

Poisson regression models revealed that incidence rates of the three skin cancer types were associated with different environmental and socio-demographic area-level risk factors. If these associations reflect actual individual-level risk factors, they go some way to explaining the varying geographical patterns observed in the maps in Figure 2. Adjusted rate ratios across radon categories provided evidence of an exposure-response relationship between radon and squamous cell carcinoma incidence. Whilst this finding is subject to study limitations, it provides an important indication that radon may indeed be a risk factor for this type of skin cancer, and warrants further investigation. This finding is consistent with a previous ecological study carried out in the same area using cancer registration data for 1989-1992.[6] This previous study investigated associations between mean small area radon concentrations and registration rates of a range of cancers, and found an association only with non-melanoma skin cancer. The authors did not analyse non-melanoma sub-types, nor publish rate ratios. However, comparing published age standardised rates for 1989-92 within the same radon categories as used here (>230 vs. 0-39 $Bq/m^3$) produces rate ratios of similar magnitude (1.73 for men, 1.66 for women).

The positive association between radon and squamous cell carcinoma risk is biologically plausible. Both basal and squamous cell carcinomas arise from metastatic transformation of the same cell type (keratinocyte). Squamous cell carcinoma develops within the epidermal skin layer, the thickness of which varies between 70 and 120 μm,[30] whereas the progenitor cells of basal cell carcinoma arise from the much deeper lying intrafollicular epidermis.[31,32] Alpha particles emitted by radon or its daughter products can travel between 40-70 μm in tissues,[33] suggesting that it is only able to affect cells within the epidermal skin layer. It is therefore unlikely to play a role in the transformation of basal cell carcinoma progenitor cells. Furthermore squamous cell carcinoma occurs predominantly on UV (and radon) exposed skin of the head, neck and back of the hands, whereas a high proportion of basal cell carcinoma occurs on non-sun-exposed areas of skin where clothing also prevents the penetration of alpha radiation.[15]

The observed association between radon and squamous cell carcinoma incidence could also be due to residual or unmeasured confounding. For example, the analysis adjusts for geographical variation in bright sunshine, and coastal proximity accounts to some extent for the possibility of increased sun exposure on beaches. However, data were not available to adjust for human behaviour, which may vary geographically. Since the relationship between frequency/intensity of sunlight exposure and risk of skin cancer varies according to skin cancer type, and behaviour resulting in sun exposure may vary geographically, it is plausible that the differential geographical patterns observed could still be driven by UV exposure variation. The limited variation in solar irradiance across the relatively small study area (mean bright summer sunshine 6.1 hours/day, range 5.5 to 6.9 hours/day) means that UV exposure variation will be largely dictated by behaviour, which we cannot control for. It is therefore perhaps unsurprising to find no association between the summer sunshine variable and skin cancer registration rates.

Regarding the other associations detected, it is interesting to note a coastal effect for both melanoma and squamous, but not basal cell carcinoma; this coastal variable might in fact provide some degree of adjustment for behaviour-related UV exposure. Coastal residents may spend more time outdoors with unprotected skin, thereby increasing UV exposure, and a lack of association with basal cell carcinoma might be explained by the frequency/intensity of exposure variation described above. The lower incidence of basal cell carcinoma observed in areas with more people in primarily outdoor occupations is not consistent with previous findings, although the lower incidence of melanoma in these areas is as expected.[34,35] This inconsistency may indicate that the measure used of outdoor occupational exposure is too crude, and could be subject to residual confounding.

The lower malignant melanoma incidence in areas with more people in lower socio-economic strata is consistent with previous studies.[36,37] Acute, intense exposure to sunlight is associated with increased malignant melanoma risk.[14] The higher incidence in higher socio-economic status populations (and those with greater prevalence of indoor occupations) may therefore indicate generally low UV exposure punctuated by high exposure episodes, perhaps during holidays in high UV environments.

*Strengths & Limitations*

Our investigation uses population data, and is based on sufficiently large numbers to detect variations in incidence across the study area. The regional cancer registry has a well-established system for registration of non-melanoma skin cancers, which is not the case in many areas. The study area includes a very wide range of average radon concentrations, giving the opportunity to compare different levels of exposure.

A key limitation inherent in this study design is the potential for the ecological fallacy to be in play. Associations observed at the aggregate level (postcode sector) may not necessarily hold at the level of the individual. Thus, whilst we see an association between area mean radon concentration and area squamous cell carcinoma incidence, it is possible that individuals living in dwellings with high radon concentrations are not the individuals that go on to develop this form of skin cancer. Further, as indicated elsewhere, it is possible that the observed association is due to unmeasured or residual confounding. It is possible that certain socio-economic circumstances and/or behaviours (such as dwelling characteristics or ventilation habits) could affect household radon and also be associated with the outcomes of interest, although we do not have any existing evidence that this is the case. There is no specific reason for indoor radon to be related to sun exposure behaviour, although if that is the case this would be a key unmeasured confounder given the strength of association between UV and skin cancers. Whilst these issues cannot be rectified within the confines of this study, the specificity of the association between radon and squamous (and not basal) cell carcinoma lends credence to the findings, given the biological plausibility and theoretical dosimetry already described.

We assume that our estimate of radon concentration for each postcode sector is a good estimate of radon exposure for all residents within that area, and that household radon concentration is a good indicator of personal exposure. As indicated above, it is likely that dwellings within a sector will have variable radon concentrations, depending on immediate geology and building characteristics, although the mean is likely to be reasonably representative of dwellings within the sector.[5] Areas with high radon levels tend to have had more measurements made, so the precision of sector concentration estimates increases with increasing radon concentrations. However, the vast majority of postcode sector means are based on a large number of measurements. A sensitivity analysis of the squamous cell carcinoma model excluding the 9 postcode sectors with fewer than 50 radon measurements resulted in negligible differences compared with the reported findings. Residents spend differing amounts of time indoors exposed to particular radon concentrations, so individual radon exposures within dwellings may also vary. However, studies comparing household and personal radon monitoring indicate that dwelling measurements provide good indication of personal exposure. One study found a moderate correlation ($r^2$=0.52) between personal and dwelling radon measures,[38] while another found a strong correlation ($r^2$=0.85).[39] A final point regarding exposure estimation is that exposure and outcome measures are for the same point in time, and we therefore assume current exposure (based on long term accumulated radon measurements for current residence location) is a reasonable estimate of total exposure. This may lead to misclassification, for example where a person classified as living in a high radon area only moved there recently from a low radon area. In terms of data issues, postal boundaries are subject to change over time leading to errors in matching radon and skin cancer data. The 'distance-to-coast' indicator provided a reasonable indicator of coastal proximity, but as some postcode sectors are large and extend some way inland, a portion of the population classified as living within 2 km of the coast will have been misclassified. As with many small area studies, population denominator data that exactly match registration (numerator) data are unavailable. The application of regional population growth rates to postcode sector populations for 2001 presumes that growth/shrinkage was uniform across the whole study area between 2000 and 2004. This is unlikely, and it is possible that if a sector experienced substantial changes in population during this time, the incidence rate for that sector could be an under- or over-estimate. However, overall geographical patterns of incidence rates across the study area are unlikely to be significantly affected, and adjustment improves the validity of the comparison of study area rates with national figures.

Many of these limitations are common to ecological environmental epidemiological studies, and whilst they are important, they do not negate our findings. We have found a population level association between radon exposure and skin cancer incidence, specifically with squamous cell carcinoma. The use of population data mean that results should be generalisable to elsewhere in the UK and other countries. The radon concentrations at which increased risk is observed are also found elsewhere, indicating that this issue is not confined to the study region alone.

**Conclusions**

We have found evidence of an ecological association between small-area measures of environmental radon concentration and incidence of squamous cell carcinoma. There is an indication of an exposure-response relationship, and the association persists following adjustment for potential confounders. No such association was observed with either malignant melanoma or basal cell carcinoma. Whilst these findings are biologically plausible, they are subject to the limitations of the ecological study design. Further investigation is warranted, particularly to assess individual long-term environmental radon exposure and subsequent risk of squamous cell carcinoma.

Author's post-peer review version, including online supplemental material
Published version - *Epidemiology* 23 (1), 2012. http://dx.doi.org/10.1097/EDE.0b013e31823b6139

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**Table 1.** National and study area skin cancer age-specific registration rates per 100,000 population per year, 2000-2004 (95% confidence interval in parentheses).

| Age group | Malignant melanoma[a] | | Non-melanoma skin cancer[b] | |
|---|---|---|---|---|
| | Study Area[c] | England[d] | Study Area[c] | England[d] |
| 15-29 | 5.1 (4.0, 6.5) | 3.7 (3.5, 3.9) | 4.3 (3.2, 5.5) | 2.6 (2.4, 2.7) |
| 30-44 | 16.7 (14.8, 18.9) | 10.4 (10.2, 10.7) | 35.7 (32.9, 38.8) | 20.2 (19.8, 20.6) |
| 45-59 | 31.2 (28.6, 34.0) | 18.5 (18.1, 18.9) | 159.6 (153.6, 165.8) | 89.6 (88.7, 90.5) |
| 60-64 | 46.1 (40.2, 52.7) | 24.5 (23.6, 25.4) | 311.3 (295.5, 327.6) | 200.3 (197.8, 202.8) |
| 65-74 | 52.5 (47.6, 57.7) | 29.1 (28.4, 29.9) | 521.5 (505.9, 537.5) | 338.2 (335.7, 340.8) |
| 75-84 | 66.9 (60.4, 73.9) | 36.0 (35.0, 37.0) | 834.8 (811.5, 858.6) | 578.8 (574.8, 582.8) |
| 85+ | 57.7 (48.0, 68.7) | 41.3 (39.5, 43.2) | 1,109.1 (1,065.3, 1,154.1) | 785.4 (777.4, 793.4) |
| Total (15+) | 30.2 (28.9, 31.6) | 16.0 (15.8, 16.2) | 244.0 (240.2, 247.8) | 132.4 (131.9, 132.9) |

a) based on number of melanomas registered (i.e. number of tumours)

b) based on the first instance of each type of tumour (i.e. number of individuals)

c) total across 287 postcode sectors included in study

d) data for England from Office for National Statistics (Series MB1), Crown Copyright 2010

**Table 2.** Poisson regression results: outcome is postcode sector malignant melanoma registration rate 2000-2004 (n=287). RR: Rate Ratio; CI: Confidence Interval.

| Explanatory variable | Value | Unadjusted models[a] | | Fully adjusted model | |
|---|---|---|---|---|---|
| | | RR | 95% CI | RR | 95% CI |
| Postcode sector mean radon concentration (Bq/m3) | 0-39[b] | 1.00 | | 1.00 | |
| | 40-44 | 1.05 | (0.84,1.30) | 1.05 | (0.85,1.28) |
| | 45-49 | 1.04 | (0.88,1.24) | 1.00 | (0.84,1.20) |
| | 50-59 | 0.92 | (0.75,1.14) | 0.89 | (0.73,1.09) |
| | 60-74 | 0.98 | (0.79,1.22) | 0.96 | (0.77,1.19) |
| | 75-99 | 1.05 | (0.87,1.28) | 0.96 | (0.79,1.16) |
| | 100-129 | 1.00 | (0.83,1.19) | 0.95 | (0.80,1.14) |
| | 130-159 | 1.08 | (0.86,1.35) | 0.98 | (0.79,1.21) |
| | 160-229 | 0.96 | (0.80,1.16) | 0.92 | (0.76,1.11) |
| | >=230 | 0.81 | (0.62,1.07) | 0.85 | (0.65,1.11) |
| Mean daily hours bright sunshine April-September (quintiles[c]) | 1[b] (lowest) | 1.00 | | 1.00 | |
| | 2 | 1.05 | (0.88,1.24) | 1.06 | (0.89,1.26) |
| | 3 | 1.14 | (0.94,1.39) | 1.10 | (0.91,1.33) |
| | 4 | 1.13 | (0.97,1.32) | 1.06 | (0.86,1.32) |
| | 5 | 1.13 | (0.95,1.34) | 1.07 | (0.86,1.33) |
| Coastal proximity | >2km | 1.00 | | 1.00 | |
| | <=2km | 1.14 | (1.03,1.27) | 1.14 | (0.99,1.31) |
| Population density (people per hectare) | 0 to <5[b] | 1.00 | | 1.00 | |
| | 5 to <20 | 0.90 | (0.79,1.02) | 0.83 | (0.69,0.99) |
| | 20+ | 0.93 | (0.82,1.05) | 0.87 | (0.71,1.06) |
| % Population in low socio-economic classifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 0.88 | (0.74,1.05) | 0.88 | (0.74,1.04) |
| | 3 | 0.94 | (0.82,1.08) | 0.94 | (0.81,1.10) |
| | 4 | 0.77 | (0.67,0.88) | 0.79 | (0.66,0.93) |
| | 5 | 0.72 | (0.62,0.83) | 0.73 | (0.60,0.89) |
| % Population with no qualifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 0.89 | (0.75,1.05) | 0.99 | (0.84,1.17) |
| | 3 | 0.81 | (0.70,0.95) | 1.01 | (0.83,1.22) |
| | 4 | 0.79 | (0.68,0.93) | 1.02 | (0.84,1.24) |
| | 5 | 0.78 | (0.67,0.90) | 1.10 | (0.90,1.33) |
| % Population unemployed (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 1.00 | (0.84,1.19) | 1.01 | (0.87,1.19) |
| | 3 | 0.91 | (0.77,1.08) | 0.96 | (0.83,1.10) |
| | 4 | 0.96 | (0.80,1.16) | 1.01 | (0.84,1.22) |
| | 5 | 0.83 | (0.70,0.99) | 0.89 | (0.74,1.07) |
| % Population in primarily outside occupations (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 0.86 | (0.74,1.00) | 0.91 | (0.79,1.05) |
| | 3 | 0.91 | (0.80,1.05) | 0.87 | (0.74,1.01) |
| | 4 | 0.87 | (0.72,1.04) | 0.77 | (0.62,0.96) |
| | 5 | 0.90 | (0.76,1.06) | 0.79 | (0.63,0.99) |

a All univariate models adjust for age group and % male in postcode sector
b Baseline category
c Quintiles across postcode sectors i.e. quintile 1 = lowest fifth of sectors across study area

**Table 3.** Poisson regression results: outcome is postcode sector basal cell carcinoma registration rate 2000-2004 (n=287). RR: Rate Ratio; CI: Confidence Interval.

| Explanatory variable | Value | Unadjusted models[a] | | Fully adjusted model | |
|---|---|---|---|---|---|
| | | RR | 95% CI | RR | 95% CI |
| Postcode sector mean radon concentration (Bq/m3) | 0-39[b] | 1.00 | | 1.00 | |
| | 40-44 | 1.00 | (0.90,1.11) | 1.03 | (0.90,1.19) |
| | 45-49 | 1.12 | (1.00,1.25) | 1.15 | (1.01,1.32) |
| | 50-59 | 0.93 | (0.75,1.16) | 0.98 | (0.84,1.16) |
| | 60-74 | 1.12 | (1.00,1.25) | 1.20 | (1.06,1.35) |
| | 75-99 | 1.09 | (0.97,1.22) | 1.13 | (1.00,1.28) |
| | 100-129 | 0.89 | (0.77,1.03) | 0.91 | (0.79,1.04) |
| | 130-159 | 0.96 | (0.82,1.13) | 1.02 | (0.88,1.18) |
| | 160-229 | 0.94 | (0.82,1.08) | 1.01 | (0.87,1.17) |
| | >=230 | 0.72 | (0.60,0.86) | 0.81 | (0.66,1.00) |
| Mean daily hours bright sunshine April-September (quintiles[c]) | 1[b] (lowest) | 1.00 | | 1.00 | |
| | 2 | 1.03 | (0.95,1.12) | 1.09 | (0.97,1.21) |
| | 3 | 0.88 | (0.76,1.01) | 0.89 | (0.77,1.03) |
| | 4 | 0.99 | (0.91,1.08) | 1.00 | (0.89,1.13) |
| | 5 | 1.05 | (0.94,1.17) | 1.08 | (0.93,1.25) |
| Coastal proximity | >2km | 1.00 | | 1.00 | |
| | <=2km | 1.01 | (0.92,1.10) | 0.97 | (0.89,1.06) |
| Population density (people per hectare) | 0 to <5[b] | 1.00 | | 1.00 | |
| | 5 to <20 | 1.07 | (0.97,1.17) | 0.93 | (0.83,1.05) |
| | 20+ | 0.97 | (0.87,1.08) | 0.83 | (0.73,0.94) |
| % Population in low socio-economic classifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 1.07 | (0.95,1.21) | 1.12 | (1.00,1.26) |
| | 3 | 1.03 | (0.92,1.16) | 1.02 | (0.91,1.13) |
| | 4 | 0.93 | (0.80,1.07) | 0.91 | (0.78,1.06) |
| | 5 | 1.00 | (0.89,1.11) | 0.99 | (0.85,1.15) |
| % Population with no qualifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 0.95 | (0.80,1.11) | 0.94 | (0.83,1.08) |
| | 3 | 1.03 | (0.92,1.15) | 1.04 | (0.92,1.17) |
| | 4 | 0.97 | (0.87,1.09) | 1.00 | (0.88,1.14) |
| | 5 | 0.96 | (0.85,1.08) | 1.04 | (0.91,1.20) |
| % Population unemployed (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 1.07 | (0.92,1.25) | 1.08 | (0.96,1.22) |
| | 3 | 1.00 | (0.86,1.17) | 1.04 | (0.93,1.16) |
| | 4 | 0.91 | (0.77,1.07) | 0.94 | (0.82,1.08) |
| | 5 | 0.97 | (0.83,1.14) | 1.02 | (0.87,1.18) |
| % Population in primarily outside occupations (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 1.03 | (0.90,1.18) | 0.97 | (0.88,1.07) |
| | 3 | 0.97 | (0.85,1.12) | 0.90 | (0.79,1.02) |
| | 4 | 0.87 | (0.75,1.00) | 0.76 | (0.65,0.88) |
| | 5 | 0.90 | (0.79,1.04) | 0.73 | (0.62,0.86) |

a All univariate models adjust for age group and % male in postcode sector
b Baseline category
c Quintiles across postcode sectors i.e. quintile 1 = lowest fifth of sectors across study area

**Table 4.** Poisson regression results: outcome is postcode sector squamous cell carcinoma registration rate 2000-2004 (n=287). RR: Rate Ratio; CI: Confidence Interval.

| Explanatory variable | Value | Unadjusted models[a] | | Fully adjusted model | |
|---|---|---|---|---|---|
| | | RR | 95% CI | RR | 95% CI |
| Postcode sector mean radon concentration (Bq/m3) | 0-39[b] | 1.00 | | 1.00 | |
| | 40-44 | 1.00 | (0.85,1.19) | 1.00 | (0.82,1.23) |
| | 45-49 | 1.02 | (0.85,1.22) | 1.02 | (0.84,1.25) |
| | 50-59 | 1.06 | (0.84,1.33) | 1.11 | (0.91,1.34) |
| | 60-74 | 1.26 | (1.07,1.49) | 1.30 | (1.10,1.54) |
| | 75-99 | 1.47 | (1.23,1.77) | 1.44 | (1.20,1.74) |
| | 100-129 | 1.73 | (1.46,2.05) | 1.68 | (1.42,1.99) |
| | 130-159 | 1.56 | (1.23,1.98) | 1.55 | (1.23,1.96) |
| | 160-229 | 1.65 | (1.35,2.02) | 1.62 | (1.31,2.00) |
| | >=230 | 1.75 | (1.50,2.05) | 1.76 | (1.46,2.11) |
| Mean daily hours bright sunshine April-September (quintiles[c]) | 1[b] (lowest) | 1.00 | | 1.00 | |
| | 2 | 1.23 | (1.05,1.45) | 0.95 | (0.81,1.11) |
| | 3 | 1.36 | (1.13,1.65) | 1.05 | (0.88,1.25) |
| | 4 | 1.41 | (1.20,1.66) | 1.15 | (0.98,1.36) |
| | 5 | 1.30 | (1.11,1.53) | 0.98 | (0.80,1.19) |
| Coastal proximity | >2km | 1.00 | | 1.00 | |
| | <=2km | 1.27 | (1.14,1.42) | 1.16 | (1.04,1.30) |
| Population density (people per hectare) | 0 to <5[b] | 1.00 | | 1.00 | |
| | 5 to <20 | 0.93 | (0.82,1.07) | 0.96 | (0.82,1.12) |
| | 20+ | 0.87 | (0.75,1.01) | 0.96 | (0.80,1.16) |
| % Population in low socio-economic classifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 1.00 | (0.83,1.21) | 0.93 | (0.80,1.09) |
| | 3 | 1.02 | (0.85,1.23) | 0.98 | (0.83,1.16) |
| | 4 | 0.91 | (0.74,1.11) | 0.90 | (0.74,1.10) |
| | 5 | 1.07 | (0.90,1.27) | 1.09 | (0.89,1.33) |
| % Population with no qualifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 0.97 | (0.78,1.20) | 0.92 | (0.77,1.11) |
| | 3 | 1.04 | (0.85,1.26) | 1.01 | (0.84,1.22) |
| | 4 | 1.04 | (0.86,1.26) | 1.01 | (0.82,1.24) |
| | 5 | 0.98 | (0.81,1.19) | 0.93 | (0.75,1.16) |
| % Population unemployed (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 1.18 | (0.99,1.40) | 1.09 | (0.94,1.27) |
| | 3 | 1.29 | (1.06,1.57) | 1.19 | (1.02,1.39) |
| | 4 | 1.33 | (1.13,1.57) | 1.11 | (0.94,1.32) |
| | 5 | 1.36 | (1.14,1.63) | 1.15 | (0.94,1.41) |
| % Population in primarily outside occupations (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | |
| | 2 | 1.16 | (0.99,1.37) | 1.05 | (0.92,1.21) |
| | 3 | 1.16 | (0.97,1.40) | 1.00 | (0.85,1.18) |
| | 4 | 1.27 | (1.07,1.52) | 1.05 | (0.86,1.29) |
| | 5 | 1.17 | (0.98,1.39) | 1.06 | (0.87,1.30) |

a All univariate models adjust for age group and % male in postcode sector
b Baseline category
c Quintiles across postcode sectors i.e. quintile 1 = lowest fifth of sectors across study area

**Figure 1.** Map of radon concentrations across the study area: mean of value for all dwellings that have had a radon measurement within each postcode sector. Note: Boundary data are © Crown Copyright and supplied by EDINA UKBorders with the support of the ESRC and JISC.

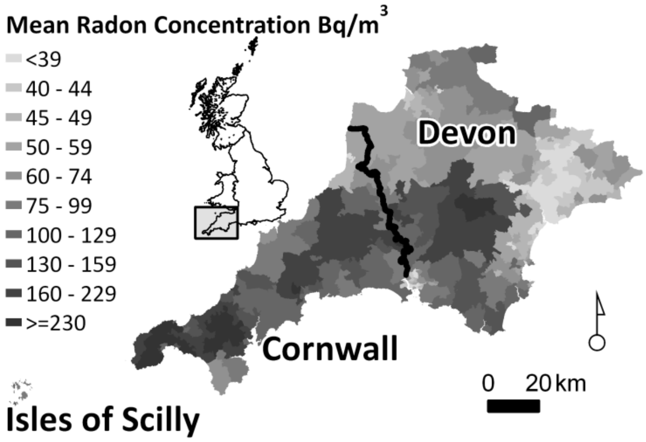


**Figure 2.** Directly age-standardised registration rate per 100,000 population per year, 2000-2004, by postcode sector, of a) malignant melanoma, b) basal cell carcinoma and c) squamous cell carcinoma. Note: Boundary data are © Crown Copyright and supplied by EDINA UKBorders with the support of the ESRC and JISC.

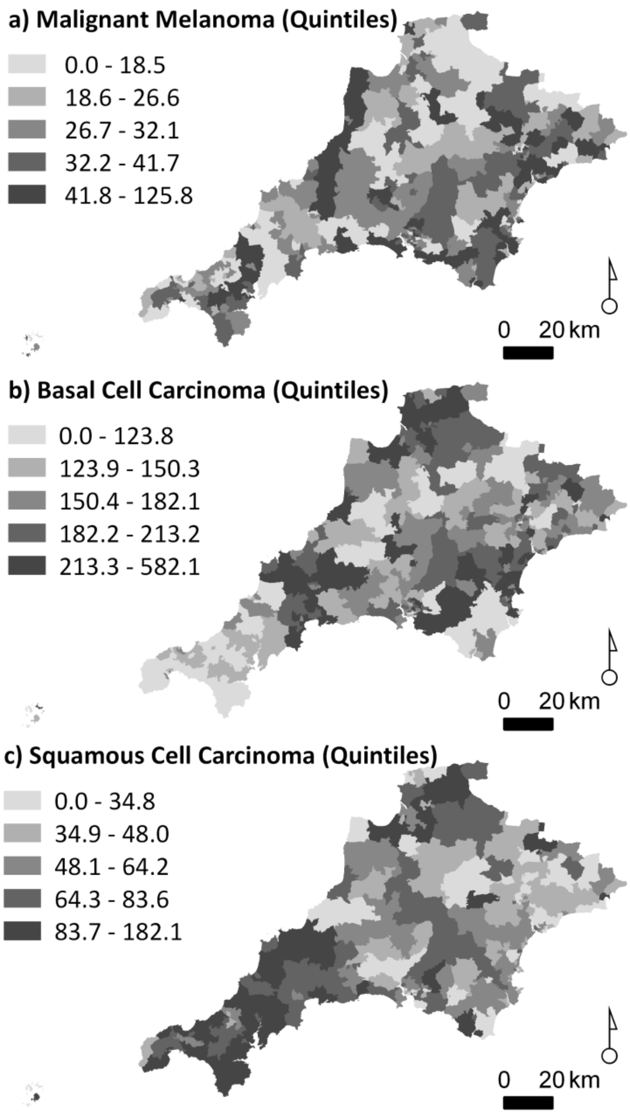
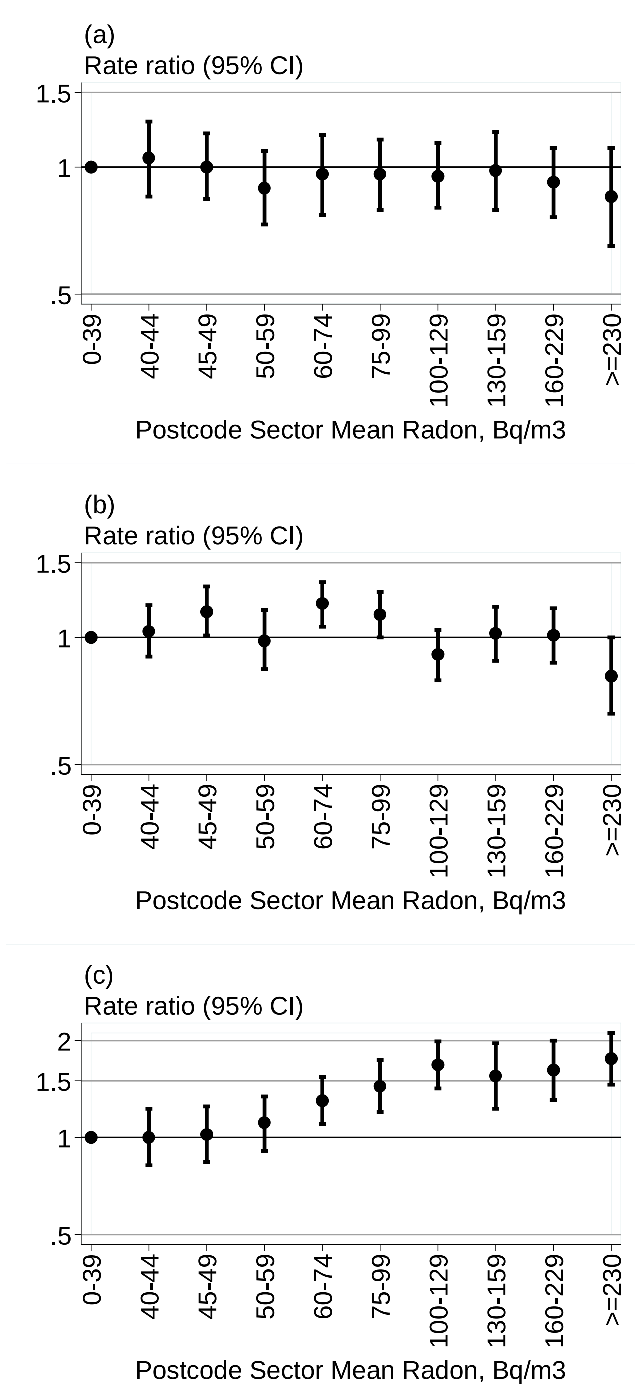


**Figure 3.** Rate ratios across radon categories from fully adjusted models (Tables 2-4). Reference category 0-39 Bq/m$^3$ (RR=1) a) malignant melanoma b) basal cell carcinoma c) squamous cell carcinoma. CI: Confidence Interval




Author's post-peer review version, including online supplemental material
Published version - *Epidemiology* 23 (1), 2012. http://dx.doi.org/10.1097/EDE.0b013e31823b6139 

**Supplemental Digital Content**
**Radon and skin cancer in south-west England: an ecological study**
Benedict W. Wheeler, James Allen, Michael H. Depledge & Alison Curnow

**SDC eTable 1.** Study area age-specific registration rate of non-melanoma skin cancer sub-types per 100,000 population per year (95% Confidence Interval), 2000-2004.

| Age group | Non-melanoma skin cancer tumour type (% of total registrations) | | |
|---|---|---|---|
| | Basal cell carcinoma (70%) | Squamous cell carcinoma (24%) | Other non-melanoma (6%) |
| 15-29 | 3.5 (2.6, 4.7) | 0.2 (0.0, 0.7) | 0.5 (0.2, 1.1) |
| 30-44 | 31.2 (28.5, 34.0) | 2.1 (1.5, 3.0) | 2.4 (1.7, 3.3) |
| 45-59 | 132.4 (126.9, 138.0) | 19.5 (17.4, 21.7) | 7.8 (6.5, 9.2) |
| 60-64 | 247.3 (233.3, 261.9) | 48.5 (42.4, 55.2) | 15.5 (12.2, 19.5) |
| 65-74 | 374.5 (361.3, 388.1) | 116.8 (109.5, 124.5) | 30.2 (26.5, 34.2) |
| 75-84 | 537.5 (518.8, 556.6) | 246.5 (233.9, 259.6) | 50.8 (45.2, 56.9) |
| 85+ | 606.0 (573.8, 639.6) | 417.0 (390.3, 445.0) | 86.1 (74.2, 99.3) |
| Total 15+ | 171.1 (168.0, 174.3) | 58.2 (56.4, 60.1) | 14.7 (13.8, 15.6) |

**SDC eTable 2.** Registered cases of skin cancer in study area, 2000-2004.

| Age group | Malignant melanoma | Non-melanoma skin cancer | Non-melanoma sub-types | | |
|---|---|---|---|---|---|
| | | | Basal cell carcinoma | Squamous cell carcinoma | Other non-melanoma |
| 15-29 | 67 | 56 | 46 | - | - |
| 30-44 | 269 | 574 | 501 | 34 | 39 |
| 45-59 | 523 | 2672 | 2216 | 326 | 130 |
| 60-64 | 217 | 1464 | 1163 | 228 | 73 |
| 65-74 | 426 | 4233 | 3040 | 948 | 245 |
| 75-84 | 390 | 4866 | 3133 | 1437 | 296 |
| 85+ | 126 | 2423 | 1324 | 911 | 188 |
| Total | 2018 | 16288 | 11423 | 3887 | 978 |

Notes: Counts below 10 have been suppressed to avoid any confidentiality issues. Malignant melanoma data are based on number of melanomas registered (i.e. number of tumours); non-melanoma data are based on the first instance of each type of tumour (i.e. number of individuals).

**SDC eTable 3.** Expanded Poisson regression results: outcome is postcode sector malignant melanoma registration rate 2000-2004 (n=287). RR: Rate Ratio; CI: Confidence Interval.

| Explanatory variable | Value | Unadjusted models[a] RR | Unadjusted models[a] 95% CI | Fully adjusted model RR | Fully adjusted model 95% CI | Full model p-value (for trend where appropriate) | Unadjusted mean strata specific age-standardised registration rate per 100,000 | n (postcode sectors) | n (2001 population) |
|---|---|---|---|---|---|---|---|---|---|
| Postcode sector mean radon concentration (Bq/m3) | 0-39[b] | 1.00 | | 1.00 | | | 31.7 | 43 | 220133 |
| | 40-44 | 1.05 | (0.84,1.30) | 1.05 | (0.85,1.28) | | 34.2 | 19 | 88080 |
| | 45-49 | 1.04 | (0.88,1.24) | 1.00 | (0.84,1.20) | | 31.8 | 22 | 111600 |
| | 50-59 | 0.92 | (0.75,1.14) | 0.89 | (0.73,1.09) | | 30.8 | 30 | 155252 |
| | 60-74 | 0.98 | (0.79,1.22) | 0.96 | (0.77,1.19) | | 29.4 | 30 | 155139 |
| | 75-99 | 1.05 | (0.87,1.28) | 0.96 | (0.79,1.16) | | 29.5 | 38 | 163678 |
| | 100-129 | 1.00 | (0.83,1.19) | 0.95 | (0.80,1.14) | | 31.8 | 39 | 157720 |
| | 130-159 | 1.08 | (0.86,1.35) | 0.98 | (0.79,1.21) | | 37.1 | 19 | 77503 |
| | 160-229 | 0.96 | (0.80,1.16) | 0.92 | (0.76,1.11) | | 29.8 | 28 | 121082 |
| | >=230 | 0.81 | (0.62,1.07) | 0.85 | (0.65,1.11) | 0.200 | 26.2 | 19 | 72891 |
| Mean daily hours bright sunshine April-September (quintiles[c]) | 1[b] (lowest) | 1.00 | | 1.00 | | | 29.2 | 59 | 229880 |
| | 2 | 1.05 | (0.88,1.24) | 1.06 | (0.89,1.26) | | 28.9 | 56 | 240140 |
| | 3 | 1.14 | (0.94,1.39) | 1.10 | (0.91,1.33) | | 33.8 | 58 | 293451 |
| | 4 | 1.13 | (0.97,1.32) | 1.06 | (0.86,1.32) | | 30.7 | 57 | 308295 |
| | 5 | 1.13 | (0.95,1.34) | 1.07 | (0.86,1.33) | 0.753 | 32.7 | 57 | 251312 |
| Coastal proximity | >2km | 1.00 | | 1.00 | | | 28.2 | 130 | 599263 |
| | <=2km | 1.14 | (1.03,1.27) | 1.14 | (0.99,1.31) | 0.062 | 33.5 | 157 | 723815 |
| Population density (people per hectare) | 0 to <5[b] | 1.00 | | 1.00 | | | 32.4 | 165 | 595203 |
| | 5 to <20 | 0.90 | (0.79,1.02) | 0.83 | (0.69,0.99) | 0.034 | 28.9 | 53 | 303781 |
| | 20+ | 0.93 | (0.82,1.05) | 0.87 | (0.71,1.06) | 0.159 | 29.7 | 69 | 424094 |
| % Population in low socio-economic classifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 37.1 | 58 | 215756 |
| | 2 | 0.88 | (0.74,1.05) | 0.88 | (0.74,1.04) | | 32.8 | 57 | 209911 |
| | 3 | 0.94 | (0.82,1.08) | 0.94 | (0.81,1.10) | | 32.5 | 58 | 279267 |
| | 4 | 0.77 | (0.67,0.88) | 0.79 | (0.66,0.93) | | 28.2 | 57 | 290203 |
| | 5 | 0.72 | (0.62,0.83) | 0.73 | (0.60,0.89) | 0.002 | 24.7 | 57 | 327941 |
| % Population with no qualifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 38.2 | 58 | 235422 |
| | 2 | 0.89 | (0.75,1.05) | 0.99 | (0.84,1.17) | | 32.1 | 57 | 274766 |
| | 3 | 0.81 | (0.70,0.95) | 1.01 | (0.83,1.22) | | 27.9 | 58 | 262985 |
| | 4 | 0.79 | (0.68,0.93) | 1.02 | (0.84,1.24) | | 28.6 | 57 | 242152 |
| | 5 | 0.78 | (0.67,0.90) | 1.10 | (0.90,1.33) | 0.293 | 28.5 | 57 | 307753 |
| % Population unemployed (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 35.0 | 58 | 242949 |
| | 2 | 1.00 | (0.84,1.19) | 1.01 | (0.87,1.19) | | 31.8 | 57 | 273185 |
| | 3 | 0.91 | (0.77,1.08) | 0.96 | (0.83,1.10) | | 29.7 | 58 | 251312 |
| | 4 | 0.96 | (0.80,1.16) | 1.01 | (0.84,1.22) | | 32.0 | 57 | 272230 |
| | 5 | 0.83 | (0.70,0.99) | 0.89 | (0.74,1.07) | 0.355 | 26.9 | 57 | 283402 |
| % Population in primarily outside occupations (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 33.9 | 58 | 353120 |
| | 2 | 0.86 | (0.74,1.00) | 0.91 | (0.79,1.05) | | 28.6 | 57 | 317462 |
| | 3 | 0.91 | (0.80,1.05) | 0.87 | (0.74,1.01) | | 30.3 | 58 | 273818 |
| | 4 | 0.87 | (0.72,1.04) | 0.77 | (0.62,0.96) | | 29.4 | 57 | 209269 |
| | 5 | 0.90 | (0.76,1.06) | 0.79 | (0.63,0.99) | 0.021 | 33.2 | 57 | 169409 |

a All univariate models adjust for age group and % male in postcode sector

b Baseline category

c Quintiles across postcode sectors i.e. quintile 1 = lowest fifth of sectors across study area

**SDC eTable 4.** Expanded Poisson regression results: outcome is postcode sector basal cell carcinoma registration rate 2000-2004 (n=287). RR: Rate Ratio; CI: Confidence Interval.

| Explanatory variable | Value | Unadjusted models[a] RR | Unadjusted models[a] 95% CI | Fully adjusted model RR | Fully adjusted model 95% CI | Full model p-value (for trend where appropriate) | Unadjusted mean strata specific age-standardised registration rate per 100,000 | n (postcode sectors) | n (2001 population) |
|---|---|---|---|---|---|---|---|---|---|
| Postcode sector mean radon concentration (Bq/m3) | 0-39[b] | 1.00 | | 1.00 | | | 163.5 | 43 | 220133 |
| | 40-44 | 1.00 | (0.90,1.11) | 1.03 | (0.90,1.19) | | 165.0 | 19 | 88080 |
| | 45-49 | 1.12 | (1.00,1.25) | 1.15 | (1.01,1.32) | | 195.7 | 22 | 111600 |
| | 50-59 | 0.93 | (0.75,1.16) | 0.98 | (0.84,1.16) | | 169.5 | 30 | 155252 |
| | 60-74 | 1.12 | (1.00,1.25) | 1.20 | (1.06,1.35) | | 182.9 | 30 | 155139 |
| | 75-99 | 1.09 | (0.97,1.22) | 1.13 | (1.00,1.28) | | 188.2 | 38 | 163678 |
| | 100-129 | 0.89 | (0.77,1.03) | 0.91 | (0.79,1.04) | | 153.5 | 39 | 157720 |
| | 130-159 | 0.96 | (0.82,1.13) | 1.02 | (0.88,1.18) | | 155.2 | 19 | 77503 |
| | 160-229 | 0.94 | (0.82,1.08) | 1.01 | (0.87,1.17) | | 166.9 | 28 | 121082 |
| | >=230 | 0.72 | (0.60,0.86) | 0.81 | (0.66,1.00) | 0.176 | 123.6 | 19 | 72891 |
| Mean daily hours bright sunshine April-September (quintiles[c]) | 1[b] (lowest) | 1.00 | | 1.00 | | | 163.9 | 59 | 229880 |
| | 2 | 1.03 | (0.95,1.12) | 1.09 | (0.97,1.21) | | 179.4 | 56 | 240140 |
| | 3 | 0.88 | (0.76,1.01) | 0.89 | (0.77,1.03) | | 156.2 | 58 | 293451 |
| | 4 | 0.99 | (0.91,1.08) | 1.00 | (0.89,1.13) | | 165.7 | 57 | 308295 |
| | 5 | 1.05 | (0.94,1.17) | 1.08 | (0.93,1.25) | 0.446 | 174.2 | 57 | 251312 |
| Coastal proximity | >2km | 1.00 | | 1.00 | | | 169.7 | 130 | 599263 |
| | <=2km | 1.01 | (0.92,1.10) | 0.97 | (0.89,1.06) | 0.467 | 166.2 | 157 | 723815 |
| Population density (people per hectare) | 0 to <5[b] | 1.00 | | 1.00 | | | 165.3 | 165 | 595203 |
| | 5 to <20 | 1.07 | (0.97,1.17) | 0.93 | (0.83,1.05) | 0.236 | 177.3 | 53 | 303781 |
| | 20+ | 0.97 | (0.87,1.08) | 0.83 | (0.73,0.94) | 0.004 | 166.4 | 69 | 424094 |
| % Population in low socio-economic classifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 163.3 | 58 | 215756 |
| | 2 | 1.07 | (0.95,1.21) | 1.12 | (1.00,1.26) | | 177.1 | 57 | 209911 |
| | 3 | 1.03 | (0.92,1.16) | 1.02 | (0.91,1.13) | | 170.0 | 58 | 279267 |
| | 4 | 0.93 | (0.80,1.07) | 0.91 | (0.78,1.06) | | 164.7 | 57 | 290203 |
| | 5 | 1.00 | (0.89,1.11) | 0.99 | (0.85,1.15) | 0.19 | 163.8 | 57 | 327941 |
| % Population with no qualifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 166.8 | 58 | 235422 |
| | 2 | 0.95 | (0.80,1.11) | 0.94 | (0.83,1.08) | | 165.2 | 57 | 274766 |
| | 3 | 1.03 | (0.92,1.15) | 1.04 | (0.92,1.17) | | 174.4 | 58 | 262985 |
| | 4 | 0.97 | (0.87,1.09) | 1.00 | (0.88,1.14) | | 169.0 | 57 | 242152 |
| | 5 | 0.96 | (0.85,1.08) | 1.04 | (0.91,1.20) | 0.385 | 163.4 | 57 | 307753 |
| % Population unemployed (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 169.1 | 58 | 242949 |
| | 2 | 1.07 | (0.92,1.25) | 1.08 | (0.96,1.22) | | 189.5 | 57 | 273185 |
| | 3 | 1.00 | (0.86,1.17) | 1.04 | (0.93,1.16) | | 164.9 | 58 | 251312 |
| | 4 | 0.91 | (0.77,1.07) | 0.94 | (0.82,1.08) | | 156.5 | 57 | 272230 |
| | 5 | 0.97 | (0.83,1.14) | 1.02 | (0.87,1.18) | 0.528 | 158.8 | 57 | 283402 |
| % Population in primarily outside occupations (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 171.6 | 58 | 353120 |
| | 2 | 1.03 | (0.90,1.18) | 0.97 | (0.88,1.07) | | 182.5 | 57 | 317462 |
| | 3 | 0.97 | (0.85,1.12) | 0.90 | (0.79,1.02) | | 170.2 | 58 | 273818 |
| | 4 | 0.87 | (0.75,1.00) | 0.76 | (0.65,0.88) | | 159.5 | 57 | 209269 |
| | 5 | 0.90 | (0.79,1.04) | 0.73 | (0.62,0.86) | <0.001 | 154.9 | 57 | 169409 |

a All univariate models adjust for age group and % male in postcode sector

b Baseline category

c Quintiles across postcode sectors i.e. quintile 1 = lowest fifth of sectors across study area

**SDC eTable 5.** Expanded Poisson regression results: outcome is postcode sector squamous cell carcinoma registration rate 2000-2004 (n=287). RR: Rate Ratio; CI: Confidence Interval.

| Explanatory variable | Value | Unadjusted models[a] RR | Unadjusted models[a] 95% CI | Fully adjusted model RR | Fully adjusted model 95% CI | Full model p-value (for trend where appropriate) | Unadjusted mean strata specific age-standardised registration rate per 100,000 | n (postcode sectors) | n (2001 population) |
|---|---|---|---|---|---|---|---|---|---|
| Postcode sector mean radon concentration (Bq/m3) | 0-39[b] | 1.00 | | 1.00 | | | 41.2 | 43 | 220133 |
| | 40-44 | 1.00 | (0.85,1.19) | 1.00 | (0.82,1.23) | | 42.5 | 19 | 88080 |
| | 45-49 | 1.02 | (0.85,1.22) | 1.02 | (0.84,1.25) | | 43.8 | 22 | 111600 |
| | 50-59 | 1.06 | (0.84,1.33) | 1.11 | (0.91,1.34) | | 49.3 | 30 | 155252 |
| | 60-74 | 1.26 | (1.07,1.49) | 1.30 | (1.10,1.54) | | 57.0 | 30 | 155139 |
| | 75-99 | 1.47 | (1.23,1.77) | 1.44 | (1.20,1.74) | | 65.7 | 38 | 163678 |
| | 100-129 | 1.73 | (1.46,2.05) | 1.68 | (1.42,1.99) | | 78.8 | 39 | 157720 |
| | 130-159 | 1.56 | (1.23,1.98) | 1.55 | (1.23,1.96) | | 66.0 | 19 | 77503 |
| | 160-229 | 1.65 | (1.35,2.02) | 1.62 | (1.31,2.00) | | 69.4 | 28 | 121082 |
| | >=230 | 1.75 | (1.50,2.05) | 1.76 | (1.46,2.11) | <0.001 | 80.0 | 19 | 72891 |
| Mean daily hours bright sunshine April-September (quintiles[c]) | 1[b] (lowest) | 1.00 | | 1.00 | | | 46.4 | 59 | 229880 |
| | 2 | 1.23 | (1.05,1.45) | 0.95 | (0.81,1.11) | | 56.7 | 56 | 240140 |
| | 3 | 1.36 | (1.13,1.65) | 1.05 | (0.88,1.25) | | 66.4 | 58 | 293451 |
| | 4 | 1.41 | (1.20,1.66) | 1.15 | (0.98,1.36) | | 67.6 | 57 | 308295 |
| | 5 | 1.30 | (1.11,1.53) | 0.98 | (0.80,1.19) | 0.595 | 59.8 | 57 | 251312 |
| Coastal proximity | >2km | 1.00 | | 1.00 | | | 52.1 | 130 | 599263 |
| | <=2km | 1.27 | (1.14,1.42) | 1.16 | (1.04,1.30) | 0.010 | 65.3 | 157 | 723815 |
| Population density (people per hectare) | 0 to <5[b] | 1.00 | | 1.00 | | | 61.5 | 165 | 595203 |
| | 5 to <20 | 0.93 | (0.82,1.07) | 0.96 | (0.82,1.12) | 0.568 | 58.6 | 53 | 303781 |
| | 20+ | 0.87 | (0.75,1.01) | 0.96 | (0.80,1.16) | 0.681 | 54.6 | 69 | 424094 |
| % Population in low socio-economic classifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 59.2 | 58 | 215756 |
| | 2 | 1.00 | (0.83,1.21) | 0.93 | (0.80,1.09) | | 60.9 | 57 | 209911 |
| | 3 | 1.02 | (0.85,1.23) | 0.98 | (0.83,1.16) | | 60.8 | 58 | 279267 |
| | 4 | 0.91 | (0.74,1.11) | 0.90 | (0.74,1.10) | | 55.3 | 57 | 290203 |
| | 5 | 1.07 | (0.90,1.27) | 1.09 | (0.89,1.33) | 0.652 | 60.3 | 57 | 327941 |
| % Population with no qualifications (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 55.5 | 58 | 235422 |
| | 2 | 0.97 | (0.78,1.20) | 0.92 | (0.77,1.11) | | 60.9 | 57 | 274766 |
| | 3 | 1.04 | (0.85,1.26) | 1.01 | (0.84,1.22) | | 61.9 | 58 | 262985 |
| | 4 | 1.04 | (0.86,1.26) | 1.01 | (0.82,1.24) | | 60.4 | 57 | 242152 |
| | 5 | 0.98 | (0.81,1.19) | 0.93 | (0.75,1.16) | 0.758 | 57.8 | 57 | 307753 |
| % Population unemployed (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 49.4 | 58 | 242949 |
| | 2 | 1.18 | (0.99,1.40) | 1.09 | (0.94,1.27) | | 57.2 | 57 | 273185 |
| | 3 | 1.29 | (1.06,1.57) | 1.19 | (1.02,1.39) | | 59.6 | 58 | 251312 |
| | 4 | 1.33 | (1.13,1.57) | 1.11 | (0.94,1.32) | | 63.5 | 57 | 272230 |
| | 5 | 1.36 | (1.14,1.63) | 1.15 | (0.94,1.41) | 0.217 | 66.9 | 57 | 283402 |
| % Population in primarily outside occupations (quintiles[c]) | 1[b] (lowest %) | 1.00 | | 1.00 | | | 50.2 | 58 | 353120 |
| | 2 | 1.16 | (0.99,1.37) | 1.05 | (0.92,1.21) | | 59.4 | 57 | 317462 |
| | 3 | 1.16 | (0.97,1.40) | 1.00 | (0.85,1.18) | | 62.1 | 58 | 273818 |
| | 4 | 1.27 | (1.07,1.52) | 1.05 | (0.86,1.29) | | 66.8 | 57 | 209269 |
| | 5 | 1.17 | (0.98,1.39) | 1.06 | (0.87,1.30) | 0.676 | 58.1 | 57 | 169409 |

a All univariate models adjust for age group and % male in postcode sector

b Baseline category

c Quintiles across postcode sectors i.e. quintile 1 = lowest fifth of sectors across study area