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Industrial pollution and pleural cancer mortality in Spain ☆

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ABSTRACT

Pleural cancer mortality is an acknowledged indicator of exposure to asbestos and mesothelioma mortality but in 15%–20% of cases no exposure can be recalled. In the past, asbestos was used in many industries and it is still found in many installations. Our objective was to ascertain whether there might be excess pleural cancer mortality among populations residing in the vicinity of Spanish industrial installations that are governed by the Integrated Pollution Prevention and Control (IPPC) Directive and the European Pollutant Release and Transfer Register Regulation and report their emissions to air. An ecological study was designed to examine pleural cancer mortality at a municipal level (8098 Spanish towns) over the period 1997–2006, during which 2146 deaths were registered. We conducted an exploratory "near vs. far" analysis to estimate the relative risks (RRs) of towns situated at a distance of <2 km from installations. This analysis was repeated for each of the 24 industrial groups. RR and their 95% credible intervals (95% CIs) were estimated on the basis of a Poisson conditional autoregressive Bayesian model with explanatory variables. Integrated nested Laplace approximations were used as a Bayesian inference tool. Analysis showed statistically significant RRs in both sexes in the vicinity of 7 of the 24 industrial groups studied (RR, 95% CI), namely, biocide facilities (2.595, 1.459–4.621), ship-building (2.321, 1.379–3.918), glass and mineral fibre production (1.667, 1.041–2.665), non-hazardous waste treatment (1.737, 1.077–2.799), galvanising (1.637, 1.139–2.347), organic chemical plants (1.386, 1.075–1.782) and the food and beverage sector (1.255, 1.006–1.562). In the proximity of sources pertaining to the biocide, organic chemical and galvanising sectors, the risk was seen to be rising among men and women, a finding that could indicate airborne environmental exposure. These results support that residing in the vicinity of IPPC-registered industries that release pollutants to the air constitutes a risk factor for pleural cancer.

1. Introduction

Pleural cancer is a recognised indicator of exposure to asbestos and mesothelioma mortality (Micheli et al., 2003). Incidence and mortality vary widely among countries, depending on their respective degrees of development and statutory restrictions imposed (Park et al., 2011).

Available information about mesothelioma incidence and mortality is biased toward developed countries and is grossly underreported in many developing countries, because mesothelioma is rare and difficult to diagnose (Nishikawa et al., 2008). There is consensus that the pattern of use of asbestos affects the mesothelioma incidence and mortality, and taking this into account, the countries with the highest number of cases predicted are Russia, Kazakhstan, China and India (Park et al., 2011). In Spain, 183 and 58 deaths were recorded among men and women respectively in 2009 (4.2 and 1.0 per million, age-adjusted rates), with the annual mortality trend rising in terms of the absolute number of cases and age-adjusted rates (López-Abente, 2011).

Although malignant mesotheliomas are strictly related to asbestos and 80%–85% are attributable to occupational exposure, in a proportion of cases no asbestos exposure can be recalled (Mirabelli et al., 2010). Increased risk has been reported for workers employed in asbestos mines, asbestos plants, installation and manufacture of insulating materials, production of anti-gas masks, shipyards, railways and other occupations involving inhalation of asbestos dust (IARC, 1987; Agudo et al., 2000). There is sufficient evidence to link asbestos exposure to other types of cancer, such as those of lung, larynx and ovary, and limited evidence to links it to cancers of the digestive system (colorectal, pharyngeal and stomach) (Straif et al., 2009).

Furthermore, there are also reports of mesothelioma development deriving from non-occupational exposure to asbestos. This problem is present in populations living in the proximity of asbestos mines and plants, and family members of workers, who come into household contact with asbestos dust deposited and brought home on work clothes (Magnani et al., 2000; Mirabelli et al., 2010). The presence of

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asbestos in the structure of buildings is yet another potential risk for the appearance of mesotheliomas, due to the release of fibres in asbestos-stripping and demolition tasks (IARC, 1987; Frost et al., 2008).

Due to its excellent physical properties, asbestos has been widely used in many types of industry and for a wide variety of manufactured products. Massive amounts of asbestos were used in shipbuilding and commercial construction prior to the mid-1970s. Exposure to asbestos may take place directly in occupations related with shipbuilding and repair, the asbestos-cement industry, railway carriage construction and maintenance, asbestos mining, ports handling asbestos, textile industry, and friction material, gasket and packaging production. Occupations that use asbestos indirectly (insulation and auxiliary tools) constitute another form of exposure, and accidental or unintended exposures in many other occupations can also occur (Marinaccio et al., 2011).

Geographical variations in the proportion of mesothelioma cases (8%) attributable to non-occupational exposures may be explained by the past distribution of asbestos-using industries (Mirabelli et al., 2010).

In view of the great number of occupations with potential exposure to asbestos, its use in different industrial sectors and the possible existence of emissions, research into the risk of pleural cancer in the vicinity of pollutant industries is of special interest.

European Commission directives passed in 2002 afforded a new means of studying the consequences of industrial pollution: 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 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 PRTR records thus constitute an 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 to be studied (García-Pérez et al., 2009; Monge-Corella et al., 2008; Ramis et al., 2009; López-Cima et al., 2011).

This paper sought to ascertain whether there might be excess mortality due to pleural cancer among the population residing in the vicinity of Spanish industrial installations that are governed by the IPPC Directive and E-PRTR Regulation and report their emissions to air.

2. Methods

An ecological study was designed to examine pleural cancer mortality at a municipal level (8,098 Spanish towns) over the period 1997–2006. Separate analyses were performed for the overall population and each 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 coded as malignant pleural neoplasm, namely, codes 163 (International Classification of Diseases-9th Revision/ICD-9) and C38.4, C45.0 (ICD-10). 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 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. 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 exposure to industrial pollution was estimated by reference to the distance from the centroid of town of residence to the industrial facility. Data on industries that reported releases to air in 2007 were obtained from the IPPC database provided by the Spanish Ministry for the Environment and Rural & Marine Habitats. The geographical coordinates of their respective locations were previously validated. Every single address on IPPC 2007 database was carefully checked using Google Earth (with aerial images and the street-view application), the Spanish Farm Plot Geographic Information System — SIGPAC (SIGPAC, 2010) (which includes orthophotos of the entire surface of Spanish territory, along with topographic maps showing the names of the industries, industrial estates, roads, buildings and streets), the GoogleMaps server (Google, 2010) (which allows for a search of address and companies, and offers high-quality aerial photographs), the "yellow-pages" web page (which allows for a search of addresses and companies), Internet aerial photographs, and the web pages of the industries themselves, to ensure that the location of the industrial facility was positioned exactly where it should be.

In a first phase, an initial exploratory "near vs. far" analysis was conducted to estimate the relative risks (RRs) of towns situated at distances of less than 2 km from installations. This analysis was repeated for each industrial group. These groups were formed on the basis of the similarity of their air-pollutant emission patterns, and their PRTR-defined codes (BOE, 2007) (Official Government Gazette 2007-BOE).

The exposure variable for each industrial group was coded as a "dummy" ($Expos_i$) with the following three levels: 1) exposed group ("near"), i.e., towns having their municipal centroid at a distance ≤2 km from an installation belonging to the group in question; 2) intermediate group, i.e., towns lying at a distance ≤2 km from any industrial installation other than the group analysed; and, 3) unexposed group ("far"), i.e., towns having no IPPC-registered industry within 2 km of their municipal centroid (reference level). In addition, a dichotomous variable was created for all the installations as a whole, namely: 1) exposed group ("near"), i.e., towns having their municipal centroid at a distance ≤2 km from an installation; and, 2) unexposed group ("far"), i.e., towns having no IPPC-registered industry within 2 km of their municipal centroid (reference level).

RRs and their 95% credible/confidence intervals (95% CIs) were estimated on the basis of Poisson regression models, using two types of modelling: a) a Bayesian conditional autoregressive model proposed by Besag, York and Mollié (BYM) (Besag et al., 1991), with explanatory variables; and b) a mixed regression model. In both cases, observed deaths (O_i) were the dependent variable and expected deaths (E_i) were the offset. All estimates for the variable of exposure, described above, were adjusted for the following standardised socio-demographic indicators (Soc_i), chosen for their availability at a municipal level and potential explanatory ability vis-à-vis certain geographic mortality patterns: population size; percentage of illiteracy, farmers and unemployed; average persons per household according to the 1991 census; and, mean income as a measure of income level (Ayuso-Orejana et al., 1993). The variable of exposure and potential confounding covariates were fixed-effects terms in the models.

In the BYM Bayesian autoregressive model, the random effects terms include two components: a spatial term containing municipal contiguities (b_i); and the municipal heterogeneity term (h_i):

$$
\begin{aligned}
&O_i \sim Poisson(\mu_i = E_i \lambda_i)\\
&\log(\lambda_i) = \alpha Expos_i + \textstyle\sum_j \beta_j Soc_i + h_i + b_i \Rightarrow \log(\mu_i)\\
&\qquad = \log(E_i) + \alpha Expos_i + \textstyle\sum_j \beta_j Soc_i + h_i + b_i\\
&h_i \sim Normal(\theta, \tau_h)\\
&b_i \sim Car.Normal(\eta_i, \tau_b)\\
&\tau_h \sim Gamma(\alpha, \beta)\\
&\tau_b \sim Gamma(\gamma, \delta)
\end{aligned}
$$

Integrated nested Laplace approximations (INLAs) were used as a tool for Bayesian inference. For the purpose, we used R-INLA (Rue and

Martino, 2010) with the option of Gaussian estimation of the parameters, a package available in the R environment (R Development Core Team, 2005). A total of 8098 towns were included, and the spatial data on municipal contiguities was obtained by processing the official *INE* maps.

The Poisson regression mixed model (Breslow and Day, 1987; Gelman and Hill, 2007) includes province as a random effects term (p_i), to enable geographic variability to be taken into account and unexposed towns belonging to the same geographic setting to be considered as the reference level, something that is justified by the geographic differences observed in mortality attributable to these tumours (López-Abente et al., 2005):

$$O_i \sim Poisson(\mu_i = E_i\lambda_i)$$
$$\log(\lambda_i) = \alpha Expos_i + \sum_j \beta_j Soc_i + p_i \Rightarrow \log(\mu_i) = \log(E_i) + \alpha Expos_i + \sum_j \beta_j Soc_i + p_i$$

The results of both estimates are shown graphically for ease of interpretation using forestplots. The “boxes” depicted in the figure are proportional in size to the accuracy of the estimator and, thus, to the number of observations included. Of the industrial groups shown in Table 1, we analysed a total of 24, excluding groups 22, 25 and 27 owing to the low number of sources, and group 24 due the fact that it corresponded to farms of little interest for the purposes of our study. No account was taken of induction periods because the year of commencement of industrial operations was unknown to us at the date of analysis.

Table 1
Industrial groups with E-PRTR categories used. Number of installations and towns lying within <2 km. Spain 2007.

Industrial group	E-PRTR category	No. of ind. facilities	Towns <2 km
1 Combustion installations	1.c	138	43
2 Refineries and coke ovens	1.a, 1.d	12	5
3 Production and processing of metals	2.a, 2.b, 2.c.i, 2.c.ii, 2.d, 2.e	172	98
4 Galvanising	2.c.iii	36	22
5 Surface treatment of metals and plastic	2.f	248	156
6 Mining	3.a, 3.b	33	14
7 Cement and lime	3.c, 3.d	70	35
8 Glass and mineral fibres	3.e, 3.f	56	20
9 Ceramics	3.g	457	159
10 Organic chemical industry	4.a	149	77
11 Inorganic chemical industry	4.b	70	28
12 Fertilisers	4.c	23	19
13 Biocides	4.d	12	8
14 Pharmaceutical products	4.e	55	35
15 Explosives and pyrotechnics	4.f	58	28
16 Hazardous waste	5.a, 5.b	90	42
17 Non-hazardous waste	5.c, 5.d	144	29
18 Disposal or recycling of animal waste	5.e	38	22
19 Urban waste-water treatment plants	5.f, 5.g	86	32
20 Paper and wood production	6.a, 6.b, 6.c	88	70
21 Pre-treatment or dyeing of textiles	9.a	25	24
22 Tanning of hides and skins	9.b	2	2
23 Food and beverage sector	8.a, 8.b, 8.c	310	157
24 Intensive rearing of poultry or pigs	7.a	1783	-
26 Surface treatment using organic solvents	9.c	80	48
27 Production of carbon or electro-graphite	9.d	2	0
28 Ship building	9.e	8	4

3. Results

Table 1 shows the groups of industrial sectors used, along with the number of pollutant sources and the number of towns having their centroid at 2 km or less from the pollution source, giving an idea of the importance of the industrial sectors and the studies size. There were 2146 deaths due to pleural cancer across the ten-year study period.

Fig. 1 depicts the results for both sexes of the analyses performed by type of industry, using the two regression models. For each industrial group the figure shows: observed and expected cases in towns situated at 2 km or less from pollutant industries; the RRs obtained with the two estimates; and the 95% credible (BYM model) and confidence intervals (mixed model). Figs. 2 and 3 depict the results for men and women respectively. The results indicate that, across the sexes, populations residing ≤2 km from pollutant facilities faced a higher risk than did unexposed or distant populations (around 20% for the BYM and mixed model).

The highest statistically significant RRs in the analysis of both sexes (BYM model) were detected (RR, 95% CI) (from highest to lowest) in the vicinity of biocide facilities (2.595, 1.459–4.621, ship building (2.321, 1.379–3.918), non-hazardous waste treatment (1.737, 1.077–2.799), glass and mineral fibre production (1.667, 1.041–2.665), galvanising (1.637, 1.139–2.347), organic chemical plants (1.386, 1.075–1.782) and the food and beverage sector (1.255, 1.006–1.562).

Among men, statistically significant excess mortality was detected (BYM model) in towns lying in the vicinity of ship building (2.921, 1.606–5.334), biocide facilities (2.884, 1.465–5.690), non-hazardous waste treatment (2.184, 1.281–3.723), galvanising (1.778, 1.157–2.724), glass and mineral fibre production (1.774, 1.031–3.046), combustion installations (1.512, 1.011–2.259), organic chemical plants (1.431, 1.067–1.916), the food and beverage sector (1.396, 1.081–1.799), and surface treatment of metals and plastics (1.313, 1.040–1.659).

Among women, statistically significant excess mortality was detected in towns lying in the vicinity of refineries (2.828, 1.107–7.252), biocide facilities (3.176, 1.253–8.045), organic chemical plants (1.788, 1.234–2.597) and galvanising (1.750, 0.972–3.150), with the results in these last three sectors coinciding with those for men.

4. Discussion

The results indicate that residing in the proximity of IPPC-registered industries with pollutant emissions to air is associated with pleural cancer mortality. The high number of industrial sectors displaying increased RRs in their environs is probably an indicator of the great amount of occupations which have been described in the literature as being associated with pleural mesotheliomas. These are occupations that are common to many types of industrial activity. Yet, the results also point to a possible increase in risk due to emissions to the environment in the vicinity of some industrial groups, inasmuch as the excess risk is observed among men and women alike.

With respect to the results broken down by sex, attention should be drawn to the RRs (BYM model) registered for men in towns lying near many industrial groups. The fact that 5 of these associations were found in men rather than women leads one to think that the explanation may lie in occupational exposures, with the clearest example being that of shipyards with an RR of close on 3. In the proximity of sources pertaining to the biocide, organic chemical and galvanising sectors, however, the risk was seen to be rising among men and women, a finding that could indicate airborne environmental exposure.

An issue to be discussed is the potential implications of using two classifications for the death codes during the period of interest (ICD-9 and ICD-10). Specifically, for ICD-10 the code corresponding to pleural mesothelioma is C45.0, while C38.4 is rather a topographical code indicating that there is a cancer in the pleura, independently of the

PLEURAL. BOTH SEXES

	Obs	Exp	RR	RR*
1 Combustion installations	50	32.3	1.4	1.493
2 Refineries and coke ovens	16	12.9	1.274	1.585
3 Metallurgical	124	84.2	1.11	1.172
4 Galvanization	48	23.1	1.637	1.891
5 Surface treatment of metals and plastic	252	171.1	1.189	1.248
6 Mineral industry	9	6.1	1.473	1.513
7 Cement and lime	25	12.5	1.611	1.789
8 Glass and mineral fibres	31	14.3	1.667	1.921
9 Ceramic	50	67	0.893	0.88
10 Organic chemical industry	135	69.1	1.386	1.501
11 Inorganic chemical industry	39		1.413	1.318
12 Fertilisers	34	31.2	1.302	1.18
13 Biocides	17	5.2	2.595	2.604
14 Pharmaceutical products	67	40.2	1.148	1.289
15 Explosives and pyrotechnic	8	15.7	0.661	0.598
16 Hazardous waste	45	27.4	1.208	1.459
17 Non-hazardous waste	35	15.1	1.737	1.872
18 Disposal or recycling of animal waste	11	7.7	1.252	1.361
19 Urban waste-water treatment plants	40	39.1	0.978	0.925
20 Paper and wood production	86	65.3	1.134	1.229
21 Pre-treatment or dyeing of textiles	14	10.4	1.216	1.179
23 Food and beverage sector	140	105.4	1.255	1.326
26 Surface treatment using organic solvents	56	47.3	1.019	1.084
28 Building of ships	71	33.3	2.321	2.272
INDUSTRY	**742**	**576.4**	**1.202**	**1.237**

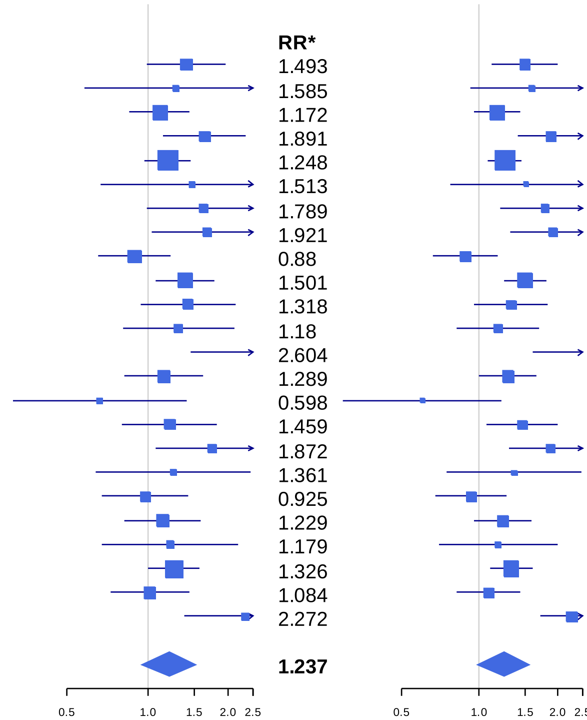


Fig. 1. Pleural cancer mortality in towns situated near pollutant industries belonging to different industrial groups. Observed and expected deaths in towns lying 2 km or less from pollutant industries, relative risks obtained with the two models used, and 95% credible (BYM model) and confidence intervals (mixed model). Both sexes. Spain 1997–2006. Obs = observed cases. Exp = expected cases. RR = relative risk BYM model. RR* = relative risk Poisson regression mixed model.

morphology. ICD-9 only contains a rubric about pleural cancer (163). In this case, the approval of rubrics among classifications used in cancer of pleura is that we have implemented and it is the accepted way to complete the mortality series (WHO, 2008).

A critical question in study design is the choice of radius surrounding industrial installations. Our choice of 2 km as the threshold distance in the "near vs. far" comparisons coincides with that used by other authors (de Marco et al., 2010; Yang et al., 2003) and is justified

PLEURAL. MEN

	Obs	Exp	RR	RR*
1 Combustion installations	38	23.2	1.512	1.613
2 Refineries and coke ovens	7	9	0.901	0.991
3 Metallurgical	92	60.6	1.146	1.207
4 Galvanization	35	16.6	1.778	2.011
5 Surface treatment of metals and plastic	187	122.4	1.313	1.334
6 Mineral industry	7	4.3	1.814	1.771
7 Cement and lime	18	9.1	1.597	1.863
8 Glass and mineral fibres	24	10.3	1.774	2.04
9 Ceramic	39	48.5	0.99	0.974
10 Organic chemical industry	98	50	1.431	1.54
11 Inorganic chemical industry	28	15.9	1.367	1.343
12 Fertilisers	20	21.9	1.069	0.989
13 Biocides	12	3.7	2.884	2.665
14 Pharmaceutical products	56	29.1	1.435	1.517
15 Explosives and pyrotechnic	6	11.2	0.697	0.652
16 Hazardous waste	36	19.6	1.304	1.625
17 Non-hazardous waste	31	10.8	2.184	2.279
18 Disposal or recycling of animal waste	7	5.6	1.126	1.202
19 Urban waste-water treatment plants	26	28.3	0.913	0.834
20 Paper and wood production	70	46.3	1.434	1.541
21 Pre-treatment or dyeing of textiles	10	7.5	1.305	1.201
23 Food and beverage sector	107	75.6	1.396	1.468
26 Surface treatment using organic solvents	39	34	0.971	1.041
28 Building of ships	61	23.2	2.921	2.967
INDUSTRY	**557**	**412.4**	**1.188**	**1.239**

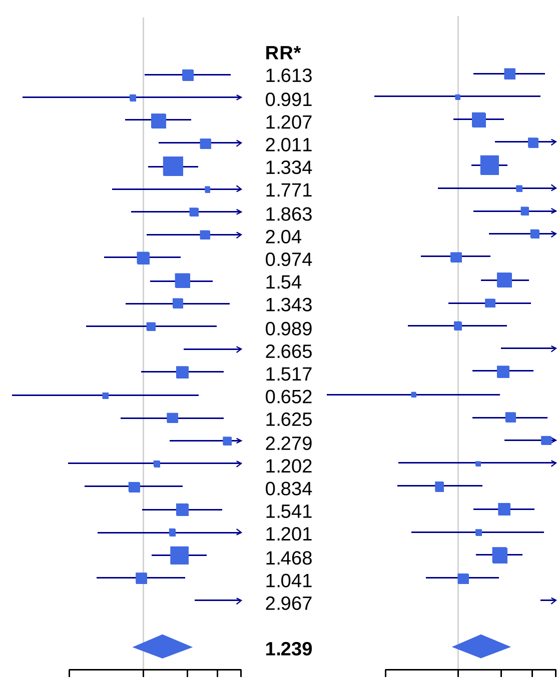
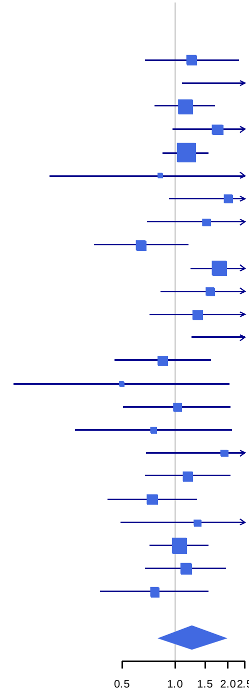


Fig. 2. Pleural cancer mortality in towns situated near pollutant industries belonging to different industrial groups. Observed and expected deaths in towns lying 2 km or less from pollutant industries, relative risks obtained with the two models used, and 95% credible (BYM model) and confidence intervals (mixed model). Men. Spain 1997–2006. Obs = observed cases. Exp = expected cases. RR = relative risk BYM model. RR* = relative risk Poisson regression mixed model.

PLEURAL. WOMEN

	Obs	Exp	RR	RR*
1 Combustion installations	12	9.1	1.249	1.217
2 Refineries and coke ovens	9	3.9	2.828	2.526
3 Metallurgical	32	23.6	1.149	1.115
4 Galvanization	13	6.5	1.75	1.658
5 Surface treatment of metals and plastic	65	48.7	1.155	1.082
6 Mineral industry	2	1.8	0.827	0.975
7 Cement and lime	7	3.5	2.008	1.681
8 Glass and mineral fibres	7	4	1.523	1.622
9 Ceramic	11	18.5	0.643	0.659
10 Organic chemical industry	37	19.1	1.788	1.465
11 Inorganic chemical industry	11	6.2	1.587	1.309
12 Fertilisers	14	9.3	1.353	1.515
13 Biocides	5	1.4	3.176	2.544
14 Pharmaceutical products	11	11.2	0.854	0.761
15 Explosives and pyrotechnic	2	4.4	0.496	0.478
16 Hazardous waste	9	7.8	1.033	1.033
17 Non-hazardous waste	4	4.3	0.757	0.82
18 Disposal or recycling of animal waste	4	2.1	1.905	1.823
19 Urban waste-water treatment plants	14	10.7	1.187	1.185
20 Paper and wood production	16	18.9	0.745	0.672
21 Pre-treatment or dyeing of textiles	4	2.9	1.345	1.159
23 Food and beverage sector	33	29.8	1.062	1.022
26 Surface treatment using organic solvents	17	13.3	1.154	1.197
28 Building of ships	10	10.1	0.768	0.866
INDUSTRY	**185**	**164**	**1.265**	**1.231**



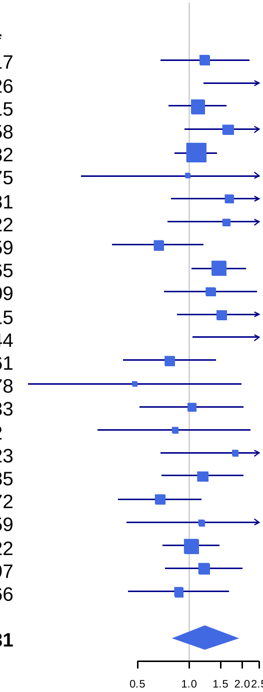


Fig. 3. Pleural cancer mortality in towns situated near pollutant industries belonging to different industrial groups. Observed and expected deaths in towns lying 2 km or less from pollutant industries, relative risks obtained with the two models used, and 95% credible (BYM model) and confidence intervals (mixed model). Women. Spain 1997–2006. Obs = observed cases. Exp = expected cases. RR = relative risk BYM model. RR* = relative risk Poisson regression mixed model.

because, in these types of studies, if some increase in risk were to be found, it would most likely be in areas lying closest to the pollutant source. In general, our results are noteworthy by virtue of the magnitude of the RR, since in ecological studies effect estimators for exposures like environmental pollution tend to be very low.

One of the chief strengths of this study is the use of a spatial hierarchical model at a municipal level, which includes explanatory variables. The inclusion of spatial terms in the model, not only means that it less susceptible to the possible presence of the ecological fallacy (Clayton et al., 1993), but also ensures that the geographic heterogeneity of the distribution of mortality is taken into account.

Although the results are not very different in the two models used, it should be mentioned that some estimators of the RR may change sign depending on the model chosen and in other cases the association may disappear (e.g., combustion installations, cement and lime production). The use of the mixed model would be justified by its ease of adjustment and shorter computation times (Ramis Prieto et al., 2007) but the method of estimation afforded by INLA, as alternative to Markov chain Monte Carlo methods, amounts to a qualitative leap in the use of hierarchical models with explanatory variables (Rue et al., 2009).

Another strength of the study, apart from its statistical power, is that reporting to the PRTR is compulsory by law and the geographic coordinates used in this study were duly validated. In Spain the quality of the information for cancer in terms both of diagnostic accuracy of cause of death is good (Pérez-Gómez et al., 2006), although we do not know exactly the pleural cancer death certificate accuracy. However, we believe that there shall be no significant differences among regional mortality registries, working under common criteria for cause of death codification.

Insofar as exposure to asbestos in Spain is concerned, though not a producer country itself, around 800 Spanish-based companies used 2.6 million tonnes of asbestos between 1900 and 2000 (with chrysotile accounting for 90% of the total) (Cárcoba et al., 2000). Use was particularly high from 1960 to the mid 1980s, and reached a peak in 1973 (112,000 tonnes) (Castejón et al., 1987). Asbestos regulations were first introduced in 1984 and the substance was banned in 2001; residual activities involving asbestos exposure were regulated in 2006 (BOE 2006).

It has been estimated that the number of workers exposed to asbestos in 1991 was 60,488 (INSHT, 1993) in Spain and 1.2 million (0.86% of the economically active population) in the European Union, 50% as construction workers (Kauppinen et al., 2000).

Of all cases of asbestos-related diseases, a high proportion is related to work exposure. Other cases suggest non-work or "passive" exposure. This could be just living with or having close contact with a worker who brings asbestos fibres home after finishing the day's work. There are also environmental causes, such as living close to an asbestos source or an industrial asbestos deposit (vicinity). The use of damaged domestic utensils containing asbestos likewise warrants mention (Rosell-Murphy et al., 2010).

The risk of mesothelioma associated with exposure due to living near an industrial asbestos source (mines, mills, asbestos processing plants) has been clearly confirmed. No solid epidemiological data currently justify any judgement regarding possible health effects associated with passive exposure in buildings containing asbestos. Non-occupational exposure to asbestos may account for approximately 20% of all mesotheliomas in industrialised countries (Goldberg and Luce, 2009).

A study of occupation and cancer in Nordic countries showed that, despite the rareness of mesothelioma, 14 of the 53 occupational categories had a statistically significant excess risk in men, and 18 of the groups had a statistically significant deficit risk. In women, only a few occupations had a statistically significant excess risk (Pukkala et al., 2009). The smoothed map of pleural cancer mortality in Spain (López-Abente et al., 2005) "flags" towns and cities in which some form of exposure to asbestos has occurred. Hence, places in which shipyards or some other type of asbestos-using industry existed for many years, are highlighted. Barcelona Province displays a remarkable pattern of excess mortality. Possibly, it is the fibre-cement industry that accounts for this increased risk (González et al., 1993) as well as the pattern observed in the south of the Madrid Region (Getafe)

(López-Abente et al., 2005). Nevertheless, these maps show many other isolated towns which register a higher than expected mortality, a finding that may possibly be related with the statistical associations reported in this study.

Currently, asbestos is neither produced nor used in Spain, so that exposure among workers has practically disappeared, with the exception of those involved in demolition work on installations and buildings, and in ship breaking yards. In this connection, the E-PRTR is incorporating additional information on hazardous waste treatment, including the amounts annually generated by industrial complexes, such as construction and insulation materials with asbestos or waste from fibre-cement production that contains this mineral.

The results of our study suggest that a great number of industries may have used asbestos and that this is reflected in pleural cancer mortality. In this regard, industries engaged in biocides, glass/mineral fibre and organic chemical production may well have been the ones responsible for the greatest releases to the environment of this pollutant. In addition, there are still many materials which not only contain asbestos but are, moreover, omnipresent, and in the light of our results, it cannot be ruled out that there may have been external pollution in the vicinity of industries which have used it.

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