Health Information and Quality Authority

An tÚdarás Um Fhaisnéis agus Cáilíocht Sláinte

Analysis of spatial patterns of respiratory mortality in the HSE Mid-West region

December 2020

Safer Better Care

About the Health Information and Quality Authority (HIQA)

The Health Information and Quality Authority (HIQA) is an independent statutory authority established to promote safety and quality in the provision of health and social care services for the benefit of the health and welfare of the public.
HIQA's mandate to date extends across a wide range of public, private and voluntary sector services. Reporting to the Minister for Health and engaging with the Minister for Children and Youth Affairs, HIQA has responsibility for the following:

- **Setting standards for health and social care services** — Developing person-centred standards and guidance, based on evidence and international best practice, for health and social care services in Ireland.

- **Regulating social care services** — The Office of the Chief Inspector within HIQA is responsible for registering and inspecting residential services for older people and people with a disability, and children's special care units.

- **Regulating health services —** Regulating medical exposure to ionising radiation.

- **Monitoring services** — Monitoring the safety and quality of health services and children's social services, and investigating as necessary serious concerns about the health and welfare of people who use these services.

- **Health technology assessment** — Evaluating the clinical and cost-effectiveness of health programmes, policies, medicines, medical equipment, diagnostic and surgical techniques, health promotion and protection activities, and providing advice to enable the best use of resources and the best outcomes for people who use our health service.

- **Health information** — Advising on the efficient and secure collection and sharing of health information, setting standards, evaluating information resources and publishing information on the delivery and performance of Ireland's health and social care services.

- **National Care Experience Programme** — Carrying out national service-user experience surveys across a range of health services, in conjunction with the Department of Health and the HSE.

Evaluation team

This report was compiled by Conor Teljeur and Máirín Ryan of the HTA Directorate in HIQA.

Peer review

This report was reviewed by external experts to ensure that the methods and interpretation were appropriate.

- Andrew Kibble - Centre for Radiation, Chemical and Environmental Hazards, Public Health England
- Paul Callow - Centre for Radiation, Chemical and Environmental Hazards, Public Health England
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The results presented in this report are based on analysis of mortality data sourced from strictly controlled Research Microdata Files provided by the Central Statistics Office (CSO). The CSO does not take any responsibility for the views expressed or the outputs generated from this research.

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Summary

In September 2017, the Health Service Executive (HSE) Department of Public Health Mid-West requested an analysis of spatial patterns of respiratory mortality in the HSE Mid-West region. The HSE Mid-West comprises Clare, Limerick and Tipperary North.

Mortality rates vary by geographical location for a variety of reasons, including demographic, socio-economic and environmental factors. Many causes of death are associated with a socio-economic gradient such that mortality rates are higher in those people with lower socio-economic status. The major risk factors for chronic respiratory disease include tobacco smoke, indoor and outdoor air pollutants, and allergens, although most of the burden is generated by tobacco smoking. Exposure to airborne pollutants can also lead to increased morbidity and mortality in exposed populations. In relation to the HSE Mid-West, there was particular interest in exploring whether there was any association between respiratory mortality and proximity to the Irish Cement plant.

The analysis used small area data on respiratory mortality from 2011 to 2015. The analysis investigated whether area deprivation, urban status and distance to the Irish Cement plant could potentially explain variation in respiratory mortality rates.

The key findings of the analysis were that there was:

- a significant association between deprivation and respiratory mortality, and
- no association between proximity to the Irish Cement plant and respiratory mortality.

Limerick City is the most deprived local authority area in Ireland and contained 21 of the 24 electoral divisions in the HSE Mid-West that were found to have significant elevated respiratory mortality rates.

The study had some limitations. Mortality data were based on area of residence which may not be a good proxy for exposure. Distance to the plant was examined but the prevailing wind direction was not taken in to account. There was no evidence of an elevated mortality rate in the electoral divisions within the estimated plume area of the plant.

On the basis of the analysis presented here, there is a strong association between respiratory mortality in the HSE Mid-West and deprivation: respiratory mortality is higher in more deprived areas. There is no apparent association between proximity to the Irish Cement plant and respiratory mortality. Structures to ensure the routine small area coding of mortality and morbidity data would facilitate analyses in relation to public health concerns.

1 Introduction

1.1 Background to the request

In September 2017, the Health Service Executive (HSE) Department of Public Health Mid-West requested an analysis of spatial patterns of respiratory mortality in the HSE Mid-West region. The request came on foot of a public perception of a potential clustering of respiratory health outcomes in the HSE Mid-West region.

1.2 Overview

Demographic, ethnic, socio-economic and environmental factors vary by geographical location. Mortality rates are known to vary by geographical location and also to depend on demographic, environmental and socio-economic factors. According to the first law of geography, regions that are in closer proximity are expected to be more similar than those that are further apart.[(1)] As such, areas close to each other tend to have similar mortality because of similar socio-economic and environmental conditions and demographic characteristics. In analysing the spatial distribution of mortality, it is important to consider the factors that may impact on rates and to account for the fact that neighbouring areas may have similar rates.

That social inequalities exist in health status and health outcomes is well established and has been demonstrated for both morbidity and mortality.[(2)] However, the reasons for health inequalities can be complex and the impact of socio-economic disparities varies by health outcome. The health status of an individual is influenced by individual-level characteristics and behaviours, by their peers and the immediate community, by their living and working conditions, and finally by general socioeconomic, cultural and environmental conditions.[(3)] Behaviours such as tobacco smoking can have substantial negative consequences for health and are often more prevalent in areas of high deprivation. The major risk factors for chronic respiratory disease include tobacco smoke, indoor and outdoor air pollutants, and allergens, although most of the burden is generated by tobacco smoking.[(4)] Social inequalities in exposure to ambient air pollution have been demonstrated in Western Europe.[(5)] Health inequalities have also been observed for respiratory mortality, with people of lower socio-economic status having higher mortality rates.[(6)] An analysis of Irish mortality data showed a strong positive correlation between measures of deprivation and respiratory mortality, highlighting the presence of health inequalities in Ireland.[(7)] It is therefore clear that more deprived communities may have a greater burden of respiratory morbidity and mortality due to higher rates of tobacco smoking and increased exposure to air pollution. Acknowledging the presence of health inequalities is an important facet of an analysis of spatial patterns of health outcomes. However, it is also important to acknowledge that measures of socio-economic status may act as a proxy for exposure to environmental conditions, and therefore an analysis should be carried out both with and without measures of deprivation.[8]

The incineration of fuel, hazardous waste, municipal solid waste, and medical waste all lead to the dispersal of airborne pollutants in the vicinity of an incineration facility. Airborne pollutants can lead to increased morbidity and mortality in exposed populations. Some of the commonly produced pollutants have been found to cause various adverse health effects, although typically at concentrations much higher than those usually produced by emissions from an incineration facility.[9] There is a long history of analyses of the association between proximity to a point source of pollution and health outcomes. Large scale analyses have often used a simple measure of proximity in lieu of data on actual exposure to pollutants. In the absence of detailed pollution data, the area of exposure for point sources of pollution has typically been set as a radius of 3km or less.[9-11] The use of simple radii assumes that everyone at a specified distance or within a specified distance band has the same exposure, ignoring the issue of how pollutants may be distributed due to wind and topography.[12] Although such arbitrary use of distance as a proxy for exposure may limit the applicability of the analyses,[13] it can facilitate an exploratory analysis that may highlight the need for more detailed data collection.

Ireland has a number of laws in place that are intended to reduce pollutants in the air. The Environmental Protection Agency (EPA) is the competent authority for the implementation of all Irish and EU ambient air quality legislation including the EU Clean Air for Europe (CAFÉ) Directive and is responsible for monitoring ambient air quality. The EPA is the regulatory body responsible for licensing and regulating large scale industrial activities (e.g., cement manufacturing) and waste facilities (e.g., incinerators) so that they do not endanger human health or harm the environment. The remit of the EPA includes setting limits on emissions and overseeing compliance at facilities. The limits set for emissions are designed to protect human health and avoid adverse outcomes. Studies in the UK have found that the emissions from modern municipal waste incinerators contribute only a small proportion to background particulate matter levels within 10km of those incinerators.[14] In the absence of evidence of an effect on human health, Public Health England have stated that: "modern, well run and regulated municipal waste incinerators are not a significant risk to public health. While it is not possible to rule out adverse health effects from these incinerators completely, any potential effect for people living close by is likely to be very small."[15]

Any potential association between a point source of pollution and respiratory outcomes might be highly localised, depending on the factors affecting the dispersion of pollutants (e.g., prevailing wind conditions, type of pollutants, stack height). An analysis at a highly aggregated level, such as county, would be unlikely to identify whether any association between pollutant exposure and health outcomes was present. More typical approaches might be to use individual geolocations for households, or to use small administrative areas, such as post codes or electoral divisions (EDs). Use of individual house points creates substantial challenges in terms of data gathering and coding, and often necessitates a case-control type analysis where known cases are matched to controls. An analysis based on small area data can reduce the data coding burden, and is facilitated by the routine collection of population data through the national census. Small areas need to be sufficiently small that differences in exposure can be captured adequately. However, small areas give rise to the issue of small numbers, particularly for rare events: that is, there may be very few or no events in a given small area over the time period of interest. In such cases, a difference of one or two events could lead to markedly different interpretations about the event rate in an area.

Statistical models are available that incorporate information from neighbouring small areas to adjust estimates of the local event rate. These methods have been widely used. For example, in the mid-1990's, an analysis of health was carried out due to concerns over exposure to emissions from the Aughinish Alumina facility near Askeaton in Co. Limerick.[16] The work was instigated on foot of complaints by the farming community of animal health problems. That analysis included a module on human health which assessed cancer and mortality in addition to other outcomes. As part of that work, proximity to the facility and deprivation were both incorporated into the analysis and the methodology used a spatial modelling approach appropriate for small numbers.

1.3 Purpose of the study

The main purpose of this study was to conduct a spatial analysis of the distribution of respiratory mortality in the HSE Mid-West region. As part of the analysis, we sought to explore whether there is any evidence of a potential relationship between proximity to the Irish Cement plant in County Limerick and respiratory mortality in the HSE Mid-West region.

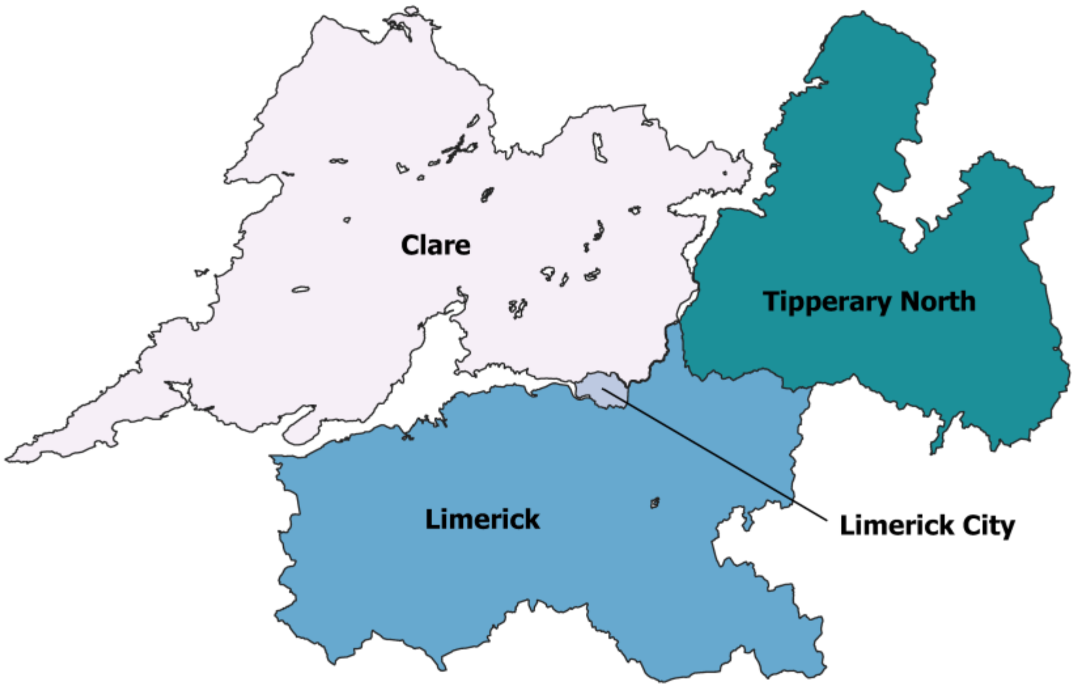
2 Methods

This chapter describes the methods and data used for the spatial analysis.

2.1 Region

The HSE Mid-West region comprises the administrative counties Clare, Limerick and Tipperary North. Limerick is further split in to Limerick City and County (Figure 2.1). The region had a population of 379,327 in 2011 and 384,998 in 2016. The region comprises 404 electoral divisions (EDs) that range in population from 66 to 18,388 persons. For the subsequent analyses, 'Limerick County' is all of Limerick excluding Limerick City.

Figure 2.1 HSE Mid-West region



2.2 Mortality data

Respiratory deaths for all ages were provided by the Central Statistics Office (CSO) for the HSE Mid-West region for the five years from 2011 to 2015. This study was initiated in 2017 and, at the time, the 2015 mortality data were the most recent complete year of data available for analysis. Due to the anticipated small numbers of deaths for many of the EDs, five years of data were used to ensure adequate data to be able to detect spatial patterns of mortality.

2.3 Spatial data

Mortality data were coded to the 404 EDs in the HSE Mid-West region for the purposes of analysis. Coding was based on the address data included in the death certificates of all cases.

ED boundary data were obtained from the CSO. ED boundaries were required to determine the neighbourhood matrix – that is, which EDs bordered each other. The spatial analysis models use adjacency as part of the spatial smoothing algorithm. The map data incorporated bodies of water (e.g., the Shannon estuary) to ensure that EDs that were separated by water were not considered neighbours for the purposes of analysis.

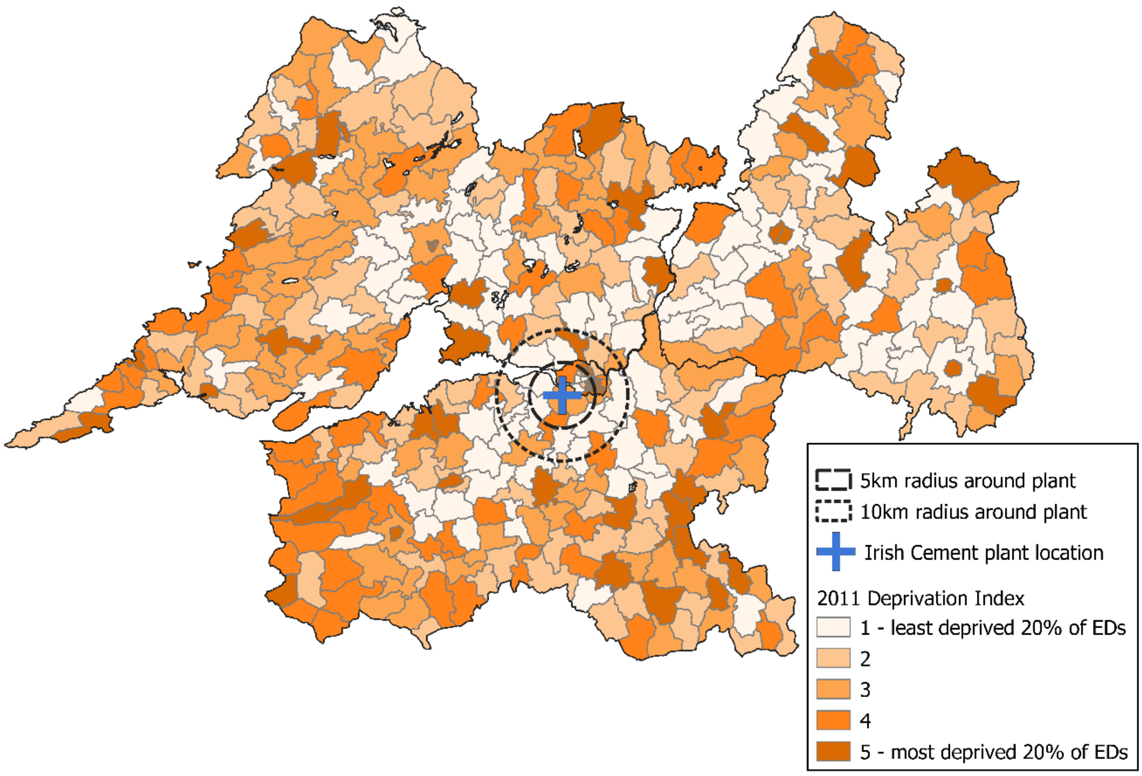
2.4 Covariates

Observed spatial patterns of mortality may be due to a range of factors. As in any regression model, available area-level covariates may be included. For this analysis, three covariates were considered: distance from the Irish Cement plant; urban area;(17) and deprivation.(18) The distance from the Irish Cement facility was calculated as a straight line distance from the plant to each population weighted ED centroid. The relationship between exposure and distance may be complex, and challenging to model accurately. For this preliminary analysis, EDs were classified according to whether they were within 5km, 5 to 10km or greater than 10km from the Irish Cement plant. A cut-off of 5km was used due to the limited number of small areas within that distance: only one ED was within 3km of the facility. While the highest ground concentrations of pollutants may occur a short distance from a pollutant source, it is highly likely that they would still be within a kilometre of the source. The 5km radius around the plant will contain the population at highest risk of exposure. However, a 5km region will also include populations not at risk of exposure as they may be upwind of the plant. At greater distances, any effect associated with emissions from the Irish Cement plant would be negligible due to dispersion and dilution. Based on data from the Shannon Airport synoptic weather station, the prevailing wind direction for the region is south to south-westerly (Appendix 1).

Exposure to air pollution may be expected to be higher in urban areas due to increased traffic, industry and other point sources of emissions. To account for this potential influence on respiratory mortality, a measure of the urban-rural status of areas was included as a covariate. The status was measured using a multi-dimensional measure developed for health services research,(17) with the index updated using 2011 data. The index reflects the living conditions of the majority of the population in an electoral division on the basis of population density, population living in a town or city, and distance to the nearest urban centre.

As stated previously, for many health outcomes a relationship with socio-economic status (SES) may be observed such that people with lower SES have poorer outcomes. In the absence of individual-level data on the SES of those who died, deprivation for an individual's area of residence can be used as a marker of SES. The deprivation index is a composite based on four indicators: unemployment, low social class, local authority housing and car ownership. The index is computed at electoral division-level and has been widely used in health services research in Ireland. While the mortality data span the period for 2011 to 2015, an average deprivation score has limited meaning so the 2011 data were used. The deprivation index was incorporated separately as a continuous variable and categorised into quintiles (Figure 2.2). The deprivation index follows a skewed distribution, with high values observed in some EDs. When included as a categorical variable, EDs that are grouped together in the most deprived quintile may have very different levels of deprivation. In other words, the span of deprivation captured varies by quintile. However, when included as a continuous variable, the coefficient associated with the variable can be challenging to interpret.

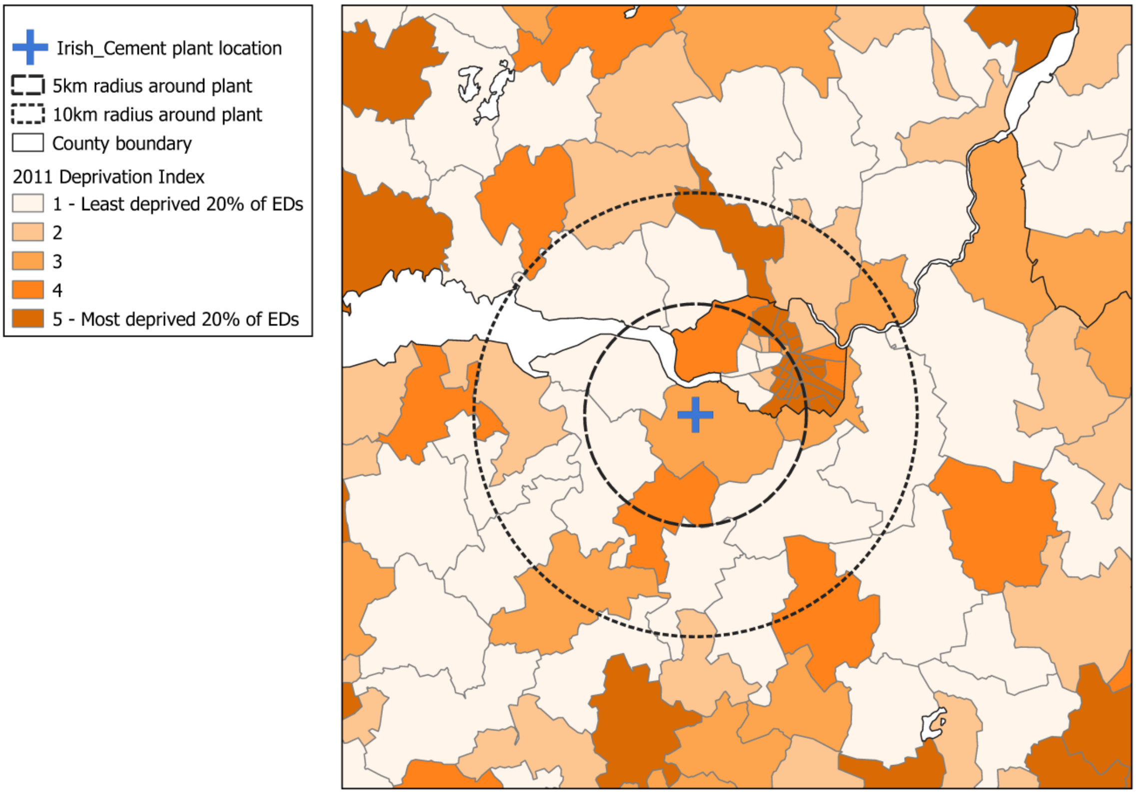
Figure 2.2 Area-level deprivation* in the HSE Mid-West region



* Based on the 2011 SAHRU deprivation index[18]

There is a concentration of highly deprived EDs in Limerick City (Figure 2.3). The Irish Cement plant is located to the south-west of Limerick City (Figure 2.3). Part of the city falls within 5km of the Irish Cement plant and the remainder of the city is situated within 10km of the plant. Limerick City is the most deprived local authority in Ireland. The percentage of the population living in an ED in the most deprived 10% of EDs in the country is 58.5% in Limerick City and 19.1% nationally. The equivalent figures are 25.6% for Tipperary North, 6.9% for Clare, and 8.4% for Limerick County. Limerick City contributes 13.4% of the population in the HSE Mid-West and 43.9% of the population in the most deprived 10% of EDs in the region. Although the 2011 deprivation index was used, it should be noted that there is limited change in deprivation scores over time at an ED level. The 2011 scores were therefore considered applicable across the study period.

Figure 2.3 The location of the Irish Cement plant relative to Limerick City



2.5 Analysis

To account for the small numbers of cases, Bayesian methods for estimating disease rates were used. Incidence is expressed as smoothed incidence rates estimated using conditional autoregressive (CAR) models based on a spatial Poisson model with two random effects.[19] The neighbourhood matrix was defined based on contiguous neighbours.[20] Models were fitted using Markov Chain Monte Carlo

(MCMC) algorithms with WinBUGS software.[21] Estimates were checked to ensure convergence had been reached. A burn-in of 40,000 iterations was performed for each model and the posterior distributions were derived from the subsequent 100,000 iterations. Models were compared on the basis of the Deviance Information Criterion (DIC), which is a criterion that is based on a trade-off between the fit of the data to the model and the corresponding complexity of the model.[22] A model with a lower DIC is better supported by the data. Differences of two or less in the DIC are not considered meaningful when comparing models.[20] Models including none, one, two or all three covariates were evaluated to determine which provided the best fit to the data.

3 Results

The mortality dataset received from the CSO included 1,706 deaths. Fifty six of the addresses were outside the Mid-West region. After geocoding a further 21 cases were removed as they could not be coded to an ED, leaving 1,629 respiratory deaths assigned to the 404 EDs in the region over the five year period 2011 to 2015. That equates to less than one death per ED per year, on average. A total of 61 EDs (15%) had no respiratory deaths recorded over the five year period.

The Irish Cement plant is located in Ballycummin ED which is classified as urban and in deprivation quintile 3.

Based on a simple unadjusted analysis, the aggregate standardised mortality ratio (SMR) is highest greater than 10km from the Irish Cement plant and in the most deprived quintile (Table 3.1). Standardised mortality was lower in deprivation quintile three. There was no evident effect associated with urban-rural status.

Table 3.1 Unadjusted observed and expected respiratory deaths in the HSE Mid-West region (2011-2015) by distance from the Irish Cement plant, by area deprivation quintile and by urban-rural status

Covariate	EDs	Observed	Expected	SMR* (95% CI)	
Distance from Irish Cement					
<5 km	25	208	203.8	102.1	(88.9 – 116.7)
5 to 9.99 km	29	1187	1237.0	96.0	(90.6 – 101.5)
>=10 km	350	234	188.1	124.4	(109.2 – 141.1)
Deprivation quintile					
1 – least deprived	98	288	310.6	92.7	(82.5 – 103.9)
2	91	231	237.9	97.1	(85.2 – 110.2)
3	80	269	303.0	88.8	(78.6 – 99.9)
4	66	245	248.8	98.5	(86.7 – 111.4)
5 – most deprived	69	596	528.7	112.7	(103.9 – 122.1)
Urban-rural status					
Rural	339	932	914.8	101.9	(95.4 – 108.5)
Urban	65	697	714.2	97.6	(90.5 – 105.0)

* Standardised mortality ratio

A total of nine models were run as part of the analysis (Table 3.2).

Table 3.2 Description of the nine models

Model	
1	No covariates
2	Deprivation (as continuous)
3	Deprivation (as quintiles)
4	Distance
5	Deprivation (as quintiles) and distance
6	Deprivation (as continuous) and distance
7	Urban status
8	Deprivation (as continuous) and urban status
9	Deprivation (as continuous) and distance and urban status

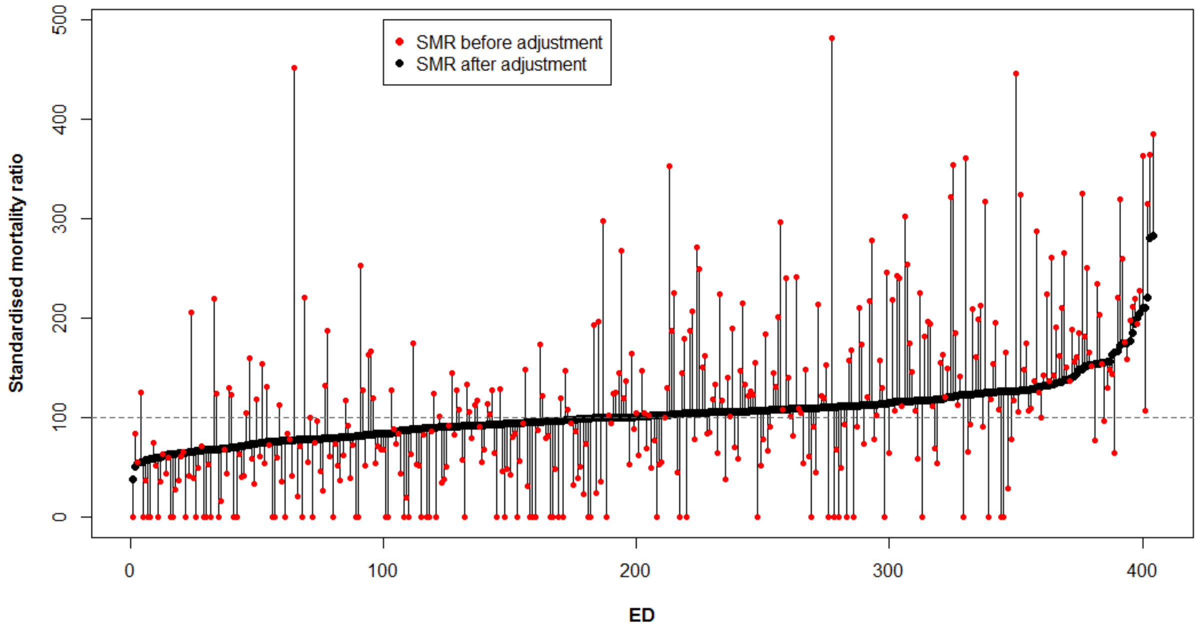
The spatial model adjusts ED-level SMRs taking into account small numbers of observations, events in neighbouring areas, and any included covariates. Figure 3.1 indicates the degree of shrinkage by individual ED. It can be seen that EDs with zero events were adjusted upwards while EDs with very high crude SMRs are generally adjusted downwards. This represents shrinkage towards the mean, with the degree of shrinkage affected by the variance in the ED estimate and the expected SMR based on the covariates.

The deviance information criterion (DIC) was similar for five of the models (1, 3, 4, 5 and 7), but lower in the four models that included deprivation as a continuous variable (Table 3.3). The inclusion of distance from the Irish Cement plant and urban status did not improve the model fit. The best fitting model included deprivation and urban status (model 8). However, inclusion of distance did not markedly reduce the fit and the difference in DIC between models 8 and 9 was less than two. As distance was the covariate of interest, the model 9 incorporating all three covariates [deprivation (as a continuous variable), urban status and distance] was used for the subsequent analysis.

When deprivation was included as a continuous variable, the coefficient was positive and the credible interval did not include zero. That is, SMRs are higher in areas with increased deprivation. When included as quintiles, only quintile 5 (the 20% most deprived EDs) was associated with increased mortality. Due to the impact on the DIC, deprivation as a continuous measure was favoured in the model. The association between mortality and deprivation score is shown in Figure 3.2: more deprived EDs tend to have higher mortality.

When distance was included in the model, the credible intervals for the coefficients included zero and hence distance from the Irish Cement plant was not a significant predictor of respiratory mortality. When deprivation was also included as a covariate, the coefficients for distance were reduced closer to zero.

Figure 3.1 Adjustment to standardised mortality ratios for respiratory mortality in the HSE Mid-West region, 2011-2015

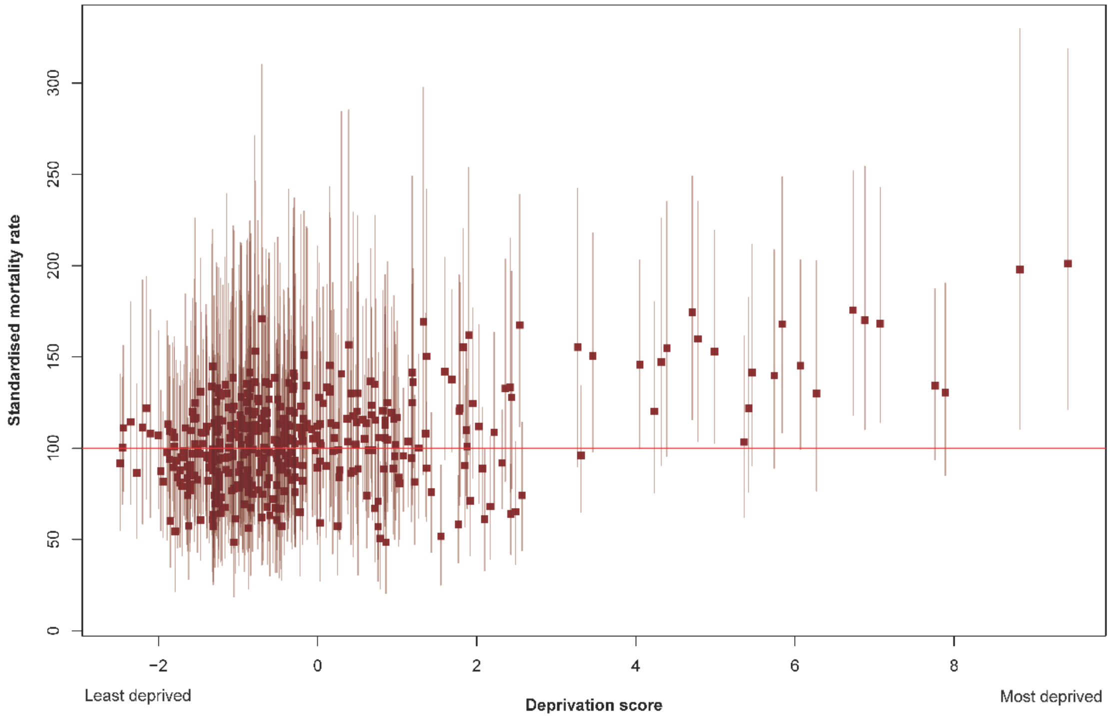


Note: the red points are Electoral Division (ED) SMRs before adjustment, each with a black line connecting it to the SMR value after adjustment for deprivation, urban status and distance from the Irish Cement plant. EDs have been sorted by SMR after adjustment for covariates. For a small number of EDs, there was little or no change in the estimated SMR after adjustment. However, for most EDs the unadjusted SMR was shrunk towards the average value by adjustment reflecting the small numbers of cases and associated uncertainty in the true SMR.

Urban status was associated with a negative coefficient which was not significant in the absence of other covariates. With the addition of deprivation the coefficient for urban status increased in magnitude and became significant. The coefficients for deprivation and urban status were unaffected by the addition of distance to the Irish Cement plant. The fact that the coefficient for urban status was negative suggests that it may reflect an interaction with deprivation rather than necessarily suggesting that urban areas have a protective effect against respiratory mortality relative to rural areas.

The mean standardised mortality ratios for respiratory deaths by ED in the HSE Mid-West region (2011-2015) adjusted for deprivation, urban status and distance from Irish Cement plant are provided in Figures 3.3 (whole region) and 3.4 (area in proximity to the Irish Cement plant).

Figure 3.2 Standardised mortality ratios for respiratory mortality in the HSE Mid-West region (2011-2015) and deprivation score



Note: SMRs here are not adjusted for deprivation, urban status or distance from the Irish Cement plant. SMRs increase with increasing deprivation.

Figure 3.3 Mean standardised mortality ratios for respiratory deaths by ED in the HSE Mid-West region, 2011-2015 (adjusted for deprivation, distance from Irish Cement plant and urban status)

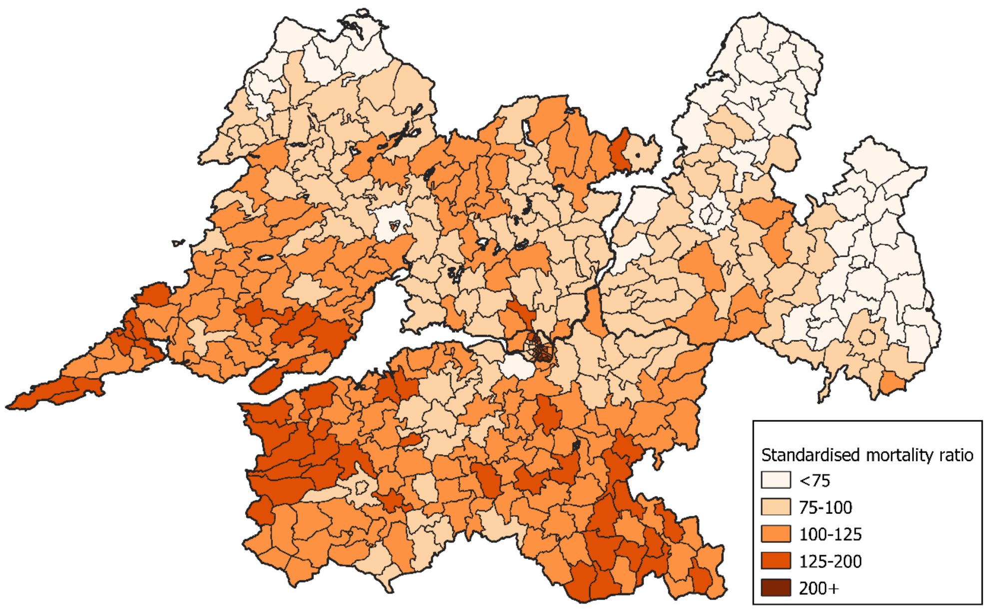


Table 3.3 Model results: coefficients associated with covariates

	Model					
	1	**2**	**3**	**4**	**5**	**6**
DIC*	1585.6	1573.5	1585.1	1585.3	1585.6	1574.8
Intercept	-0.49 [-3.08, 1.49]	1.24 [-1.65, 5.31]	1.80 [-1.57, 5.25]	0.95 [-2.34, 4.77]	1.22 [-1.75, 5.25]	2.13 [-1.63, 6.08]
Deprivation						
Continuous		0.08 [0.05, 0.11]				0.08 [0.05, 0.11]
Quintile 1†			0		0	
Quintile 2			-0.03 [-0.24, 0.17]		-0.03 [-0.24, 0.17]	
Quintile 3			-0.04 [-0.24, 0.16]		-0.04 [-0.24, 0.17]	
Quintile 4			-0.07 [-0.28, 0.13]		-0.07 [-0.28, 0.14]	
Quintile 5			0.19 [0.01, 0.38]		0.18 [-0.01, 0.37]	
Distance (km)						
<5				0	0	0
5 – 9.99				0.25 [-0.04, 0.55]	0.19 [-0.10, 0.48]	0.12 [-0.16, 0.41]
>=10				0.25 [-0.15, 0.66]	0.20 [-0.17, 0.57]	0.15 [-0.21, 0.51]
Urban status						
Rural						
Urban						

* DIC = deviance information criterion

† Quintile 1 is least deprived, quintile 5 is most deprived

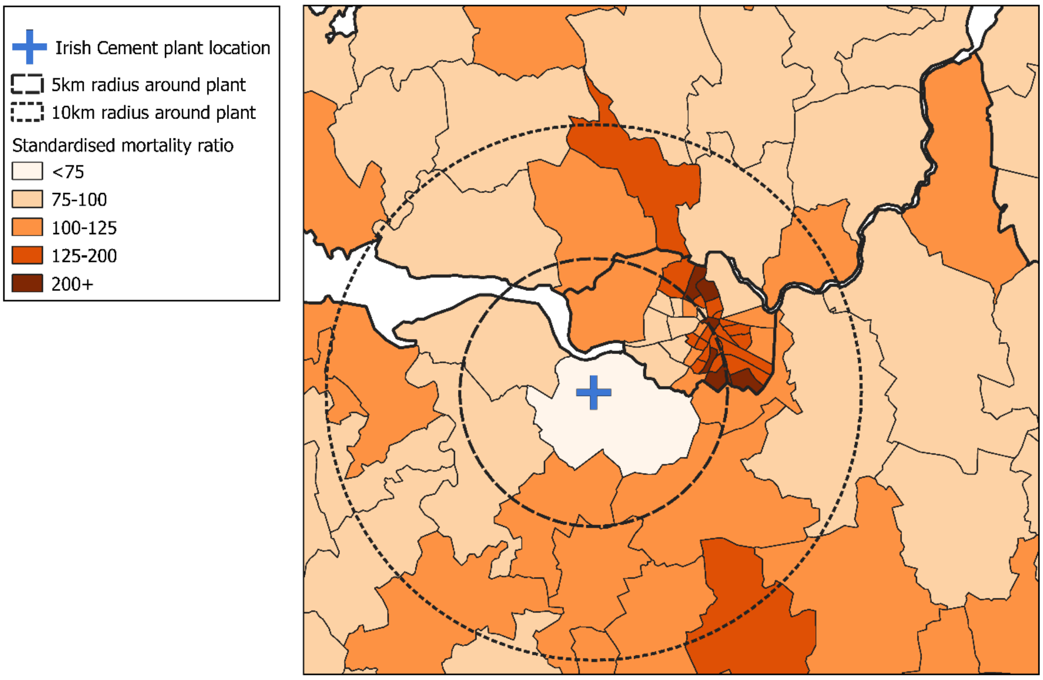
Table 3.3 continued Model results: coefficients associated with covariates

	Model 7	8	9
DIC*	1586.3	1571.4	1573.2
Intercept	5.58 [1.97, 8.61]	8.42 [0.72, 13.85]	3.33 [0.20, 5.40]
Deprivation			
Continuous		0.09 [0.06, 0.12]	0.09 [0.06, 0.12]
Quintile 1†			
Quintile 2			
Quintile 3			
Quintile 4			
Quintile 5			
Distance (km)			
<5			0
5 – 9.99			0.10 [-0.16, 0.37]
>=10			0.01 [-0.33, 0.36]
Urban status			
Rural	0	0	0
Urban	-0.10 [-0.29, 0.08]	-0.25 [-0.43, -0.07]	-0.26 [-0.44, -0.07]

* DIC = deviance information criterion

† Quintile 1 is least deprived, quintile 5 is most deprived

Figure 3.4 Mean SMRs for respiratory deaths by ED in the HSE Mid-West region, 2011-2015 (adjusted for deprivation, distance from Irish Cement plant and urban status)



Based on the model including deprivation (as continuous), distance and urban status, a total of 24 EDs (based on the preferred model, model 9) had SMRs that are considered high based on a lower bound of greater than 100 (Table 3.4). This means that there is a 97.5% chance that the ED SMR is above average. Twenty one of the 24 EDs are in Limerick City and the remaining three are in Limerick County (Figures 3.5 and 3.6). Twenty two of the 24 EDs are in the most deprived 10% of EDs in the country while the remaining two are in the most deprived 20% of EDs in the country. When no adjustment for deprivation, urban status or distance from the Irish Cement plant is made, eleven EDs (all in Limerick City) have a significantly high SMR.

Figure 3.5 Standardised mortality ratios for respiratory deaths in the HSE Mid-West region, 2011-2015 (adjusted for deprivation, distance from Irish Cement plant and urban status)

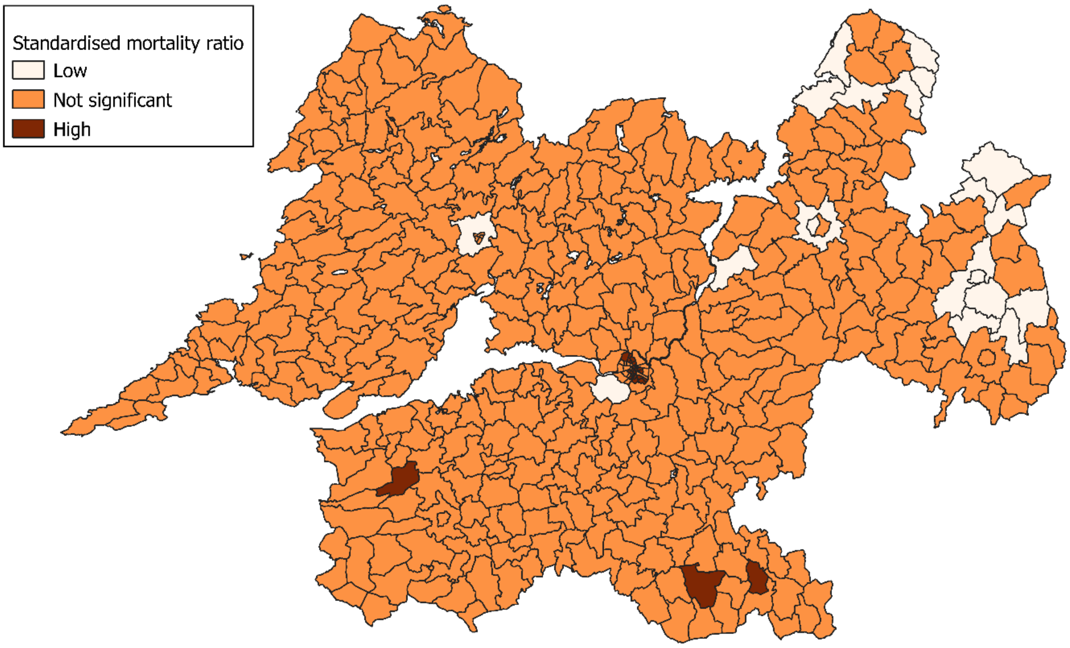


Figure 3.6 Standardised mortality ratios for respiratory deaths in the HSE Mid-West region (2011-2015) in the vicinity of the Irish Cement plant (adjusted for deprivation, distance from Irish Cement plant and urban status)

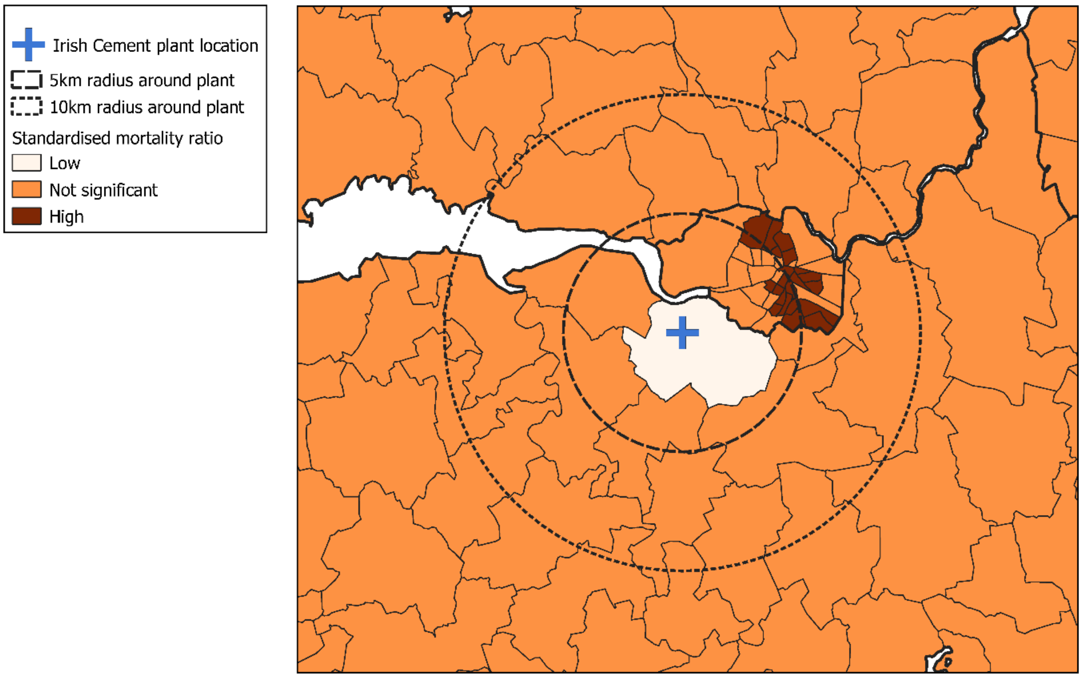
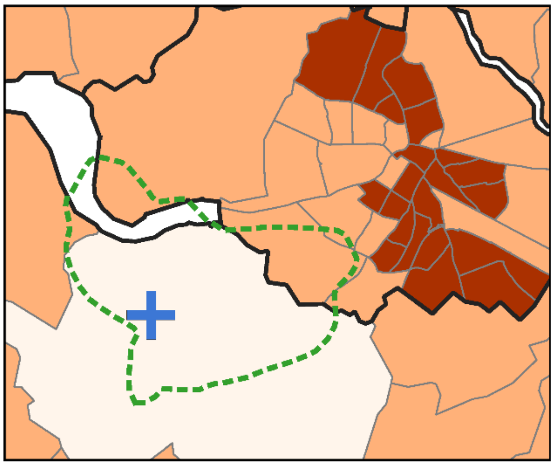


Table 3.4 EDs in the HSE Mid-West region with an elevated standardised mortality ratio for respiratory mortality, 2011-2015

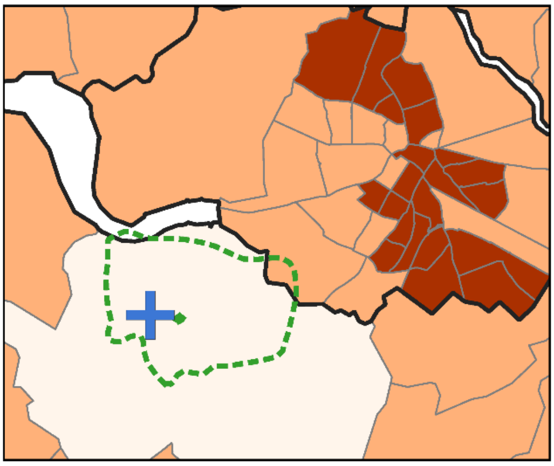
ED ID	ED name	County	SMR (mean [95% CI])	
			Model 1	Model 9
20003	Abbey C	Limerick City		177.6 [120.3 - 250.6]
20004	Abbey D	Limerick City		155.3 [110.6 - 209.8]
20007	Ballynanty	Limerick City		199.8 [141.9 - 270.1]
20013	Custom House	Limerick City		210.5 [141.4 - 298.2]
20014	Dock A	Limerick City		153.9 [101.9 - 220.3]
20015	Dock B	Limerick City		154.7 [101.8 - 225.2]
20019	Galvone A	Limerick City		156.1 [106.3 - 219.1]
20020	Galvone B	Limerick City	198.0 [110.3 - 329.9]	280.6 [169.4 - 434.8]
20021	Glentworth A	Limerick City		156.7 [103.1 - 228.3]
20022	Glentworth B	Limerick City	167.4 [112.0 - 239.1]	148.4 [102.4 - 207.7]
20023	Glentworth C	Limerick City	170.1 [110.2 - 254.5]	210.0 [142.1 - 300.6]
20024	Johns A	Limerick City	201.1 [121.3 - 318.8]	283.2 [183.3 - 416.1]
20025	Johns B	Limerick City		175.4 [125.2 - 235.8]
20027	Killeely A	Limerick City	168.3 [114.1 - 242.6]	220.6 [156.7 - 302.4]
20028	Killeely B	Limerick City	168.0 [108.5 - 248.7]	193.9 [132.6 - 272.9]
20029	Market	Limerick City	152.9 [102.7 - 219.3]	175.2 [123.5 - 239.7]
20030	Prospect A	Limerick City	159.8 [103.9 - 235.0]	167.2 [114.9 - 235.4]
20031	Prospect B	Limerick City		165.4 [104.6 - 243.8]
20032	Rathbane	Limerick City	175.7 [118.1 - 251.7]	204.9 [141.6 - 284.9]
20033	St Laurence	Limerick City	155.3 [105.8 - 220.5]	
20035	Shannon B	Limerick City		163.3 [109.6 - 233.3]
20036	Singland A	Limerick City	174.5 [115.8 - 249.1]	185.3 [128.7 - 256.1]
21039	Kilfinnane	Limerick County		152.7 [105.8 - 212.5]
21070	Ballylanders	Limerick County		174.5 [110.7 - 260.7]
21094	Glensharrold	Limerick County		155.9 [103.3 - 226.1]

The analysis presented included distance from the Irish Cement plant as a covariate, with distance converted into three bands (<5km, 5 to 9.99km, and ≥10km). In classifying distance in that manner, it was assumed that exposure to pollutants would be similar for people living within a distance band. Due to a prevailing south to south-westerly wind direction, the plume is unlikely to be circular. In an environmental impact statement submitted by Irish Cement Ltd. to the EPA, ground-level concentrations were estimated for NO_2 and particulate matter based on emissions data and plume modelling.[23] The areas of greatest impact on ground concentrations of NO_2 and particulate matter are shown in Figure 3.7 and show that none reach the EDs with statistically significant elevated respiratory mortality. The levels mapped are what are considered by EPA to be within safe levels from a population health perspective. Higher concentrations may occur closer to the plant location.

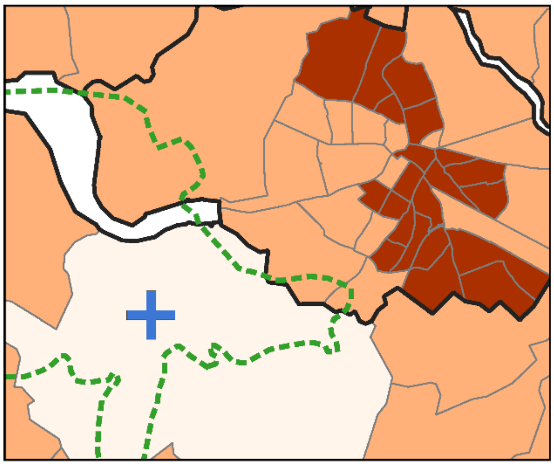
Figure 3.7 Standardised mortality ratios for respiratory deaths in the HSE Mid-West region (2011-2015) in relation to the Irish Cement plant, also showing extent of ground concentration of pollutants



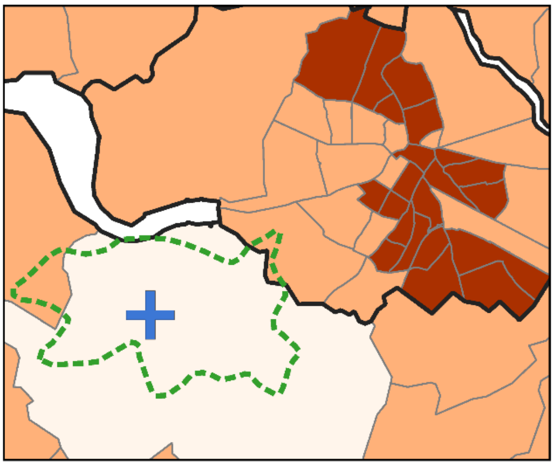
Extent of annual mean $NO_2 \geq 1$ µg/m³



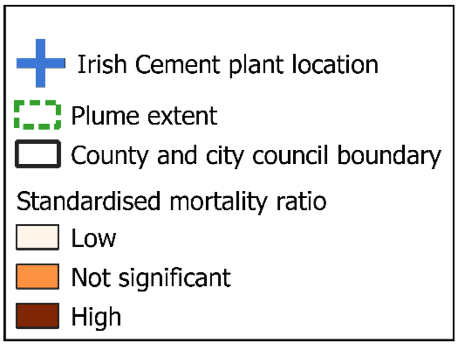
Extent of annual mean PM ≥ 1 µg/m³



Extent of maximum 1 hour $NO_2 \geq 50$ µg/m³



Extent of maximum 24 hour PM ≥ 10 µg/m³



Note: PM, particulate matter.

4 Discussion

The purpose of this study was to explore the spatial distribution of respiratory mortality in the HSE Mid-West region. The analysis was based on the most recent five years of mortality data available, coded to small areas.

4.1 Findings

A range of statistical models were developed with and without covariates of deprivation, urban status and distance to the Irish Cement plant. The model with the best fit included both deprivation as a continuous variable and urban status. The next best model and with similar fit included the covariate of distance to the plant. There was evidence of an association between respiratory mortality and deprivation such that increasing deprivation was associated with a higher standardised mortality ratio. There was no compelling evidence of an association between respiratory mortality and distance to the Irish Cement plant. Based on the model selected on the basis of best fit, 24 EDs were identified with an elevated SMR, twenty one of which were in Limerick City and the remaining three in County Limerick. All but two of the EDs are in the most deprived 10% of areas in Ireland, the remaining two being in the most deprived 20% of EDs nationally. For EDs with an elevated SMR, the SMRs ranged from 148 to 283.

When distance is included as a covariate without deprivation, the findings are that mortality increases with distance from the plant. However, given the width of the credible intervals, it is not possible to rule out no effect of distance. The ED that the plant is in, Ballycummin ED, has a low mortality rate. Based on the available modelled estimates of ground concentrations of pollutants, an association between plant emissions and mortality would be observed within 5km of the plant and not increasing with greater distance. It is likely that distance is acting as a crude measure of what is captured using the deprivation variable. This is further evidenced by the reduced coefficients for distance when deprivation is included as a covariate.

The inclusion of a covariate of urban status suggested that urban areas are associated with a reduced respiratory mortality rate. One might expect that exposure to air pollution would be higher in urban areas due to traffic and industry, and hence respiratory mortality would be higher in urban areas. However, the main contributor to respiratory mortality is tobacco smoking and, in the absence of small area data on smoking prevalence, we cannot comment on whether it is higher in urban areas (after adjusting for deprivation). On its own, urban-rural status was not a significant predictor of respiratory mortality, but was when combined with deprivation. It is possible that urban-rural status is moderating for the fact that deprivation was included as a continuous variable. Deprivation follows a skewed distribution with extreme high values observed in Limerick City, and thus urban-rural status may be attenuating the effect of those high values on mortality.

4.2 Strengths and limitations

The analysis presented here is subject to a number of limitations. Despite the use of five years of respiratory mortality data, there were only 1,629 deaths across the 404 EDs and 61 EDs (15%) had no respiratory deaths recorded over the five year period. Seventy six percent of EDs had five or fewer deaths in the time period. While the analytical methods used were suitable for such rare events, there were still limited data with which to assess potential patterns of mortality. EDs vary in terms of geographic coverage and population. Consideration could be given to analysing data on the basis of small areas rather than EDs. While this may increase the number areas with no events, it would potentially allow for greater granularity in the areas bordering Limerick City.

The analysis did not have access to detailed data on the plume area associated with discharges from the Irish Cement plant. Without plume data, the area of maximum exposure was crudely estimated as a 5km radius around the facility. The assumption underpinning this approach is that all people within the same distance band have equal exposure to emissions. Given the prevailing wind direction, it is likely that exposure is greater to the east and north-east of the plant. Data submitted by Irish Cement Ltd. as part of an environment impact statement included estimated regions of ground concentrations of NO_2 and particulate matter. The mapped areas were mostly contained within Ballycummin ED, with some extending into neighbouring Ballinacurra A ED. The SMR in Ballycummin ED was low (SMR 75, 95% CI: 58 – 94) and not significant in Ballinacurra A ED (SMR 78, 95% CI: 55 – 110). None of the EDs within 4km of the plant had an elevated SMR (that is, an SMR for which the lower credible interval was above 100). A more detailed analysis could seek to use local data on air quality. However, given the findings of a UK study, emissions from the plant might only contribute a small proportion of background concentrations of pollutants.[14] Given that the monitored levels are within what are considered acceptable levels based on air quality standards, coupled with the significant association of mortality rates with deprivation, a more detailed analysis would be unlikely to generate different conclusions.

Another important consideration is the potential lag effect between exposure and respiratory mortality. The vast majority of respiratory deaths were in people aged 65 years and older. It is possible that limited exposure could lead to complications or exacerbations of pre-existing conditions. For younger people it is more likely that prolonged exposure would be required to induce adverse events. Without historical location data, it was assumed that exposure is directly linked to proximity. As death certificate data only records address at the time of death, it was not possible to estimate duration of exposure. In other words, some of those who died may only have moved into the area shortly before their death and hence not had exposure to any potential air pollution originating from the plant. The duration of emissions from the plant and whether it has operated at a consistent capacity over time was not considered in the analysis. Given the central finding that there was no association between respiratory mortality and proximity to the plant, the level of emissions might only be important if it had changed substantially in the last ten years or less. It is worth reiterating that there are air quality regulations and that the EPA have monitoring procedures in place to assess whether emissions exceed acceptable levels.

It should be noted that the analysis of respiratory mortality was part of the Askeaton project which was published in 2001. That analysis was based on a number of study areas within the former Mid-Western Health Board, now HSE Mid-West. The equivalent analysis to that presented here was of respiratory mortality for males and females combined, all ages. The analysis finding was that there was no statistically significant difference within the areas. Comparison with the findings presented here is complicated by the fact that the former analysis used study areas rather than individual EDs in the region.

This analysis adjusted for area-level deprivation. The association between socio-economic status and respiratory mortality is complex due to the fact that exposure to pollutants tends to be higher in more deprived areas. The analysis was carried out with and without deprivation as a covariate. It is important to consider that the prevalence of smoking is much higher in disadvantaged areas than in affluent areas. For context, Limerick City is the most deprived local authority area in Ireland: six of the most deprived 20 EDs in the country are in Limerick City. It would be expected to see a high burden in Limerick City for any health outcome for which there is a strong association with deprivation. It is also possible that deprivation may in part act as a measure of exposure to airborne pollutants. Areas of high deprivation tend to be concentrated in urban centres, such as Limerick City, where air pollution due to traffic and other sources is likely to be high. While a further analysis could seek to incorporate any local data on levels of air pollution, the absence of small area data on smoking prevalence would limit the utility given that smoking is likely to have a much greater effect than atmospheric air pollution. When including socio-economic status in an analysis such as the one presented here, there is a risk that its inclusion may effectively mask an association with environmental factors. Deprived communities typically have greater exposure to environmental hazards than less deprived areas. To mitigate for this potential issue, models were included with and without deprivation. Distance to the plant and urban status were not significant predictors of mortality when deprivation was excluded.

There are significant challenges in linking exposure data and health outcomes. Detailed data are required to establish even a potential link. It should be borne in mind that mortality is an extreme outcome for pollutant exposure. An extension of the analysis could be to investigate morbidity patterns. In Ireland that would be limited to hospitalisation due to the lack of systematic data collection in primary care. Hospital inpatient and daycase data are routinely collected through the Hospital Inpatient Enquiry (HIPE) system with the limitation that area of residence is only coded to county. As noted previously, such a level of aggregation would not facilitate a meaningful analysis of exposure to pollution from a facility. In the conclusions to the Askeaton study published in 2001, it was highlighted that the lack of routine coding of mortality data to a small area-level was unacceptable. Eighteen years on, there is still no routine coding of mortality data to small area-level, hampering the ability of rapid analyses in response to potentially serious public health concerns. With the introduction of the EirCode in 2015, it is possible that small area coding of mortality and morbidity data will become easier in the future if the EirCode becomes integrated into routine data collection. The EirCode records unique house points and therefore does not limit the area-level that an analysis can take place at. From the perspective of mortality data, the death certificate records the place of residence rather than the place of death which can introduce bias, particularly for certain causes of mortality. In the case of the respiratory mortality analysed here, the majority of deaths were in the elderly and the place of residence may be an acceptable proxy for place of death as exposure may have occurred primarily in relation to their place of residence.

It has been noted that use of health service utilisation data can be at substantial risk of bias in the context of air pollution studies, particularly at a primary care-level.[12] The analysis of air pollution effects must therefore take a multifaceted approach that combines health data with contextual information (e.g., air quality, deprivation, and other factors influencing health).

4.3 Conclusions

On the basis of the analysis presented here, there is a strong association between respiratory mortality in the HSE Mid-West and deprivation: respiratory mortality is higher in more deprived areas. There is no apparent association between proximity to the Irish Cement plant and respiratory mortality. Structures to ensure the routine small area coding of mortality and morbidity data would facilitate timely analyses in relation to public health concerns.

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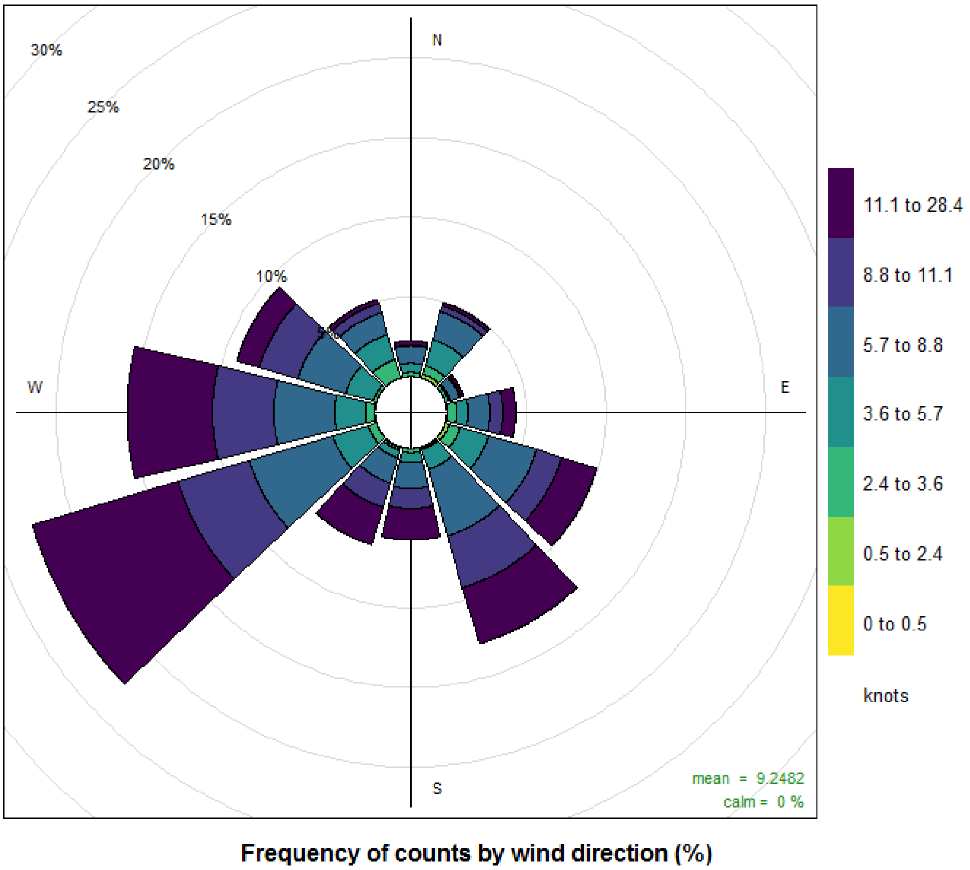
Glossary

Confidence interval	The range of values in which the true value of a parameter (e.g., a proportion) is likely to be found. By convention a 95% confidence interval is usually calculated i.e. the range that will include the true value 95% of the time.
Covariate	A measure of interest that varies across individuals, groups or geographic areas. For example: age, sex, socio-economic group.
Deprivation	A population or community is considered deprived if it lacks the resources to obtain the types of diet, participate in the activities and have the living conditions and amenities which are typical in the societies to which they belong. The deprivation of areas is often measured using data recorded in the Census.
ED	Electoral division the smallest legally-defined administrative area for which small area population statistics are published from the Census. In the 2011 and 2016 Census reports, data were published for 3,409 EDs nationally.
Health inequalities	Health inequality refers to the difference in the prevalence or incidence of health problems between individual people of higher and lower socio-economic status.
Mortality data	Deaths classified by year of death, excluding late registrations but including deaths of non-residents. The Tenth Revision of the International Classification of Diseases, Injuries and Causes of Death (ICD-10) is used to classify deaths in Ireland. The Central Statistics Office is responsible for compiling registered deaths in computerised format
NO_2	Nitrogen dioxide is a chemical compound produced as a result of road traffic and other fossil fuel combustion processes. The main effect of breathing in raised levels of nitrogen dioxide is the increased likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections.
Plume	The mass of smoke, dust or similar substance that rises up into the air from a chimney stack.
PM	PM is particulate matter: a mixture of solid particles and liquid droplets found in the air. PM can impact on health when levels are elevated. Increased levels of PM can also reduce visibility and cause the air to appear hazy.
Quintile	One of five equal groups. Deprivation is sometimes categorized into five levels, where each level contains one fifth of areas.
SMR	Method of comparing mortality of one population with that of another. It is obtained by calculating the expected number of deaths in a given population (if the population had the same mortality as the standard population) and dividing the observed number of deaths by the expected number. Other standardised ratios (e.g. standardised low birth weight ratios) are calculated in the same way

Appendix 1

Daily wind speed and direction data for the Shannon Airport weather station for the study period (1/1/2011 to 31/12/2015) were obtained from Met Éireann.(24)

Figure A.1 Windrose showing wind speed and direction at the Shannon Airport weather station (1/1/2011 to 31/12/2015)



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