Science of the Total Environment 435–436 (2012) 66–73

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

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

Proximity to mining industry and cancer mortality

Pablo Fernández-Navarro [a,b,*], Javier García-Pérez [a,b], Rebeca Ramis [a,b,c], Elena Boldo [a,b], Gonzalo López-Abente [a,b]

[a] Cancer and Environmental Epidemiology Unit, National Center for Epidemiology, Carlos III Institute of Health, Avda. Monforte de Lemos, 5, 28029 Madrid, Spain
[b] CIBER Epidemiología y Salud Pública (CIBERESP), Spain
[c] School of Health and Medicine, Lancaster University, UK

HIGHLIGHTS

- ► Increased risk of cancer mortality among populations in the vicinity of mines.
- ► We found that underground coal mining was related to digestive cancers and thyroid cancer.
- ► We found that lung cancer was associated with open-air coal mining.
- ► We used information from the European Pollutant Release and Transfer Register.
- ► Integrated nested Laplace approximations (INLA) was used as Bayesian inference tool.

ARTICLE INFO

Article history:
Received 8 May 2012
Received in revised form 6 July 2012
Accepted 6 July 2012
Available online 28 July 2012

Keywords:
Cancer mortality
Mining industry
INLA
European Pollutant Release and Transfer Register

ABSTRACT

Mining installations are releasing toxic substances into the environment which could pose a health problem to populations in their vicinity. We sought to investigate whether there might be excess cancer-related mortality in populations residing in towns lying in the vicinity of Spanish mining industries governed by the Integrated Pollution Prevention and Control Directive, and the European Pollutant Release and Transfer Register Regulation, according to the type of extraction method used. An ecologic study was designed to examine municipal mortality due to 32 types of cancer, across the period 1997 through 2006. Population exposure to pollution was estimated on the basis of distance from town of residence to pollution source. Poisson regression models, using the Bayesian conditional autoregressive model proposed by Besag, York and Molliè and Integrated Nested Laplace Approximations for Bayesian inference, were used: to analyze risk of dying from cancer in a 5-kilometer zone around mining installations; effect of type of industrial activity; and to conduct individual analyses within a 50-kilometer radius of each installation. Excess mortality (relative risk, 95% credible interval) of colorectal cancer (1.097, 1.041–1.157), lung cancer (1.066, 1.009–1.126) specifically related with proximity to opencast coal mining, bladder cancer (1.106, 1.016–1.203) and leukemia (1.093, 1.003–1.191) related with other opencast mining installations, was detected among the overall population in the vicinity of mining installations. Other tumors also associated in the stratified analysis by type of mine, were: thyroid, gallbladder and liver cancers (underground coal installations); brain cancer (opencast coal mining); stomach cancer (coal and other opencast mining installations); and myeloma (underground mining installations). The results suggested an association between risk of dying due to digestive, respiratory, hematologic and thyroid cancers and proximity to Spanish mining industries. These associations were dependent on the type of mine.

Abbreviations: PAHs, Polycyclic aromatic hydrocarbons; IARC, International Agency for Research on Cancer; IPPC, Integrated Pollution Prevention and Control; EPER, European Pollutant Emission Register; E-PRTR, European Pollutant Release and Transfer Register; INE, *Instituto Nacional de Estadística* (National Statistics Institute); MARM, *Ministerio de Medio Ambiente y Medio Rural y Marino* (Ministry for the Environment and Rural & Marine Habitats); SMRs, Standardized Mortality Ratios; INLA, Integrated Nested Laplace Approximations; RR, Relative risks; CIs, Credible intervals; O_i, Observed deaths; E_i, Expected deaths; $Expos_i$, Variable of exposure; Soc_i, Standardized sociodemographic indicators; ill, Percentage of illiteracy; unem, Percentage of unemployed; far, Percentage of farmers; ps, Population size; pph, Average persons per household; inc, Mean income as a measure of income level.

* Corresponding author at: Área de Epidemiología Ambiental y Cáncer, Centro Nacional de Epidemiología, Instituto de Salud Carlos III, Avda. Monforte de Lemos, 5, 28029 Madrid, Spain. Tel.: +34 918222644; fax: +34 913877815.
E-mail address: pfernandezn@isciii.es (P. Fernández-Navarro).

0048-9697/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.scitotenv.2012.07.019

1. Introduction

Mining operations could be releasing toxic substances which may pose a health problem to populations. Not only are mine workers directly affected by their work environment (Gonzalez and Agudo, 1999; Donoghue, 2004; Attfield and Kuempel, 2008), but also toxic substances released may be transported from the mine site and affect local communities and the environment (Garcia-Sanchez et al., 2010; Wu et al., 2011; Gonzalez-Montana et al., 2011; Huertas et al., 2012). These toxic substances emitted from mining facilities include a wide range of toxic substances, such as dioxins, cyanide, mercury, arsenic, lead, cadmium, antimony, polycyclic aromatic hydrocarbons (PAHs) and numerous others, some of them recognized as human carcinogens by the IARC (International Agency for Research on Cancer) (1987).

Spain is a leading global producer of mineral resources in the European Union, with stress on the production of ornamental rocks and minerals (Ministerio de Ciencia e Innovación, 2012). However, the Spanish mining sector displays a general downward trend in terms of both the amount of saleable material and the number of facilities and work sites. More specifically, there has been a gradual reduction in the extraction of energy products such as coal, and a stabilization in metal ore mining (copper, nickel, tin and tungsten). In this context, certain minerals and ornamental rocks, such as celestite, feldspar, gypsum, slate, marble or granite, are becoming more relevant in the sector (Ministerio de Ciencia e Innovación, 2012). The principal coal mines are located in the northern region, specifically in the provinces of Asturias and Leon. The main iron ore deposits are also found in the north, particularly in the provinces of Santander and Vizcaya, while the south (Autonomous Region of Andalusia) is known for metal ore mining, with over half the country's production. The highest values of production in Spain are registered by the Autonomous Regions of Castille-Leon (coal, anthracite, slate, glauberite and tungsten) and Catalonia (oil, ornamental rocks and potash) (Ministerio de Ciencia e Innovación, 2009).

There is some evidence of excess risk of some cancers in the proximity of different types of mining facilities (Dondon et al., 2005; Hendryx et al., 2008; Wang et al., 2011). Dondon et al. (2005) described significant excess mortality due to lung, pharynx and digestive system cancers in the communes surrounding an ore mine in Salsigne, France. They suggested that this excess of cancer deaths is probably explained by arsenic environmental contamination typical from this kind of mining facilities. Hendryx et al. (2008) showed that residence in coal mining areas of Appalachia (USA) is a contributing factor to lung cancer, pointing that the results may be stronger for exposure to surface mining operations relative to underground mining because of greater exposure to airborne particulates from surface mining operations. Wang et al. (2011) also described significant excess mortality due to stomach cancer and other types, such as esophageal cancer in communities surrounding the ore mine of Dabaoshan in China. Moreover, Lopez-Abente et al. (2012) found no excess risk of pleural cancer in the proximity of mining facilities.

With respect to pollution sources, the European Commission directives passed in 2002 afforded a new means of studying the consequences of industrial pollution: the Integrated Pollution Prevention and Control (IPPC), governed both by Directive 96/61/CE and by Act 16/2002, which incorporates this Directive into the Spanish legal system, lays down that, to be able to operate, industries covered by the regulation must obtain the so-called Integrated Environmental Permit. Information gathered as a consequence of the application of these statutory provisions constitutes an inventory of geo-located industries with environmental impact in Spain and across Europe. This same enactment implemented the European Pollutant Emission Register (EPER), now updated in the form of the new European Pollutant Release and Transfer Register (E-PRTR), which incorporates additional information on releases. This new register makes it compulsory to declare all emissions that exceed the designated thresholds. IPPC and E-PRTR records thus constitute a public inventory of industries, created by the European Commission, which is a valuable resource for monitoring industrial pollution and, by extension, renders it possible for the association between residential proximity to such pollutant installations and risk of cancer mortality to be studied. Moreover, E-PRTR records contain information about the activities in which the installations are involved, e.g., in the case of the mining industry, there is a description of the ore-extraction method (opencast or underground) as well as the industrial sub-activity of each installation recorded. A description of this database has already been published elsewhere (Garcia-Perez et al., 2007).

In this context, due to the availability of information on several categories of mines in the IPPC + E-PRTR database, the fact that previous studies focused on only a few tumors and specific types of mines (i.e., coal or metal ore), and the different statistical approaches adopted for analyzing the association between residential proximity to pollutant installations and cancer, the aims of this study were: (1) to assess possible excess mortality due to 32 types of cancer among populations residing in the vicinity of Spanish mining installations governed by the IPPC Directive and E-PRTR Regulation; (2) to study this risk in the context of different types of mines by reference to their respective E-PRTR categories; and, (3) to perform analyses for the population, both overall and by sex, in order to assess possible differences vis-à-vis some mining installations which might or might not point to occupational exposures.

2. Materials and methods

2.1. Data

We designed an ecologic study to examine 32 causes of cancer mortality at a municipal level (8,098 Spanish towns), across the period 1997–2006. Separate analyses were performed for the population, both overall and by sex.

Observed municipal mortality data were drawn from the records of the National Statistics Institute (*Instituto Nacional de Estadística — INE*) for the study period, and corresponded to deaths due to 32 types of malignant neoplasm (Table 1 Supplementary material (SM)). Expected cases were calculated by taking the specific rates for Spain as a whole, broken down by age group (18 groups, 0–4, 5–9,…,85 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. For calculation of person-years, the two five-year periods were considered, with data corresponding to 1999 and 2004 taken as the estimator of the population at the midpoint of the study period. Population data were likewise drawn from INE records.

Population exposure to industrial pollution was estimated by reference to the distance from the town centroid (municipality) to the industrial facility. Municipal centroids used for analysis are not polygonal centroids. They are situated in the center of the most populous zone where the town hall and the main church tend to be located.

We used data on industries governed by the IPPC and facilities pertaining to industrial activities not subject to the IPPC Act 16/2002 but included in the E-PRTR (IPPC + E-PRTR), provided by the Spanish Ministry for the Environment and Rural & Marine Habitats (*Ministerio de Medio Ambiente y Medio Rural y Marino*). We selected the 120 mining installations that corresponded to facilities coded as “3a” (underground mining and related operations) or “3b” (opencast mining and quarrying) in the E-PRTR category from the Mineral Industry PRTR Industrial Activity group (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:033:0001:0017:EN:PDF), which, according to Spain's National Classifications of Economic Activities (*Clasificación Nacional de Actividades Económicas — CNAE*) governed by Royal Decree 472/2007 (see Table 2 SM). The geographic coordinates of their position recorded in the IPPC + E-PRTR database