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Cancer mortality in towns in the vicinity of installations for the production of cement, lime, plaster, and magnesium oxide

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HIGHLIGHTS

- We studied cancer mortality near cement, lime, plaster and magnesium oxide industry.
- Integrated nested Laplace approximations were used as a Bayesian inference tool.
- We found excess risk from all cancers, and especially in colon–rectum (both sexes).
- Risk was found, principally, in cement plants (men) and lime industries (women).
- Industrial registers, as PRTR, furnish useful information in epidemiologic studies.

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ABSTRACT

Our objective was to investigate whether there might be excess cancer mortality in the vicinity of Spanish installations for the production of cement, lime, plaster, and magnesium oxide, according to different categories of industrial activity. An ecologic study was designed to examine municipal mortality due to 33 types of cancer (period 1997–2006) in Spain. Population exposure to pollution was estimated on the basis of distance from town to industrial facility. Using spatial Besag–York–Mollié regression models with integrated nested Laplace approximations for Bayesian inference, we assessed the relative risk of dying from cancer in a 5-km zone around installations, analyzed the effect of category of industrial activity according to the manufactured product, and conducted individual analyses within a 50-km radius of each installation. Excess all cancer mortality (relative risk, 95% credible interval) was detected in the vicinity of these installations as a whole (1.04, 1.01–1.07 in men; 1.03, 1.00–1.06 in women), and, principally, in the vicinity of cement installations (1.05, 1.01–1.09 in men). Special mention should be made of the results for tumors of colon–rectum in both sexes (1.07, 1.01–1.14 in men; 1.10, 1.03–1.16 in women), and pleura (1.71, 1.24–2.28), peritoneum (1.62, 1.15–2.20), gallbladder (1.21, 1.02–1.42), bladder (1.11, 1.03–1.20) and stomach (1.09, 1.00–1.18) in men in the vicinity of all such installations. Our results suggest an excess risk of dying from cancer, especially in colon–rectum, in towns near these industries.

1. Introduction

Cement, lime and plaster are basic materials used for building and construction, whereas magnesium oxide is mainly used in the steel and refractory industry. During the last decades the constant increase in the construction sector has been reflected in an increase in the production of these materials in Europe (European Commission, 2014), with possible consequences in the health of the population, inasmuch as installations for the production of cement, lime, plaster, and magnesium oxide generate and release toxic emissions and waste into the environment – many

Abbreviations: IPPC, Integrated Pollution Prevention and Control; E-PRTR, European Pollutant Release and Transfer Register; NSI, National Statistics Institute; RRs, relative risks; 95% CrIs, 95% credible intervals; BYM, Besag, York and Mollié; INLAs, integrated nested Laplace approximations; PAHs, polycyclic aromatic hydrocarbons.

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of them known or suspected carcinogens, such as arsenic, chromium, and dioxins – that can pose a health problem to neighboring towns.

Some studies have linked exposure to emissions of cement plants with health risks (Schuhmacher et al., 2004), and specific health outcomes as contact dermatitis (Isikli et al., 2003), risk of hospital admission for cardiovascular or respiratory causes (Bertoldi et al., 2012), and preterm delivery (Yang et al., 2003) among populations residing in its vicinity. To our knowledge, very few epidemiologic studies focused on cancer have been conducted on populations living near cement clinker plants (excluding cement asbestos industries). With respect to installations for the production of lime, plaster and magnesium oxide there are hardly any epidemiologic studies on these installations' health effects on the populations of nearby towns, even though they are known to generate carcinogenic waste, such as mineral oils and materials containing asbestos (European Environment Agency (EEA), 2015). Great interest therefore lies in assessing the possible relationship between these pollutant industries and the frequency of cancer in their environs.

In relation to pollution sources, the European Commission passed the Integrated Pollution Prevention and Control (IPPC) in 2002 and the European Pollutant Release and Transfer Register (E-PRTR) in 2007. IPPC and E-PRTR records constitute an inventory of geo-located industries with environmental impact in Europe, which is a valuable resource for monitoring industrial pollution, and renders it possible for the association between residential proximity to such installations and health impacts, such as cancer, to be studied (Fernandez-Navarro et al., 2012; Lopez-Abente et al., 2012).

Hence, the aims of this paper were to: (1) assess possible excess mortality due to 33 types of cancer among the Spanish population residing in the vicinity of installations for the production of cement, lime, plaster, and magnesium oxide governed by the IPPC Directive and E-PRTR Regulation; (2) analyze this risk according to the different categories of industrial activity, and for each installation individually; and, (3) perform analyses for the population, both overall and by sex.

2. Materials and methods

We designed an ecologic study to examine the association between cancer mortality and proximity to installations for cement, lime, plaster, and magnesium oxide manufacturing industries at a municipal level (8098 Spanish towns), over the period 1997–2006. Separate analyses were performed for the overall population and for each sex.

2.1. Mortality data

Observed municipal mortality data were drawn from the records of the National Statistics Institute (NSI) for the study period, and corresponded to deaths due to 33 types of cancer (see Supplementary data, Table 1). Expected cases were calculated by taking the specific rates for Spain as a whole, broken down by age group (18 groups: 0–4, . . . , 80–84 years, and 85 years and over), sex, and five-year period (1997–2001, 2002–2006), and multiplying these by the person-years for each town, broken down by the same strata. Person-years for each quinquennium were calculated by multiplying the respective populations by 5 (with data corresponding to 1999 and 2004 being taken as the estimator of the population at the midpoint of the study period).

2.2. Industrial pollution exposure data

Population exposure to industrial pollution was estimated by reference to the distance from the centroid of town of residence to the industrial facility. We used the industrial database IPPC + E-PRTR provided by the Spanish Ministry for Agriculture, Food & Environment in 2009. Bearing in mind the minimum induction periods for the tumors targeted for study, generally 10 years for solid tumors and 1 year for leukemias (United Nations Scientific Committee on the Effects of Atomic Radiation, 2006), two industry databases were used:

(a) for the study of leukemias, we selected the 67 installations corresponding to IPPC category 3.1, which came into operation prior to 2002 (1 year before the mid-year of the study period), denominated "pre-2002 installations"; and,
(b) for the remaining tumors, we selected the 60 installations corresponding to IPPC category 3.1 which came into operation prior to 1993 (10 years before the mid-year of the study period), denominated "pre-1993 installations".

The year of commencement of the respective industrial activities was provided by the industries themselves.

Each of the installations was classified into one of the following 4 categories of industrial activities, according to the type of manufactured product:

1. *"Cement":* production of cement clinker (43 pre-2002 and 38 pre-1993 installations);
2. *"Lime":* production of lime (18 pre-2002 and 16 pre-1993 installations);
3. *"Plaster":* production of plaster (4 pre-2002 and 4 pre-1993 installations); and
4. *"Magnesium oxide":* production of magnesium oxide (2 pre-2002 and 2 pre-1993 installations).

Owing to the presence of errors in the initial location of industries, the geographic coordinates of the industrial locations recorded in the IPPC + E-PRTR 2009 database were previously validated: every single address was meticulously checked using Google Earth, the Spanish Agricultural Plots Geographic Information System (Spanish Ministry of Agriculture and Food and Environment, 2015), the GoogleMaps server, the "Yellow pages" web page, and the web pages of the industries themselves, to ensure that location of the industrial facility was exactly where it should be.

2.3. Statistical analysis

Three types of analysis were performed to assess possible excess cancer mortality in towns lying "near" versus those lying "far" from cement, lime, plaster, and magnesium oxide manufacturing industries, known as a "near vs. far" analysis. In all cases, a distance of 5 km was taken as the area of proximity ("exposure") to industrial installations:

(1) in a first phase, we conducted a "near vs. far" analysis to estimate the relative risks (RRs) of towns at $\leqslant$5 km from cement, lime, plaster, and magnesium oxide manufacturing industries as a whole. The variable, "exposure", was coded as: (a) exposed or proximity area ("near"): towns at $\leqslant$5 km from any cement, lime, plaster, and magnesium oxide manufacturing facility; (b) intermediate area: towns at $\leqslant$5 km from any industrial installation other than cement, lime, plaster, and magnesium oxide manufacturing facilities; and, (c) unexposed area ("far"): towns having no (IPPC + E-PRTR)-registered industry within 5 km of their municipal centroid (reference group);
(2) in a second analysis, we stratified exposed or proximity area of analysis anterior into 5 groups according to the previously defined categories of industrial activity: Group 1, made up of