BMJ Open

Enduring health effects of asbestos use in Belgian industries: a record-linked cohort study of cause-specific mortality (2001–2009)

Laura Van den Borre, Patrick Deboosere

To cite: Van den Borre L, Deboosere P. Enduring health effects of asbestos use in Belgian industries: a record-linked cohort study of cause-specific mortality (2001–2009). *BMJ Open* 2015;**5**: e007384. doi:10.1136/bmjopen-2014-007384

▸ Prepublication history for this paper is available online. To view these files please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2014-007384).

Received 5 December 2014
Revised 24 February 2015
Accepted 20 March 2015

Interface Demography, Department of Sociology, Vrije Universiteit Brussel, Brussels, Belgium

Correspondence to
Laura Van den Borre; Laura.Van.den.Borre@vub.ac.be

ABSTRACT

Objective: To investigate cause-specific mortality among asbestos workers and potentially exposed workers in Belgium and evaluate potential excess in mortality due to established and suspected asbestos-related diseases.

Design: This cohort study is based on an individual record linkage between the 1991 Belgian census and cause-specific mortality information for Flanders and Brussels (2001–2009).

Setting: Belgium (Flanders and Brussels region).

Participants: The study population consists of 1 397 699 male workers (18–65 years) with 72 074 deaths between 1 October 2001 and 31 December 2009. Using a classification of high-risk industries, mortality patterns between 2056 asbestos workers, 385 046 potentially exposed workers and the working population have been compared.

Outcome measures: Standardised mortality ratios (SMRs) and 95% CIs are calculated for manual and non-manual workers.

Results: Our findings show clear excess in asbestos-related mortality in the asbestos industry with SMRs for mesothelioma of 4071 (CI 2327 to 6611) among manual workers and of 4489 (CI 1458 to 10 476) among non-manual workers. Excess risks in asbestos-related mortality are also found in the chemical industry, the construction industry, the electrical generation and distribution industry, the basic metals manufacturing industry, the metal products manufacturing industry, the railroad industry, and the shipping industry. Oral cancer mortality is significantly higher for asbestos workers (SMR 383; CI 124 to 894), railroad workers (SMR 192; CI 112 to 308), shipping workers (SMR 172; CI 102 to 271) and construction workers (SMR 125; CI 100 to 153), indicating a possible association with occupational asbestos exposure. Workers in all four industries have elevated mortality rates for cancer of the mouth. Only construction workers experience significantly higher pharyngeal cancer mortality (SMR 151; CI 104 to 212).

Conclusions: The study identifies vulnerable groups of Belgian asbestos workers, demonstrating the current-day health repercussions of historical asbestos use. Results support the hypothesis of a possible association between the development of oral cancer and occupational asbestos exposure.

Strengths and limitations of this study

- Mortality among Belgian workers is investigated using exhaustive census-linked cause-specific mortality data at the individual level.
- The availability of a large national database allows the study of industries with a relatively small number of workers.
- Asbestos exposure data is not available for Belgium and could not be included in this study. However, high-risk industries are selected based on an extensive literature review and the strong aetiological relation between mesothelioma and asbestos exposure. A further differentiation is made between manual and non-manual workers.
- Occupational information is only available for one point in time. Workers exposed before the census date may have been included in the reference population (eg, job change) or may have left the active population (eg, health reasons). Potential confounders after the census date are not taken into account. Our results may underestimate the true influence of occupational asbestos exposure.

INTRODUCTION

Belgium has the fourth highest mesothelioma mortality rate in the world, after the UK, Australia and Italy. Since 2006, over 200 Belgians have died from mesothelioma each year.[1] Mesothelioma is considered to be a potent and sensitive indicator of asbestos exposure,[2] but further research on other asbestos-related diseases is imperative to understand the full extent of the asbestos problem in Belgium. This study focuses on the primary source of asbestos exposure: the workplace.

Asbestos minerals do not occur naturally in Belgium. With the start of one of Europe's largest asbestos companies, Eternit, in the early 1900s, Belgium rapidly became an important supplier of asbestos products. Large amounts of raw asbestos fibres were

imported for manufacturing purposes since the 1930s.[3] Belgian asbestos industries used a mix of different types of asbestos, usually consisting of 90–99% chrysotile and 10–1% crocidolite.[4] The use of relatively small amounts of amosite has also been reported.[5]

Asbestos use culminated during the 1960s–1970s, with Belgium having the highest asbestos consumption level per capita in the world.[6] Since then, overall exposure levels have gradually decreased as a result of private and public health control measures, including the mandatory use of dust masks and the installation of exhaust systems in the workplace.[7] Airborne occupational exposure limits for asbestos were implemented in 1980 to control exposure intensity and duration.[8] Nonetheless, these measures did not avert all fatal health effects due to asbestos exposure.

Despite declining asbestos exposure levels, occupational exposure in, for example, asbestos product manufacturing, shipbuilding and construction, remained relatively common until the end of the 1990s. Industrial asbestos use was reduced dramatically with a major ban on all asbestos types in 1998. Some exceptions for chrysotile products remained until 2001, when the use and transaction of all types of asbestos were finally banned.

The few Belgian studies on asbestos health risks in the workplace are based on industry findings, biomedical data or information delivered by victim compensation funds.[4 5 9 10] Considering the typical long latency periods of asbestos-related diseases and most occupational asbestos research dating back to the 1960s–1970s, results may not reflect the true public health consequences of industrial asbestos use. Selection bias, differences in diagnostic criteria and low civil awareness of compensation measures, make the representativeness of these data sources questionable.

International studies on the health of asbestos workers focus mainly on well-established asbestos-related diseases, namely asbestosis, malignant mesothelioma and lung cancer. Recently, the International Agency for Research on Cancer has acknowledged a causal effect in the development of laryngeal and ovarian cancer.[11] The association between asbestos exposure and several other malignancies remains controversial.

The present study investigates cause-specific mortality among asbestos workers and potentially exposed workers to evaluate potential excess in mortality due to established and suspected asbestos-related diseases. For the first time, mortality follow-up data and individual employment information for a large study population are available to determine the impact of asbestos exposure on Belgian male workers.

METHODS

Study design

An anonymous record linkage has been performed between detailed occupational information from the 1991 Belgian census and cause-specific mortality data from 1 October 2001 to 31 December 2009. The record linkage was based on a primary link between the 1991 Belgian census, and registration records of all deaths and migrations between the census date (1 March 1991) and 31 December 2009. Then, cause-specific mortality information was derived from death certificates for the period 2001–2009 and added to the dataset. As a result, there is a 10-year time lag between occupational information and cause-specific mortality data.

Death certificates are not available for the 3 Belgian regions. The cause-specific mortality data only covers Flanders and the Brussels Capital Region, where the majority of Belgian asbestos firms were located.[1] According to data from the Scientific Institute for Public Health, all-cause mortality in Flanders and Brussels accounts for 65% of all Belgian male deaths in 2003–2010. Approximately 80% of all male mesothelioma mortality occurs among Flemish and Brussels men.[12]

Based on the 1991 census, we have identified 1 537 805 occupationally active men (18–65 years) in Flanders and the Brussels Capital Region. Prior to 1 October 2001, 3.5% of these workers emigrated and 3.6% died. Owing to missing occupational information, 30 922 workers could not be classified.

The study investigates 72 074 deaths between 1 October 2001 and 31 December 2009, among a cohort of 1 397 699 Flemish and Brussels men with valid occupational information at the time of the 1991 census.

Classification of high-risk industries

The comprehensive character of the census data provides a snapshot of the occupational distribution. Consequently, the risks of persons who have been at least potentially exposed to asbestos can be compared with all other occupational groups. Information about exposure circumstances is not available. Because of the widespread use of asbestos fibres in Belgium, careful consideration is required to distinguish occupational asbestos exposure from environmental or secondary exposure. We have combined the distribution of mesothelioma deaths in Belgian industries with an extensive literature review to determine the industries most at risk of asbestos-related health effects.

Malignant mesothelioma mortality was used as a marker for asbestos exposure (Tenth Revision of the International Classification of Diseases, ICD-10 C45). This highly fatal cancer develops in the protective linings of the lungs, chest wall, abdomen and heart, and is caused almost exclusively by asbestos exposure. Even low levels of asbestos exposure can induce malignant mesothelioma.[13] Industrial sectors with at least three mesothelioma deaths during the period 2001–2009 were selected using the Statistical Classification of Economic Activities in the European Community (NACE).

We have cross-referenced these findings with the published literature. An extensive review of international and national studies on occupational asbestos exposure

was conducted to ascertain at least potential asbestos use in these industries. Databases PubMed and Unicat (Union Catalogue of Belgian Libraries) have been examined. Keywords included "occupation*", "industr*", "asbestos", "health", "mortality", "Belg*". Additional searches were conducted using the names of the selected industries. Only peer-reviewed articles and government documents were considered. We have made no restrictions in time or language. If industrial asbestos use was established in at least one of the studies, the industry was included in further analyses.

Finally, industries with at least three mesothelioma deaths in the period 2001–2009 and with conclusive evidence of asbestos use were considered as high-risk industries. Three broad categories can be distinguished. Table 1 presents detailed information on the activities of the analysed industries in each category. Category A includes workers in asbestos industries. Category B includes workers in industries with potential asbestos exposure. Category C consists of workers in all industries excluded from categories A or B.

A further differentiation was made between manual workers and all other occupational types in high-risk industries. The 1991 census includes information on the type of performed labour: self-employed, blue-collar, white-collar, management, etc. We defined manual workers as blue-collar workers and self-employed persons.[i]

Table 2 provides an overview of the number of manual and non-manual workers per industry, together with all-cause mortality and mesothelioma mortality. Of 704 458 manual workers in 1991, 40% were active in high-risk industries. All other occupational types in these industries account for approximately 15% of all 693 241 non-manual workers.

It is important to bear in mind an undetermined level of asbestos exposure for all categories of workers. Questions on occupational history are not included in the 1991 census. Hence, this research design cannot consider exposure duration or exposure in previous workplaces. In addition, workers may have been exposed to asbestos via the environment or through indirect contact.

Data analysis

Analyses are performed separately for manual and non-manual workers. Standardised mortality rates (SMRs) are calculated by 5-year age group with reference to workers in all other industries (category C). Lower and upper 95% CI are computed assuming that the observed deaths are Poisson variates. If the observed number of deaths is less than 100, exact limits are calculated directly from the Poisson distribution. For larger numbers, we use the Byar approximation method.[14]

[i]Self-employed persons constitute a small, but relevant, population in the construction industry (9% of manual workers), automotive industry (5% of manual workers; mainly in repair and maintenance work) and metal products manufacturing (3% of manual workers).

Data for the study period 2001–2009 are combined because of the small number of cases per year for some of the industries under investigation. Analyses are based on the underlying cause of death as recorded on the death certificate. Cause-specific mortality is coded using the ICD-10.

RESULTS

A total of 996 men died due to mesothelioma from 2001 through 2009. Although previous occupational asbestos exposure is possible, 545 mesothelioma deaths in the non-active population have been discarded from the classification process. One hundred and ninety-four deaths occurred among 173 137 men past the retirement age of 65 years in 1991, and 351 deaths occurred among 510 681 non-active men aged 18–65 years. The selection of high-risk industries is based on a total of 439 mesothelioma deaths in the active population (n=1 397 699).

Table 3 compares mesothelioma and all-cause mortality in the active and non-active population for men at working ages in 1991. From 2001 to 2009, 21 asbestos workers and 169 potentially exposed workers died due to mesothelioma. Two hundred and forty-nine mesothelioma deaths occurred in the reference population. The high overall mortality among non-active men before age 65 years indicates a "healthy worker effect". Healthy workers remain in the workforce whereas persons with health problems are more inclined to quit prematurely. We restrict further analysis to the active population in 1991.

The results on asbestos-related mortality among asbestos workers and potentially exposed workers are presented in table 4, with the SMRs and 95% CIs by occupational type for the period 2001–2009.

Asbestos-related mortality

Asbestos workers

Mesothelioma mortality is over 40 times higher among manual workers in the asbestos industry than among all other workers (SMR 4071; CI 2327 to 6611). Manual workers also experience 75% more lung cancer deaths than expected (SMR 175; CI 108 to 268). Results on laryngeal cancer mortality are inconclusive, as the ratio is based on only one observed death. No asbestosis deaths occurred among manual workers during the period 2001–2009.

We also find significant excess in asbestos-related mortality for jobs that do not involve direct contact with asbestos fibres. Non-manual workers in the asbestos industry have 45 times higher mesothelioma mortality than expected (SMR 4489; CI 1458 to 10 476). Laryngeal cancer mortality is almost 15 times higher than expected (SMR 1425; CI 173 to 5148). Contrary to their colleagues in manual labour jobs, non-manual workers do not seem to experience higher lung cancer mortality (SMR 29; CI 1 to 161).

Table 1 Types of industrial activities, per category

Industry	Industrial activity
(A)	
Asbestos industry	Asbestos cement manufacturing
	Asbestos products manufacturing
(B)	
Automotive industry	Manufacture and assembly of car parts
	Manufacture and assembly of motor cycle parts
	Repair and maintenance
Chemical industry	Manufacture of basic chemicals
	Manufacture of pesticides and other agrochemical products
	Manufacture of paints and similar coatings
	Manufacture of soap, cosmetics and detergents
	Manufacture of other chemical products
	Manufacture of man-made fibres
	Manufacture of basic pharmaceutical products
Construction	General construction and demolition
	Construction of buildings and utilities
	Civil engineering: roads and water supply
	Installation companies
	Final construction work
Electricity generation and distribution	Electricity generation and distribution
Electrotechnical products manufacturing	Manufacture of electrical appliances
	Assembly and installation of electrotechnical products
Manufacture of basic metals	Manufacture of basic iron, steel and ferroalloys
	Manufacture of steel tubes, pipes and related fitting
	Manufacture of other products of first processing of steel
	Manufacture of basic non-ferrous metals
Metal products manufacturing	Casting of metal
	Manufacture of fabricated metal products
	Manufacture and assembly structural metal parts
	Manufacture of boilers and reservoirs
	Grinderies and other
Railroad industry	Railway carriage construction
	Repair and maintenance
	Activities related to railway transport
Shipping industry	Shipyards, ship repair and maintenance
	Activities related to inland, maritime and short sea shipping
Textile industry	Wool, cotton and other
	Carpet, felt and linoleum
	Other activities
(C)	
Reference population	All other workers

Potentially exposed workers

Workers from the automotive industry, the electrical products manufacturing industry and the textile industry do not seem to experience significant excess in mortality due to asbestos-related diseases (not shown in table 4).

Mesothelioma mortality is significantly higher among manual workers in the electrical generation and distribution industry (SMR 863; CI 317 to 1878), shipping industry (SMR 475; CI 266 to 784), railroad industry (SMR 352; CI 141 to 725), chemical industry (SMR 293; CI 160 to 492), basic metals manufacturing industry (SMR 291; CI 145 to 520) and the construction industry (SMR 227; CI 168 to 302). Manual workers in the metal products manufacturing industry have a SMR of 187 (CI 85 to 354).

Lung cancer deaths are significantly higher than expected among construction workers (SMR 153; CI 144 to 163), shipping workers (SMR 141; CI 119 to 167) and metal products manufacturing workers (SMR 138; CI 119 to 158) in manual labour jobs.

With regard to laryngeal cancer mortality, observed deaths among manual workers in the construction industry are twice as high as expected (SMR 203; CI 155 to 260).

Among all potentially exposed workers in manual labour, four cases of asbestosis deaths have been recorded. Three deaths occurred among construction workers, resulting in an elevated SMR for asbestosis (SMR 401; CI 83 to 1171). One worker in metal products manufacturing died due to asbestosis.

Table 2 Mesothelioma deaths and total number of deaths for manual and non-manual workers by industry

Industry	Manual workers			Non-manual workers			Total		
	N	M	D	N	M	D	N	M	D
(A)									
Asbestos industry	1743	16	121	313	5	18	2056	21	139
(B)									
Automotive industry	52 789	8	1856	12 057	1	261	64 846	9	2417
Chemical industry	21 875	14	957	18 647	4	882	40 522	18	1839
Construction industry	100 297	48	5341	22 387	16	1333	122 684	64	6674
Electricity generation and distribution	2164	6	133	4489	7	277	6653	13	410
Electrotechnical products manufacturing	15 854	3	571	12 920	6	462	28 774	9	1033
Manufacture of basic metals	17 174	11	748	5209	3	263	22 383	14	1011
Metal products manufacturing	29 960	9	1211	6603	2	298	36 563	11	1509
Railroad industry	10 840	7	467	12 352	3	547	23 192	10	1014
Shipping industry	12 255	15	784	3380	1	204	15 635	16	988
Textile industry	20 008	3	1043	3786	2	159	23 794	5	1202
(C)									
Reference population	–	–	–	–	–	–	1 010 597	249	53 838

D, number of overall deaths; M, number of mesothelioma deaths; N, number of workers.

The results for non-manual workers show significant excess in asbestos-related mortality in two industries with potential asbestos exposure. We find significant excess in mesothelioma mortality and asbestosis mortality in the construction industry with SMRs of 260 (CI 149 to 422) and 843 (CI 102 to 3043), respectively. Mesothelioma mortality is more than four times higher among non-manual workers in the electricity generation and distribution industry (SMR 430; CI 173 to 885).

Electricity generation and distribution is also one of three industries with a significant deficit in lung cancer mortality for non-manual workers (SMR 66; CI 46 to 93). The SMRs for lung cancer in the chemical industry and the basic metal manufacturing industry are 67 (CI 55 to 81) and 57 (CI 38 to 82), respectively.

Other causes of death

Table 5 presents the number of deaths from other causes by industry and occupational type, with the corresponding SMRs and 95% CIs. Results indicate significantly more oral cancer deaths among manual workers in the asbestos industry, railroad industry, shipping industry and the construction industry. When examining more closely, high oral cancer mortality is driven by excess deaths due to cancers of the mouth (ICD-10 C01-C06) in all four industries. Mouth cancer mortality is nine times higher among asbestos workers (SMR 938; CI 305 to 2189). Railroad workers experience about four times more mouth cancer deaths (SMR 390; CI 213 to 655). Shipping workers have an elevated SMR of 211 (CI 96 to 400). Construction workers experience 40% more

Table 3 Mesothelioma and all-cause mortality in 2001–2009 by activity status for men aged 18–65 years in 1991*

Characteristics	N	Mesothelioma		Overall	
		O	SMR (CI)	O	SMR (CI)
Active population					
Asbestos workers	2056	21	2890 (1789 to 4417)	139	116 (97 to 136)
Potentially exposed workers	385 046	169	141 (121 to 164)	18 097	88 (87 to 90)
All other workers	1 010 597	249	68 (60 to 78)	53 838	85 (84 to 86)
Missing information	30 922	12	103 (53 to 180)	2460	118 (114 to 123)
Non-active population					
Pre-retirement	190 090	265	115 (101 to 130)	52 575	108 (108 to 109)
Unemployed	86 131	45	130 (95 to 175)	9012	148 (145 to 151)
Disabled	25 046	25	140 (91 to 207)	6220	194 (189 to 198)
Students	119 742	0	0 (0 to 1678)	642	65 (59 to 69)
Other	30 734	2	59 (7 to 214)	1241	152 (143 to 160)
Missing information	58 938	14	71 (39 to 119)	4912	136 (132 to 139)

*Reference population: Flemish and Brussels men (18–65 years).
N, number of men; O, observed number of deaths; SMR, standardised mortality ratio.

Table 4 Overall and asbestos-related mortality in selected industries for manual and non-manual workers*

	Asbestos industry						Chemical industry					
	Manual			Non-manual			Manual			Non-manual		
	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI
All deaths	121	150	125 to 180	18	80	47 to 126	957	97	91 to 103	882	80	75 to 86
All neoplasms	61	174	133 to 223	13	129	68 to 220	416	97	88 to 107	416	86	78 to 95
Laryngeal cancer	1	182	5 to 1015	2	1425	173 to 5148	4	60	16 to 155	11	153	76 to 274
Lung cancer	21	175	108 to 268	1	29	1 to 161	151	103	88 to 121	110	67	55 to 81
Mesothelioma	16	4071	2327 to 6611	5	4489	1458 to 10 476	14	293	160 to 492	4	75	21 to 193
Asbestosis	0	0	0 to 21 850	0	0	0 to 59 137	0	0	0 to 1809	0	0	0 to 1487

	Construction industry						Electrical generation and distribution industry					
	Manual			Non-manual			Manual			Non-manual		
	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI
All deaths	5341	119	116 to 122	1333	100	95 to 106	133	98	82 to 116	277	87	77 to 98
All neoplasms	2399	125	120 to 130	602	105	97 to 114	75	122	96 to 153	131	91	76 to 108
Laryngeal cancer	61	203	155 to 260	8	95	41 to 187	0	0	0 to 326	2	95	12 to 344
Lung cancer	995	153	144 to 163	200	104	90 to 119	25	118	76 to 174	33	66	46 to 93
Mesothelioma	48	227	168 to 302	16	260	149 to 422	6	863	317 to 1878	7	430	173 to 885
Asbestosis	3	401	83 to 1171	2	843	102 to 3043	0	0	0 to 11 166	0	0	0 to 4692

	Manufacture of basic metals						Metal products manufacturing					
	Manual			Non-manual			Manual			Non-manual		
	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI
All deaths	748	101	94 to 109	263	81	72 to 92	1211	114	108 to 121	298	84	75 to 94
All neoplasms	328	100	90 to 112	127	87	72 to 103	498	113	103 to 123	134	87	73 to 103
Laryngeal cancer	3	54	11 to 158	3	133	27 to 388	12	163	84 to 285	1	42	1 to 235
Lung cancer	127	112	94 to 134	29	57	38 to 82	203	138	119 to 158	47	90	66 to 119
Mesothelioma	11	291	145 to 520	3	178	37 to 522	9	187	85 to 354	2	118	14 to 425
Asbestosis	0	0	0 to 3205	0	0	0 to 5046	1	710	18 to 3957	1	1654	42 to 9217

	Railroad industry						Shipping industry					
	Manual			Non-manual			Manual			Non-manual		
	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI
All deaths	467	112	102 to 122	547	99	91 to 108	784	124	116 to 133	204	94	82 to 108
All neoplasms	226	126	110 to 143	223	93	81 to 105	338	121	108 to 134	95	100	81 to 122
Laryngeal cancer	7	206	83 to 424	4	93	25 to 238	5	113	37 to 264	0	0	0 to 216
Lung cancer	74	122	96 to 153	78	95	75 to 118	136	141	119 to 167	34	106	73 to 147
Mesothelioma	7	352	141 to 725	3	112	23 to 327	15	475	266 to 784	1	97	2 to 540
Asbestosis	0	0	0 to 6301	0	0	0 to 4079	0	0	0 to 2773	0	0	0 to 7192

*Reference population: manual and non-manual workers in all other industries.
O, observed number of deaths; SMR, standardised mortality ratio.

mouth cancer deaths than expected (SMR 140; CI 101 to 189). For construction workers, we also find significant excess in pharyngeal cancer mortality (SMR 151; CI 104 to 212).

Significant excess in mortality is found for two other types of malignancies. The SMR for oesophageal cancer mortality among construction workers in manual labour jobs equals 131 (CI 108 to 158). Prostate cancer deaths are two times higher among manual workers in shipping (SMR 203; CI 135 to 293).

Findings also indicate elevated mortality due to diseases of the circulatory system for manual workers in six industries: the asbestos industry, construction industry, basic metals manufacturing industry, metal products manufacturing industry, railroad industry and the shipping industry. Looking at the circulatory diseases separately, we find asbestos workers experience a higher number of deaths caused by cerebrovascular disease (SMR 200; CI 80 to 411) (not shown in table 5). Mortality due to ischaemic heart disease is significantly higher among construction workers (SMR 118; CI 109 to 127), shipping workers (SMR 124; CI 100 to 151) and railroad workers (SMR 132; CI 102 to 169) (not shown in table 5).

For mortality due to respiratory diseases, we find elevated SMRs for manual workers in the asbestos industry, construction industry, basic metals manufacturing industry, metal products manufacturing industry, railroad industry and the shipping industry. This is due to relatively high numbers of deaths from chronic obstructive pulmonary diseases (COPD). Mortality due to COPD is significantly higher for construction workers (SMR 127; CI 109 to 147), basic metals manufacturing workers (SMR 166; CI 116 to 230), metal products manufacturing workers (SMR 172; CI 128 to 226) and shipping industry workers (SMR 176; CI 124 to 243) (not shown in table 5). In addition to elevated mortality due to COPD (SMR 228; CI 84 to 496), results for asbestos workers indicate higher pneumonia mortality (SMR 336; CI 91 to 859) (not shown in table 5).

Construction workers in manual labour jobs experience excess mortality due to other diseases, because of a significantly higher number of deaths from alcoholic liver disease (SMR 138; CI 115 to 164, not shown in table 5).

DISCUSSION

Cause-specific mortality among high-risk workers and all other workers is compared to determine the current impact of asbestos exposure on Belgian workers' mortality. In addition to asbestos workers, 10 types of industrial workers are identified as potentially exposed. Results indicate significant excess in asbestos-related mortality in the asbestos industry and in seven of the selected industries, those being, the chemical industry, construction industry, electrical generation and distribution industry, basic metals manufacturing industry, metal products

Table 5 Overall and cause-specific mortality in selected industries for manual and non-manual workers*

	Asbestos industry						Chemical industry						Construction industry						Electrical generation and distribution industry					
	Manual			Non-manual			Manual			Non-manual			Manual			Non-manual			Manual			Non-manual		
	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI
All deaths	121	150	125 to 180	18	80	47 to 126	957	97	91 to 103	882	80	75 to 86	5341	119	116 to 122	1333	100	95 to 106	133	98	82 to 116	277	87	77 to 98
All neoplasms	61	174	133 to 223	13	129	68 to 220	416	97	88 to 107	416	86	78 to 95	2399	125	120 to 130	602	105	97 to 114	75	122	96 to 153	131	91	76 to 108
Malignant head and neck	6	315	115 to 685	2	436	53 to 1576	19	82	50 to 129	18	74	44 to 117	155	148	126 to 173	32	114	78 to 160	2	64	8 to 233	6	86	32 to 187
Oral cancer	5	383	124 to 894	0	0	0 to 985	15	95	53 to 157	7	43	17 to 88	89	125	100 to 153	22	116	73 to 176	2	95	12 to 344	4	86	23 to 219
Mouth	5	938	305 to 2189	0	0	0 to 2351	5	77	25 to 180	3	44	9 to 129	42	140	101 to 189	9	114	52 to 216	0	0	0 to 352	1	52	1 to 287
Pharynx	0	0	0 to 751	0	0	0 to 2993	3	62	13 to 181	4	73	20 to 187	33	151	104 to 212	7	110	44 to 227	1	164	4 to 912	2	128	15 to 462
Other head and neck	0	0	0 to 5637	0	0	0 to 21 873	0	0	0 to 469	0	0	0 to 431	5	168	55 to 393	2	244	30 to 883	0	0	0 to 3440	0	0	0 to 1516
Malignant digestive system	7	76	31 to 157	1	38	1 to 209	110	98	80 to 118	119	94	78 to 112	561	111	102 to 121	140	93	78 to 109	17	105	61 to 169	36	95	67 to 132
Oesophageal cancer	2	128	16 to 463	0	0	0 to 739	18	95	56 to 150	22	107	67 to 162	112	131	108 to 158	18	75	44 to 118	2	76	9 to 275	9	149	68 to 284
Stomach cancer	1	84	2 to 471	0	0	0 to 899	17	117	68 to 188	10	63	30 to 115	77	118	93 to 148	24	127	81 to 189	4	197	54 to 504	1	21	1 to 118
Colon cancer	1	38	1 to 214	0	0	0 to 380	33	104	71 to 146	32	87	59 to 123	152	106	90 to 125	33	75	51 to 105	2	43	5 to 156	13	118	63 to 202
Rectal cancer	2	226	27 to 818	0	0	0 to 1168	13	121	64 to 206	12	99	51 to 173	58	121	92 to 157	19	133	80 to 208	3	192	40 to 562	2	55	7 to 197
Liver cancer	0	0	0 to 290	0	0	0 to 984	9	72	33 to 136	14	98	54 to 165	53	94	70 to 123	13	77	41 to 131	2	109	13 to 393	3	70	14 to 203
Pancreas cancer	1	54	1 to 298	1	183	5 to 1020	18	79	47 to 125	28	108	72 to 156	101	99	80 to 120	31	100	68 to 142	4	122	33 to 312	8	104	45 to 204
Other digestive	0	0	0 to 3427	0	0	0 to 10 249	2	186	23 to 673	1	72	2 to 402	8	160	69 to 314	2	114	14 to 411	0	0	0 to 1864	0	0	0 to 763
Malignant urogenital system	6	159	58 to 346	2	163	20 to 590	38	82	58 to 113	48	86	63 to 113	216	103	90 to 118	65	94	73 to 120	10	144	69 to 264	19	113	68 to 177
Prostate cancer	3	175	36 to 511	0	0	0 to 498	18	85	51 to 135	27	99	66 to 145	98	101	82 to 123	28	82	55 to 119	5	153	50 to 357	8	100	43 to 196
Testicular cancer	0	0	0 to 13 840	0	0	0 to 92 164	0	0	0 to 1140	0	0	0 to 1726	3	203	42 to 594	2	683	83 to 2469	0	0	0 to 13 444	0	0	0 to 7289
Bladder cancer	1	103	3 to 573	1	322	8 to 1792	10	85	41 to 156	10	70	34 to 129	64	120	92 to 153	17	99	57 to 158	2	111	13 to 402	4	92	25 to 237
Kidney cancer	2	188	23 to 680	1	324	8 to 1806	10	77	37 to 142	11	76	38 to 135	51	88	66 to 116	18	105	62 to 166	3	160	33 to 468	7	160	64 to 329
Non-neoplasms	48	130	96 to 173	4	36	10 to 93	430	95	86 to 105	401	76	69 to 84	2313	112	107 to 116	607	94	87 to 102	51	80	59 to 105	127	84	70 to 100
Circulatory system	27	131	86 to 191	2	32	4 to 117	238	94	83 to 107	230	78	68 to 89	1298	113	107 to 119	360	100	90 to 110	31	86	58 to 122	74	87	68 to 109
Respiratory system	10	238	114 to 437	1	70	2 to 391	46	89	65 to 119	36	56	39 to 77	279	118	104 to 132	74	91	72 to 114	4	51	14 to 131	18	95	56 to 150
Other diseases	11	91	46 to 163	1	30	1 to 166	146	99	83 to 116	135	81	68 to 96	736	108	101 to 116	173	85	73 to 99	16	80	45 to 129	35	75	52 to 104
External code	12	141	73 to 247	1	64	2 to 357	111	104	86 to 125	65	71	55 to 91	629	127	118 to 138	124	111	93 to 133	7	66	27 to 137	19	87	52 to 135

	Manufacture of basic metals						Metal products manufacturing						Railroad industry						Shipping industry					
	Manual			Non-manual			Manual			Non-manual			Manual			Non-manual			Manual			Non-manual		
	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI
All deaths	748	101	94 to 109	263	81	72 to 92	1211	114	108 to 121	298	84	75 to 94	467	112	102 to 122	547	99	91 to 108	784	124	116 to 133	204	94	82 to 108
All neoplasms	328	100	90 to 112	127	87	72 to 103	498	113	103 to 123	134	87	73 to 103	226	126	110 to 143	223	93	81 to 105	338	121	108 to 134	95	100	81 to 122
Malignant head and neck	9	46	21 to 87	8	104	45 to 206	37	141	99 to 194	3	37	8 to 109	25	199	128 to 293	16	102	59 to 166	23	150	95 to 225	2	43	5 to 156
Oral cancer	6	44	16 to 96	5	96	31 to 225	24	132	85 to 196	2	37	4 to 132	17	192	112 to 308	12	110	57 to 192	18	172	102 to 271	1	32	1 to 179
Mouth	3	54	11 to 158	3	139	29 to 407	11	148	74 to 264	2	88	11 to 317	14	390	213 to 655	5	111	36 to 258	9	211	96 to 400	1	77	2 to 429
Pharynx	2	51	6 to 184	1	57	1 to 317	9	155	71 to 295	0	0	0 to 162	2	71	9 to 255	1	27	1 to 150	5	157	51 to 367	0	0	0 to 288
Other head and neck	0	0	0 to 588	0	0	0 to 1410	1	137	3 to 766	0	0	0 to 1302	1	285	7 to 1589	0	0	0 to 700	0	0	0 to 706	1	741	19 to 4131
Malignant digestive system	87	102	81 to 125	39	101	72 to 138	100	87	71 to 106	40	99	70 to 134	46	98	72 to 131	58	92	70 to 119	74	101	79 to 126	19	76	46 to 119
Oesophageal cancer	16	103	59 to 168	5	78	25 to 183	22	107	67 to 162	5	74	24 to 174	10	106	51 to 196	11	91	45 to 163	14	112	61 to 187	2	50	6 to 181
Stomach cancer	12	109	56 to 191	3	62	13 to 182	22	145	91 to 220	4	78	21 to 201	6	98	36 to 213	5	61	20 to 143	12	128	66 to 223	3	96	20 to 280

Continued

Table 5 Continued

	Manufacture of basic metals						Metal products manufacturing						Railroad industry						Shipping industry					
	Manual			Non-manual			Manual			Non-manual			Manual			Non-manual			Manual			Non-manual		
	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI	O	SMR	CI
Colon cancer	20	86	52 to 132	15	136	76 to 225	25	79	51 to 117	14	121	66 to 202	10	82	39 to 151	21	124	77 to 190	24	116	74 to 172	7	96	39 to 198
Rectal cancer	13	158	84 to 270	1	27	1 to 148	6	55	20 to 120	5	129	42 to 301	5	117	38 to 273	3	52	11 to 151	6	85	31 to 186	1	42	1 to 235
Liver cancer	7	74	30 to 152	4	91	25 to 234	10	79	38 to 145	1	22	1 to 122	5	96	31 to 225	6	85	31 to 186	5	60	20 to 141	3	106	22 to 311
Pancreas cancer	18	105	62 to 165	11	140	70 to 250	15	65	36 to 107	11	133	66 to 238	10	106	51 to 196	11	87	43 to 156	13	87	46 to 149	3	59	12 to 172
Other digestive	1	134	3 to 744	0	0	0 to 778	0	0	0 to 281	0	0	0 to 693	0	0	0 to 757	1	179	5 to 999	0	0	0 to 425	0	0	0 to 1074
Malignant urogenital system	26	80	52 to 117	19	116	70 to 181	48	108	80 to 143	16	91	52 to 148	24	147	94 to 218	23	97	62 to 146	40	132	94 to 180	13	115	61 to 197
Prostate cancer	14	100	55 to 169	5	65	21 to 153	19	98	59 to 152	9	108	49 to 205	6	90	33 to 195	10	98	47 to 181	28	203	135 to 293	8	145	63 to 285
Testicular cancer	0	0	0 to 1621	0	0	0 to 7102	0	0	0 to 604	0	0	0 to 4339	0	0	0 to 3023	0	0	0 to 2645	0	0	0 to 2329	0	0	0 to 8691
Bladder cancer	6	70	26 to 152	5	117	38 to 273	10	88	42 to 162	4	89	24 to 229	9	210	96 to 398	2	32	4 to 117	7	90	36 to 185	3	105	22 to 308
Kidney cancer	6	61	22 to 132	9	202	92 to 383	19	145	88 to 227	3	65	13 to 190	9	171	78 to 325	11	153	77 to 274	5	59	19 to 137	2	70	8 to 253
Non-neoplasms	325	99	88 to 110	111	73	60 to 88	528	112	103 to 122	139	83	70 to 98	195	104	90 to 120	260	103	91 to 117	354	121	109 to 134	92	88	71 to 108
Circulatory system	184	100	86 to 115	68	79	62 to 100	290	112	99 to 125	84	90	71 to 111	120	116	96 to 139	155	111	94 to 129	195	119	103 to 137	53	90	68 to 118
Respiratory system	52	150	112 to 197	12	66	34 to 115	68	139	108 to 176	14	70	38 to 117	27	154	101 to 224	24	93	59 to 138	45	134	97 to 179	8	61	26 to 120
Other diseases	89	80	65 to 99	31	65	44 to 92	170	105	90 to 122	41	76	55 to 104	48	73	54 to 97	81	94	75 to 117	114	120	99 to 144	31	95	64 to 135
External cod	95	115	93 to 141	25	100	64 to 147	185	126	108 to 145	25	77	50 to 114	46	89	65 to 119	64	108	84 to 139	92	155	125 to 190	17	102	59 to 163

*Reference population: manual and non-manual workers in all other industries.
O, observed number of deaths; SMR, standardised mortality ratio.

manufacturing industry, railroad industry and the shipping industry. Contrary to other reports,[15–21] we did not find significant excess risks for asbestos-related mortality in the automotive industry, textile industry or in the electrotechnical industry.

Results clearly show a very high impact of asbestos exposure on asbestos workers. Mesothelioma mortality is 41 times higher among manual workers and 45 times higher among non-manual workers than in the reference population. Significant excess in laryngeal cancer and lung cancer mortality is found for non-manual workers and manual workers, respectively. Working in the asbestos industry seems to entail serious asbestos-related health risks, regardless of the occupational type. It is likely that asbestos exposure in this industry is not confined to specific work-related tasks, but also includes site-related environmental exposure.

Among potentially exposed workers, significant excess in mesothelioma mortality is found for manual work in the chemical industry, the basic metal manufacturing industry and the railroad industry. Surprisingly, manual and non-manual workers in the electricity generation and distribution industry both have a significantly higher number of mesothelioma deaths. This may indicate more widespread asbestos exposure in this industry than expected.

Shipping industry workers in manual labour jobs experience significantly higher mesothelioma and lung cancer mortality. Results also show increased mortality risks for mesothelioma and lung cancer among manual workers in metal products manufacturing, with significant excess in lung cancer deaths.

The construction industry is the only industry with elevated SMRs for all four established asbestos-related diseases. In addition to manual workers, non-manual workers in the construction industry experience significantly higher numbers of mesothelioma and asbestosis deaths. An underestimation of asbestosis mortality is possible because asbestosis is frequently coded as a contributing cause of death, and this study is based on underlying causes of death.

Cause-specific mortality is further scrutinised to identify additional excess in mortality among high-risk workers and evaluate a potential association with asbestos exposure. The results for four industries corroborate a possible association between asbestos exposure and the development of oral cancer. Manual workers in the asbestos industry, construction industry, shipping industry and the railroad industry have significantly higher oral cancer mortality. Tobacco and alcohol consumption are considered to be major risk factors.[22] However, occupational asbestos exposure has also been reported as a possible causal factor for oral cancer types,[23–25] and for pharyngeal cancer.[26] Historical exposure circumstances should be explored further in order to answer why, specifically, these workers experience high oral cancer mortality.

Reports of elevated prostate cancer risks related to occupational asbestos exposure are scarce.[27 28]

Krstev *et al*[29] found significant excess prostate cancer mortality among unexposed shipping workers. Therefore, a causal effect of asbestos exposure is doubtful.

Potential confounding factors for laryngeal cancer are smoking and alcohol use. Tobacco consumption, a major risk factor for lung cancer, could even have a multiplicative effect when combined with asbestos.[30 31] Considering the use of various carcinogens such as nickel, cadmium or PAHs in the selected industries, concomitant occupational exposure is highly likely. Because of insufficient data, potential confounders could not be considered in our analyses. Results do show that manual workers in construction, in basic metal manufacturing, in metal products manufacturing and in shipping, have significantly higher mortality due to COPD, which is known to be caused predominantly by smoking. Occupational exposure to dust, fumes and gases has been associated with increased incidence of COPD.[32] Construction workers also experience significant excess in mortality due to alcoholic liver disease, oesophageal cancer, mouth cancer and pharyngeal cancer, suggesting high alcohol use. Although mesothelioma and asbestosis mortality provides clear indications of considerable asbestos-related health effects in these industries, further research is needed to estimate the effect of asbestos exposure on lung cancer and laryngeal cancer mortality.

The main advantage of this study is the availability of census-linked, cause-specific mortality data. The anonymous linkage at the individual level minimises the nominator-denominator bias. Furthermore, even industries with relatively small working populations could be included in this study, due to the large number of persons in the data set.

The study design has some limitations. Occupational information is only available for a specific time period. Our findings may be confounded by exposure during previous jobs. Persons who have already quit asbestos-related industries at the time of the 1991 census cannot be identified. The most heavily exposed workers may have already left the workforce due to health reasons. As only actively employed workers are studied, healthy worker effects may bias our results. Based on the number of mesothelioma deaths among pre-retired men in the non-active population, we believe that a considerable proportion of occupational asbestos victims remain unnoticed.

As a result of job changes prior to the census date, it is also possible that occupationally exposed workers are included in the reference population. Although workers in the reference population are at least partially exposed to asbestos in the environment or through indirect contact, the number of mesothelioma deaths is larger than anticipated. As recent studies estimate that 8.3% to 11% of all mesothelioma deaths are attributable to non-occupational asbestos exposure,[33 34] our results may still underestimate the true influence of occupational asbestos exposure.

Occupational information after the 1991 census is not available. Hence, potential confounders related to the last job have not been taken into account. Owing to the long period between asbestos exposure and onset of related diseases, we believe this does not alter the interpretation of our results.

Assumptions on asbestos exposure are industry-based. Although occupational type is considered, individual exposure information is not available and the number of workers at risk is surely overestimated. It is possible that asbestos exposure occurs in some industries only among specific groups of workers at specific workstations, and the effect of occupational asbestos exposure remains unnoticed. This may explain why no significant effects were found for asbestos-related mortality in the automotive industry, the textile industry and the electrotechnical industry.

The distinction between manual and non-manual workers is based on the physical or intellectual nature of the work, as stated in the labour agreement between employer and employee. This criterion is highly subject to interpretation. Reports have been made of workers doing the same job, but with different statuses (blue-collar vs white-collar status).[35 36]

In conclusion, cause-specific mortality reveals the repercussions of historical asbestos use on Belgian workers. Asbestos workers are not the only employees to experience increased asbestos-related mortality. The study also identifies eight industries with significantly elevated asbestos-related mortality, which have been previously overlooked in Belgian asbestos research. Furthermore, observations in four industries indicate a possible association between occupational asbestos exposure and the development of oral cancer. This study contributes to the large amount of international evidence on the adverse health effects of occupational asbestos exposure. Workers should be informed about the risks of past exposure and all forms of asbestos use should be banned.

Acknowledgements The authors thank Didier Willaert for his much-appreciated help in preparing the data and Jan De Schampheleire for his expert advice on the Belgian labour market.

Contributors PD and LVdB designed the study. LVdB conducted the study and wrote the first draft of the manuscript. Both authors edited the draft, discussed the interpretation and approved the final version of the manuscript.

Funding The Research Council of Vrije Universiteit Brussel supported the study. LVdB is a PhD fellow at the Research Foundation-Flanders (FWO). Preliminary results were presented at the 2014 European Population Conference and the XX World Congress on Safety and Health at Work.

Competing interests None declared.

Ethics approval The Belgian Commission for the protection of privacy.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Analyses are based on administrative data from the Belgian Census, the Belgian mortality register and death certificates provided by Statistics Belgium. The availability of the data is restricted. Permission for analyses must be granted after verification of the research goals by the Belgian Commission for the protection of privacy.

REFERENCES

1. Van den Borre L, Deboosere P. Asbestos in Belgium: an underestimated health risk. The evolution of mesothelioma mortality rates (1969–2009). *Int J Occup Environ Health* 2014;20:134–40.
2. Weill H, Hughes J, Churg A. Changing trends in US mesothelioma incidence. *Occup Environ Med* 2004;61:438–41.
3. Virta RL. *Worldwide asbestos supply and consumption trends from 1900 through 2003*. Reston, VA: U.S. Department of the Interior; 2006, U.S. Geological Survey Report No.: Circular 1298.
4. Vande Weyer R. Bilan de l'indemnisation de l'asbestose. *Acta Tuberc Pneumol Belg* 1973;64:304–51.
5. Lacquet LM, van der Linden L, Lepoutre J. Roentgenographic lung changes, asbestosis and mortality in a Belgian asbestos-cement factory. In: Wagner JC, ed. *Biological effects of mineral fibres IARC Scientific Publication 30*. Lyon, France: International Agency for Research on Cancer, 1980:783–95.
6. Nawrot T, Van Kersschaever G, Van Eycken E, *et al*. Belgium: historical champion in asbestos consumption. *Lancet* 2007;369:1692.
7. De Kezel E. *Asbest, gezondheid en veiligheid. Ontwikkelingen in het aansprakelijkheidsrecht*. Antwerpen: Intersentia, 2013.
8. Nay SY. Asbestos in Belgium: use and abuse. *Int J Occup Environ Health* 2003;9:287–93.
9. Van De Voorde H, Meulepas E, Gyselen A, *et al*. Doodsoorzaken bij de bevolking woonachtig rond en bij de arbeiders werkzaam in een asbestverwerkende nijverheid in het noorden van Brabant. *Acta Tuberc Pneumol Belg* 1967;58:924–42.
10. Vande Weyer R. Pathologie respiratoire de l'amiante en Belgique. *Rev Méd Brux* 1981;2:69–81.
11. International Agency for Research on Cancer. Asbestos (chrysotile, amosite, crocidolite, tremolite, actinolite, and anthophyllite). *A review of human carcinogens Part C: Arsenic, metals, fibres, and dusts/ IARC Working Group on the Evaluation of Carcinogenic Risks to Humans*. Vol. 100. Lyon, France: International Agency for Research on Cancer, 2012:219–309.
12. Scientific Institute of Public Health, Public Health and Surveillance. *Standardized procedures for mortality analysis*. Brussels, 2015. http s://www.wiv-isp.be/epidemio/spma
13. Hillerdal G. Mesothelioma: cases associated with non-occupational and low dose exposures. *Occup Environ Med* 1999;56:505–13. http://oem.bmj.com/cgi/doi/10.1136/oem.56.8.505
14. Rothman KJ, Boice JD. *Epidemiological analysis with a programmable calculator*. Washington DC: US Government Printing Office, 1979.
15. Paustenbach DJ, Madl AK, Donovan E, *et al*. Chrysotile asbestos exposure associated with removal of automobile exhaust systems (ca. 1945–1975) by mechanics: results of a simulation study. *J Expo Sci Environ Epidemiol* 2006;16:156–71.
16. Finkelstein MM. Asbestos fibre concentrations in the lungs of brake workers: another look. *Ann Occup Hyg* 2008;52:455–61.
17. Ameille J, Rosenberg N, Matrat M, *et al*. Asbestos-related diseases in automobile mechanics. *Ann Occup Hyg* 2012;56:55–60.
18. Lin S, Wang X, Yu ITS, *et al*. Cause-specific mortality in relation to chrysotile-asbestos exposure in a Chinese cohort. *J Thorac Oncol* 2012;7:1109–14.
19. Pira E, Pelucchi C, Piolatto PG, *et al*. First and subsequent asbestos exposures in relation to mesothelioma and lung cancer mortality. *Br J Cancer* 2007;97:1300–4.
20. Hein MJ, Stayner LT, Lehman E, *et al*. Follow-up study of chrysotile textile workers: cohort mortality and exposure-response. *Occup Environ Med* 2007;64:616–25.
21. Fear NT, Roman E, Carpenter LM, *et al*. Cancer in electrical workers: an analysis of cancer registrations in England, 1981–87. *Br J Cancer* 1996;73:935–9.
22. Hashibe M, Brennan P, Chuang S, *et al*. Interaction between tobacco and alcohol use and the risk of head and neck cancer: pooled analysis in the INHANCE Consortium. *Cancer Epidemiol Biomarkers Prev* 2009;18:541–50.
23. Paget-Bailly S, Cyr D, Luce D. Occupational exposures to asbestos, polycyclic aromatic hydrocarbons and solvents, and cancers of the oral cavity and pharynx: a quantitative literature review. *Int Arch Occup Environ Health* 2012;85:341–51.
24. Dement J, Welch L, Haile E, *et al*. Mortality among sheet metal workers participating in a medical screening program. *Am J Ind Med* 2009;52:603–13.
25. Ulvestad B, Kjærheim K, Martinsen JI, *et al*. Cancer incidence among workers in the asbestos-cement producing industry in Norway. *Scand J Work Environ Health* 2002;28:411–17.
26. Langevin SM, O'Sullivan MH, Valerio JL, *et al*. Occupational asbestos exposure is associated with pharyngeal squamous cell carcinoma in men from the greater Boston area. *Occup Environ Med* 2013;70:858–63.
27. Koskinen K, Pukkala E, Reijula K, *et al*. Incidence of cancer among the participants of the Finnish Asbestos Screening Campaign. *Scand J Work Environ Health* 2003;29:64–70.
28. Raffn E, Lynge E, Juel K, *et al*. Incidence of cancer and mortality among employees in the asbestos cement industry in Denmark. *Br J Ind Med* 1989;46:90–6.
29. Krstev S, Stewart P, Rusiecki J, *et al*. Mortality among shipyard Coast Guard workers: a retrospective cohort study. *Occup Environ Med* 2007;64:651–8.
30. Gustavsson P. Low-dose exposure to asbestos and lung cancer: dose-response relations and interaction with smoking in a population-based case-referent study in Stockholm, Sweden. *Am J Epidemiol* 2002;155:1016–22.
31. Markowitz SB, Levin SM, Miller A, *et al*. Asbestos, asbestosis, smoking, and lung cancer. New findings from the North American insulator cohort. *Am J Respir Crit Care Med* 2013;188:90–6.
32. Blanc PD, Iribarren C, Trupin L, *et al*. Occupational exposures and the risk of COPD: dusty trades revisited. *Thorax* 2009;64:6–12.
33. Boffetta P, McLaughlin JK, la Vecchia C, *et al*. "Environment" in cancer causation and etiological fraction: limitations and ambiguities. *Carcinogenesis* 2007;28:913–15.
34. Mirabelli D, Cavone D, Merler E, *et al*. Non-occupational exposure to asbestos and malignant mesothelioma in the Italian National Registry of Mesotheliomas. *Occup Environ Med* 2010;67:792–4.
35. Starr P. Social categories and claims in the liberal state. In: Douglas M, Hull D, eds. *How classification works*. Edinburgh University Press, 1992:154–79.
36. Pichault F, Xhauflair V, Deflandre D, *et al*. Flexibiliteit en Aantrekkelijkheid: Sociaal overleg in een context van projectmanagement. Report Federatie van Algemene Bouwondernemers-Fédération des Entrepreneurs Généraux de la Construction, 2005:103.