Journal of Environmental Radioactivity 182 (2018) 12–19

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

High Radon Areas and lung cancer prevalence: Evidence from Ireland

Seraphim Dempsey[a], Seán Lyons[a,b], Anne Nolan[a,b,c,*]

[a] The Economic and Social Research Institute, Sir John Rogerson's Quay, Dublin 2, Ireland
[b] Department of Economics, Trinity College Dublin, Ireland
[c] The Irish Longitudinal Study on Ageing, Trinity College Dublin, Ireland

ARTICLE INFO

Keywords:
Radon risk
Lung cancer prevalence
Logit model

ABSTRACT

This paper examined the relationship between radon risk and lung cancer prevalence using a novel dataset combining spatially-coded survey data with a radon risk map. A logit model was employed to test for significant associations between a high risk of indoor radon and lung cancer prevalence using data on 5590 people aged 50+ from The Irish Longitudinal Study on Ageing (TILDA) and radon risk data from Ireland's Environmental Protection Agency (EPA). The use of data at the individual level allowed a wide range of potentially confounding factors (such as smoking) to be included. Results indicate that those who lived in an area in which 10%–20% of households were above the national reference level (200 Bq/m^3) were 2.9–3.1 times more likely to report a lung cancer diagnosis relative to those who lived in areas in which less than 1% of households were above the national reference level.

1. Introduction

Radon is estimated to be the second most prominent cause of lung cancer worldwide (WHO, 2009). Encouraging preventative health policy (e.g. through the installation of radon preventative measures in new build homes), has the potential to reduce the number of lung cancer cases. Ireland has previously been estimated to have the eighth highest level of indoor radon concentrations amongst OECD countries (WHO, 2009) with average indoor radon concentration levels now estimated to be 77 Bq/m^3 (Dowdall et al., 2017). However, we are not aware of any studies on Ireland that have aimed to establish the relationship between lung cancer prevalence and variations in radon risk. This paper addresses this relationship using survey data on an older population in conjunction with area-based estimates of radon risk.

2. Literature review

Radon primarily enters a building by seeping through the ground floor. In particular, radon is transported into homes ``through cracks in solid floors and walls below construction level; through gaps in suspended concrete and timber floors and around service pipes; through crawl spaces, cavities in walls, construction joints, and small cracks or pores in hollow-block walls'' (Appleton, 2007). Other sources of indoor radon include building materials, and the radon concentrations of groundwater used for domestic drinking water. Radon is the predominant source of radiation exposure in Ireland (estimated to be 56% of the dose received) the majority of which is received in the home (EPA, 2016).

Radon is classified as a Group 1 carcinogen (IARC, 1988) and is the second most prominent cause of lung cancer after smoking (WHO, 2009; Bräuner et al., 2012). While initial epidemiological literature focused on increased levels of radon exposure due to occupation (e.g. underground uranium miners), the 1980s saw more studies examining the relationship between indoor radon exposure and lung cancer in the general population. In order to increase the statistical power of these studies (Lubin et al., 2004), (Darby et al., 2005) and (Krewski et al., 2006) pooled the data from these studies to analyse the relationship for China, Europe and the US respectively. Using pooled analysis from 13 European case-control studies (Darby et al., 2005), estimated a linear dose-response relationship, with the risk of lung cancer increasing by 16% for every 100 Bq/m^3 increase in radon concentration. In addition (Darby et al., 2005), found no evidence of a threshold value, with the dose-response relationship holding for individuals whose homes measured an indoor radon value less than 200 Bq/m^3 Although there is some evidence of a relationship between radon and skin cancer incidence (Wheeler et al., 2012; Bräuner et al., 2015), lymphoid malignancies in women (Teras et al., 2016) and brain tumours (Bräuner et al., 2013), evidence of other radon-induced health effects have been

* Corresponding author. The Economic and Social Research Institute, Sir John Rogerson's Quay, Dublin 2, Ireland.
E-mail address: anne.nolan@esri.ie (A. Nolan).

https://doi.org/10.1016/j.jenvrad.2017.11.014
Received 19 July 2017; Received in revised form 10 November 2017; Accepted 12 November 2017

relatively limited (WHO, 2009). The main outcome of interest in this paper is lung cancer.

Lung cancer is the leading cause of cancer deaths in Ireland, with an estimated five-year survival rate of 15% (NCRI, 2017). Roughly 2300 people are diagnosed with lung cancer every year in Ireland, with around 90% of these cases directly attributable to smoking (NCRI, 2011; NCRI, 2017). This highlights the importance of controlling for smoking when estimating the relationship between radon exposure and lung cancer. Lung cancer can also occur in individuals who have never smoked, with figures ranging from 10% (Subramanian and Govindan, 2007), to 25% (Sun et al., 2007) of all lung cancer cases. Risk factors for non-smoker lung cancer include exposure to passive smoking, asbestos, air pollution (particulate matter), occupational exposure to carcinogenic materials, genetic factors, and radon (Pallis and Syrigos, 2013). Radon exposure is estimated to be the second leading cause of lung cancer after smoking, and the number one cause of lung cancer amongst people who have never smoked (WHO, 2009). Internationally, the proportion of lung cancer cases estimated to be attributable to radon ranges from 3 to 14% depending on the average radon concentration in the country (WHO, 2009). There is also evidence of synergistic effects between radon exposure and smoking (Meenakshi and Mohankumar, 2013). This means that at any given level of radon concentration, the absolute risk of developing radon-induced lung cancer is higher among cigarette smokers than lifelong non-smokers (WHO, 2009). Indeed current smokers are estimated to be 25 times more at risk from radon than life-long non-smokers. At a radon concentration of 200 Bq/m^3, this translates to a risk of 1 in 30 for active smokers and 1 in 700 for non-smokers (EPA, 2016).

It is estimated that up to 250 cases of lung cancer are linked to radon exposure in Ireland every year (EPA, 2016). These estimates are based on the findings from (Darby et al., 2005) and applied to Irish data as described in (RPII & NCRI, 2005). However, we are not aware of any national studies, either ecological or case-control, that have examined the relationship between radon risk and the prevalence of lung cancer within an Irish context. The most notable examination of radon-induced lung cancer within an Irish context resulted from two cases of lung cancer in non-smokers which prompted the discovery of a household with levels of indoor radon 250 times higher than the national reference level (Organo et al., 2004; Organo and Murphy, 2007; McLaughlin et al., 2005). Similarly (Smyth et al., 2016), investigated reducing radon exposure as a method of secondary prevention of lung cancer in a rapid access lung cancer clinic in Galway University Hospital, Ireland.

The World Health Organisation (WHO) recommends a national reference level (maximum accepted radon concentration level in a residential building, above which remedial action is recommended) of 100 Bq/m^3 in order to minimise health hazards (WHO, 2009). However, countries which have average indoor radon levels of 80 Bq/m^3 or higher (e.g. France, Finland and Sweden) would find it extremely challenging to achieve such a low national reference level. As such the WHO recommends that in cases where country-specific conditions prevent lower reference levels being reached, that a reference level of 300 Bq/m^3 should not be exceeded (WHO, 2009). Ireland's national Reference Level is set at 200 Bq/m^3, with High Radon Areas defined as areas in which a predicted 10% or more of homes exceed the national reference level. Technical Guidance Document C of the 1997 Building Regulations requires all newly built homes to install a standby radon sump which can become activated if radon concentrations become too high. In addition, it requires that all homes in High Radon Areas install a radon barrier. The National Radon Control Strategy (NRCS, 2014) is a radon control strategy developed by an inter-agency group set up by the Irish Government in order to co-ordinate the policy response to reducing the health risks derived from exposure to radon.

2.1. Methods

Two sources of data were linked for use in our analysis. The Irish Longitudinal Study on Ageing (TILDA) is a nationally representative longitudinal study of people aged 50 and over in Ireland. Data from Wave 1 (W1) (W1 is the first interview campaign) was collected between October 2009 and July 2011 from 8175 individuals aged 50 and over, from the 6279 households that participated in the study. Interviews were also conducted with the 329 younger spouses and partners of TILDA participants (even if aged less than 50), leading to a total sample size of 8504. Interviews were conducted by trained interviewers in each respondent's homes, and were carried out using Computer Assisted Personal Interviewing (CAPI). Further waves (campaigns) were collected between February 2012 and March 2013 (Wave 2), April 2014 and December 2015 (Wave 3) and, finally, between March 2016 and December 2016 (Wave 4). At Wave 1, respondents also completed a self-completion questionnaire (SCQ), designed to collect more sensitive information (e.g. mood), and took part in a nurse-led health assessment (Whelan and Savva, 2013). However, data from the SCQ or health assessment were not used in this study. Only those aged 50 and over were included in our model, as these are the core TILDA respondents and thus nationally representative at the baseline.

Data on the outcome variable was obtained from the “Physical and Cognitive Health” Section of the CAPI questionnaire, where TILDA respondents indicated whether or not they had ever been diagnosed with lung cancer. The use of individual-level data meant that key factors could be controlled for when estimating the relationship between estimated radon risk and the probability of reporting a lung cancer diagnosis. Here we use Wave 1 data to control for the number of years each TILDA respondent smoked, alongside a number of socio-demographic characteristics such as age, gender, highest level of education and population density of the electoral division in which the respondent is located (used as a proxy for relative air pollution levels). The inclusion of these factors was motivated by drawing on the literature. As outlined above, the predominant cause of lung cancer is smoking, followed by exposure to radon. The remaining non-smoker lung cancer cases are generally attributed to either genetic factors, or such non-genetic factors as occupational exposure, socio-economic status, air pollution, household fumes and infections/medical history (Peddireddy, 2016; Marie Quinn et al., 2016; Gibelin and Couraud, 2016; Couraud et al., 2012). There is also growing evidence that gender matters with regards to the prevalence of lung cancer, with the prevalence of lung cancer in non-smokers tending to be higher in women than in men (Peddireddy, 2016; Couraud et al., 2012). Similarly, while the prevalence of lung cancer is generally found to increase with age, Pearce and Boyle (2005) found that although lung cancer rates were significantly higher in areas expected to have the highest levels of radon, this relationship was not statistically significant for those aged over 54.

It was also important to include the length of time each TILDA respondent had lived at their current address. Radon exposure is defined as the amount of time spent in any given radon concentration and is calculated by “multiplying the radon concentration, measured in Bq/m^3 of each area by the amount of time spent in that area” (WHO, 2009). Drawing upon the literature on underground miners, we assume a minimum lung cancer latency period of five years (Barros-Dios et al., 2012; Field et al., 2002), and as such, we removed data from respondents who have lived less than 5 years at their residence as of W1. Fig. 2 in the Appendix describes the construction of the final sample of 5590 TILDA respondents used in our analysis.

Fig. 1 shows the radon risk map of Ireland published by the Environmental Protection Agency,[1] which is used to segment the indoor radon risk levels of TILDA respondent residential dwellings. This radon

[1] For more information see http://gis.epa.ie/Envision.