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This is the published version of a paper published in *Scandinavian Journal of Public Health*.

Citation for the original published paper (version of record):

Järvholm, B., Burdorf, A. (2015)

Emerging evidence that the ban on asbestos use is reducing the occurrence of pleural mesothelioma in Sweden.

Scandinavian Journal of Public Health, 43(8): 875-881

<http://dx.doi.org/10.1177/1403494815596500>

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ORIGINAL ARTICLE

Emerging evidence that the ban on asbestos use is reducing the occurrence of pleural mesothelioma in Sweden

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Abstract

Aims: Several countries have banned the use of asbestos. The future health impacts of previous use have been modeled but there are to our knowledge no convincing studies showing a decreased occurrence of asbestos-related diseases due to a ban. The aim of our study was to estimate the effects of the ban and other measures to decrease the use of asbestos in Sweden. **Methods:** The effect was measured through comparing the incidence of pleural malignant mesothelioma in birth cohorts who started to work before and after the decrease in the use of asbestos, i.e. in mid-1970s. Cases were identified through the Swedish Cancer Registry and the analysis was restricted to persons born in Sweden. **Results:** Men and women born 1955–79 had a decreased risk of malignant pleural mesothelioma compared to men and women born 1940–49 (RR 0.16, 95% CI 0.11–0.25; and RR 0.47, 95% CI 0.23–0.97 respectively). The decreased use of asbestos prevented each year about 10 cases in men and two cases in women below the age of 57 years in 2012. **Conclusions: The ban and decreased use of asbestos in Sweden can be measured today in birth cohorts that started their working career after the decrease.**

Key Words: Asbestos, cancer, epidemiology, intervention, occupation, prevention

Asbestos is a well-known carcinogen responsible for cancer of the pleura and peritoneum (mesothelioma) and lung cancer. Since mesothelioma is almost exclusively caused by asbestos, the dramatic increase in mesothelioma deaths in many countries has demonstrated the profound consequences of historical exposure to asbestos [1]. Various western countries have introduced a legal ban on asbestos use in the past decades and a worldwide asbestos ban is strongly advocated by many scientists [2,3].

The first bans on asbestos use were introduced by Nordic countries, i.e. Iceland (1982), Norway (1983), and Sweden (1982), but the restrictions imposed by legislation may vary among countries [4]. In addition, in some countries asbestos use was already strongly reduced before legislation was enacted. In Sweden a collective agreement between employers and labor unions prohibited use of asbestos products in the construction industry and ship-building from the

mid-1970s onwards, thereby eliminating the largest users of asbestos.

In recent years several attempts have been made to demonstrate the impact of asbestos bans on the burden of mesothelioma deaths. A descriptive analysis in 53 European countries showed that age-adjusted mortality rates over 1994–2010 were almost 2.5-fold higher in countries with an asbestos ban before 2000 compared with countries with a later or no ban, illustrating the complexity in this ecological study design to disentangle high mesothelioma rates as a prompt for introducing policy measures with the potential impact of a ban on subsequent reduction of mesothelioma deaths [5]. In a detailed analysis in 31 countries Nishikawa and colleagues [4] reported negative annual% changes (APCs) in age-adjusted mortality rates from –0.3 to –5.9 %/year in five European countries over the period 1996–2005. Change in asbestos use during 1970–85 was a predictor of APC

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(Accepted 24 June 2015)

© 2015 the Nordic Societies of Public Health
DOI: 10.1177/1403494815596500



in mesothelioma deaths between 1996 and 2005, but the effect of a ban could not be established. A subsequent analysis in 83 countries on mesothelioma deaths over the period 1994–2008 showed a significant decrease only in the United States with an APC of -0.84 %/year (95% CI -1.34 to -0.34), and increasing trends in Europe and Japan [6].

In observational studies on trends in mesothelioma mortality rates at population level it is difficult to evaluate the impact of an asbestos ban as the primary preventive intervention. Models of the association between the risk of asbestos and mesothelioma include both cumulative exposure and time since first exposure [7]. That means that most cases will occur in high ages. Hence, an evaluation of the impact of an asbestos ban must take into account age-specific mortality rates during consecutive birth cohorts. A previous analysis has indicated that the highest risks for pleural mesothelioma in Sweden was in birth cohorts born between 1935 and 1949 [8]. Thus, an analysis of birth cohorts that started their working career when the use of asbestos had decreased would indicate the effect of a ban. Furthermore, immigration has increased and an analysis should preferably include those living in Sweden at the time of the ban.

In this study we take Sweden as an example of a country with an early asbestos ban with the aims to [1] evaluate how the ban has influenced age-specific mortality rates over time, and [2] to conduct a health impact assessment on burden of mesothelioma death avoided by this ban up to 2012.

Methods

Data on cases of pleural mesothelioma were provided by the national Swedish Cancer Register. The data were stratified for sex, birth cohort (5-year classes, 1915–1919, etc.), and if the case was born in Sweden or not. Reporting of malignant tumors to the register has been mandatory for physicians and pathologists since 1958, and we had data until 2012 on site (pleura, ICD 7 1622) and histological code (malignant mesothelioma, code 776). The Cancer Register also provides some data available on the internet (<http://www.socialstyrelsen.se/statistik/statistikdatabas/cancer>, accessed 11 February 2015). The yearly number of individuals in the birth cohorts was collected from national statistics (Statistics Sweden). We used age adjustments according to the Swedish population in 2000 as provided by the Cancer Register.

The expected number of cases in the youngest birth cohorts (1955–59, etc.) was calculated assuming similar risk as in the 1940–49 birth cohorts, adjusted for age. E.g. the reference rate for the

1955–59 birth cohort in 1988–92 was calculated as the number of cases in the 1940–44 birth cohort in the calendar period 1973–77 and the number of cases in the 1945–9 birth cohort in 1978–82 divided by the number person-years in the two cohorts in the corresponding time periods. Mesothelioma rarely occurs with short latency periods, meaning that cases caused by occupational exposure rarely occurs before the age 30 years. We planned to exclude ages below 30 years; we had birth cohorts at 5-year intervals and used a 5-year interval for observation until 2012, meaning that the youngest person in the analysis was 33 years of age (the numbers in each strata are presented in tables S1 and S2). The overall expected number was estimated by summarizing the expected numbers over all birth cohorts and calendar periods. We estimated the expected numbers for the birth cohorts from 1955 onwards from calendar years when the oldest person in the cohort was 33 years of age, i.e. 1988–2012 for the 1955–59 cohort to 2008–12 for the 1975–79 cohort.

Time trends of incidence rates from the register were analyzed as APC by linear regression of the log of the incidence rates as provided from the Cancer Register. The time trends were estimated from 1995 onwards, i.e. about 20 years after the sharp drop in import of asbestos to Sweden.

The difference in incidence for men and women were estimated by Poisson regression analysis comparing the cohorts born between 1940–49 and between 1955–79 respectively.

SAS statistical software version 9.3 (SAS statistical software version 9.3. Cary, NC: SAS Institute Inc., 2002) were used in the analysis.

Use of asbestos

The use of asbestos was estimated through the import of raw asbestos (Figure 1). Although the data comprised all forms of asbestos, the absolute majority was chrysotile. The import accelerated after World War II. It leveled off during two decades and then declined temporarily in 1973, when asbestos spraying was prohibited. An intensive media discussion, following the release of data on mesothelioma in asbestos-using industries disclosed by using the Cancer Registry (Anders Englund, personal communication), made the hazard widely recognized. The use of crocidolite was banned in 1975 but the rapid decline in import during the first half of 1976 was caused by an agreement between the employers and unions in the construction industry to abandon the use of asbestos-containing products and opt for alternative products. The decision was taken when the true incidence of mesotheliomas among the Swedish

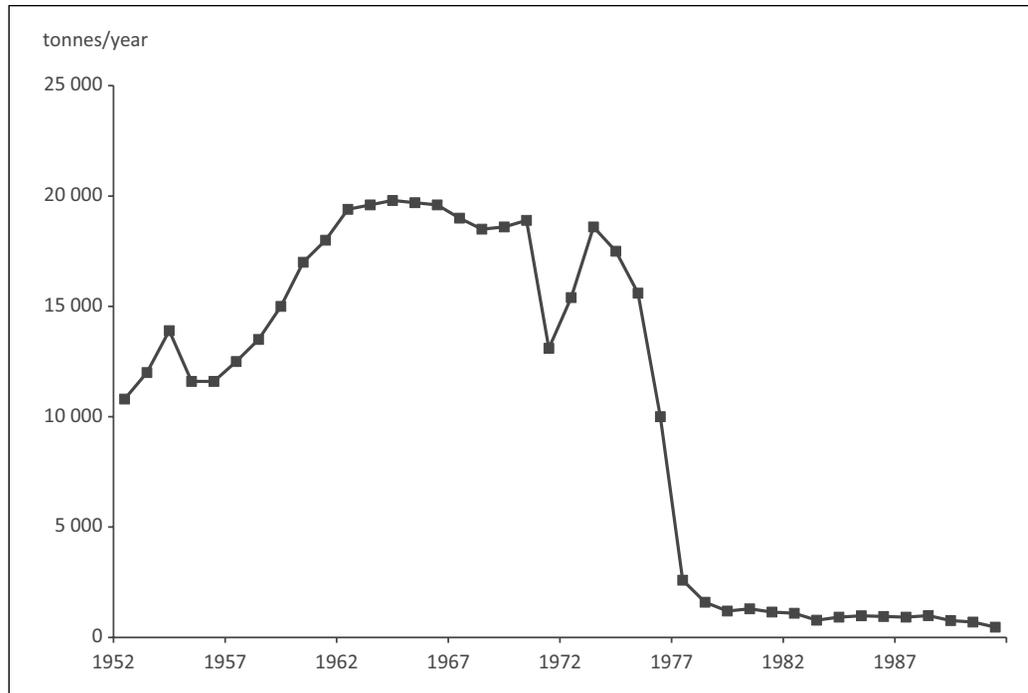


Figure 1. Import of raw asbestos to Sweden 1952–91.

construction workers had been explored by using the surveillance program put in place in that industry (BYGGHALSAN). The Work Environment Authority banned the use of asbestos in 1982 in most activities [9]. There were a few exemptions, e.g. it could be used in certain gaskets and in brake linings for heavy trucks if there were no alternatives available. Also, the handling of existing asbestos installations was regulated, e.g. demolition and reconstruction. The regulation has then been adjusted towards a total ban of all asbestos products in 1986.

Results

The total number of new cases of pleural malignant mesothelioma in Sweden has been fairly stable in Sweden since 1995, both in men and women (Figure 2). The age-adjusted incidence rate 1995–2013 has decreased slightly for men (APC -1.3%) but not for women (APC 0.6%).

Analysis by birth cohort of persons born in Sweden

To study the effect of the ban we have restricted the analysis to persons born in Sweden. The incidence rates for birth cohorts born before 1955, i.e. persons above 20 years of age before the heavy drop in import of asbestos, show a clear trend of increasing risk by increasing age (Figure 3, tables S1 and S2). The

highest incidences are in those born 1935–49, and all three birth cohorts show similar age dependence while later born cohorts show a lower incidence. Persons born in 1955 started their working life in the mid-1970s, i.e. when there was a rapid decrease in the use of asbestos.

The number of expected cases among persons born 1955 or later assuming a similar risk to those born 1940–49 shows that about 108 cases of pleural mesothelioma would have occurred through 2012 among men born 1955–79 if they have had the same risk as those born in the 1940s, Table I. For women there would have been 24.6 cases vs. 12 observed. That is in total about 121 cases less than expected ($108.0+12.6$).

However, the 121 cases are differently distributed per calendar year; in 1988–92 the difference between expected and observed is 1.7 while it is 62.7 in the period 2008–2012, i.e. about 12 cases per year in the latter period (about 10 in men and two in women).

The relative risks of pleural mesothelioma were increased for men compared to women, in cohorts born 1940–9 and 1955–79 respectively (Table II). An analysis including only persons below the age of 60 years showed similar results (table S3).

Cases in persons not born in Sweden

The analysis is based persons born in Sweden, i.e. only cases who were born in Sweden are included in

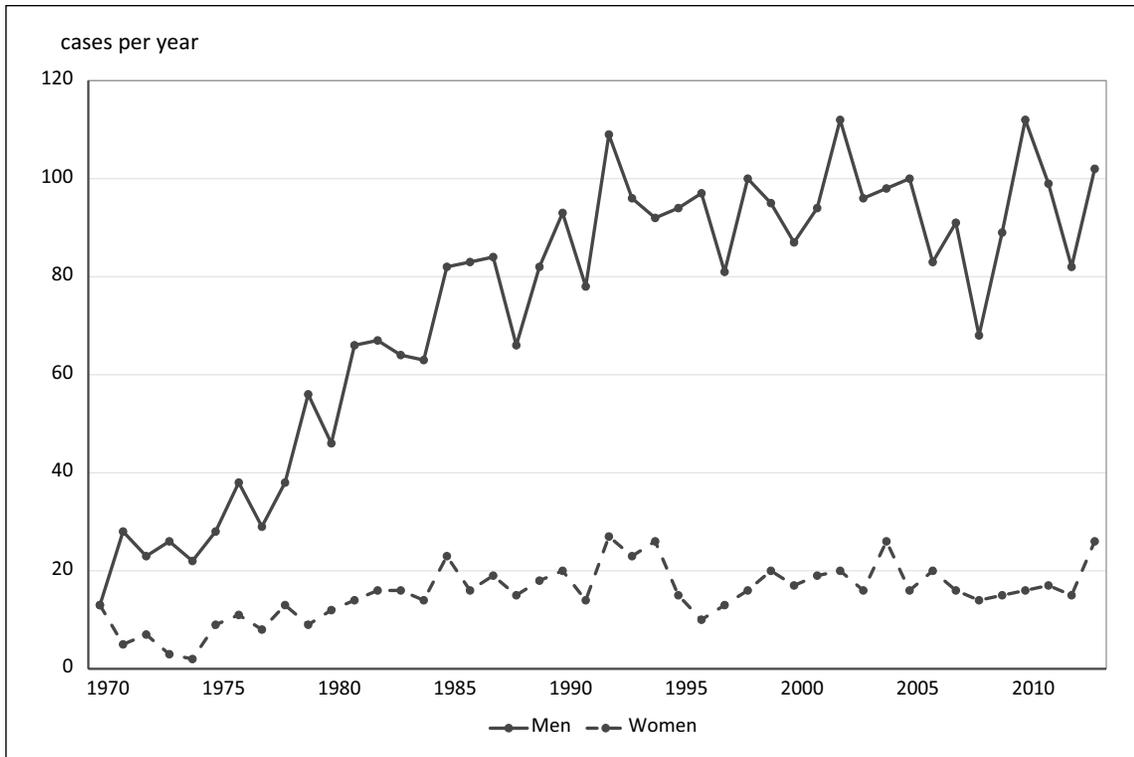


Figure 2. Incident cases of pleural malignant mesothelioma in Sweden 1970–2013.

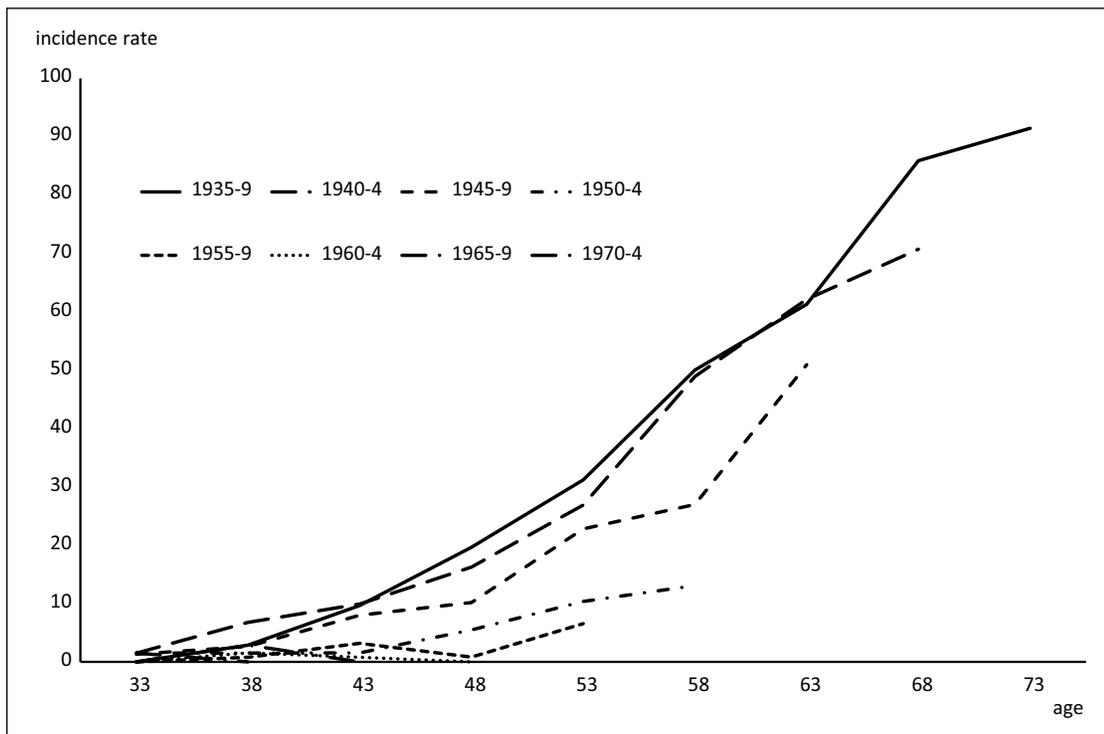


Figure 3. Incidence rates (per 1 000,000) for men according to birth cohort and age.

the analysis. Our primary reason was that we suspected that immigrants could have had occupational

asbestos exposure before coming to Sweden, which could increase the occurrence in a non-random way.

Table I. Observed and expected number of cases among cohorts born 1955 or later assuming same risk as those born 1940–49, men.

Birth cohort	Time of follow-up ^a	Observed	Expected ^b	Difference ^c
Men				
1955–59	1988–2012	14	65.1	51.1
1960–64	1993–2012	3	35.9	32.9
1965–69	1998–2012	4	20.6	16.6
1970–74	2003–2012	2	7.8	5.8
1975–79	2008–2012	0	1.6	1.6
All men	1988–2012	23	131.0	108.0
Women				
1955–59	1988–2012	6	10.3	4.3
1960–64	1993–2012	3	6.9	6.9
1965–69	1998–2012	1	4.4	3.4
1970–74	2003–2012	1	2.3	1.3
1975–79	2008–2012	1	0.8	–0.2
All women	1988–2012	12	24.6	12.6
Total	1988–2012	35	155.6	120.6

^a33+ years from the oldest born person in the cohort.

^bCalculated from incidence rates of men born 1940–9 stratified for age.

^cExpected – observed cases.

Table II. Relative risks^a for malignant pleural mesothelioma according to birth cohort.

		Relative risk (95% CI)	Relative risk (95% CI)
Within Sex			
Men	1940–49	6.12 (3.98–9.41)	1 (ref)
	1955–79	1 (ref)	0.16 (0.11–0.25)
Women	1940–49	2.13 (1.03–4.39)	1 (ref)
	1955–79	1 (ref)	0.47 (0.23–0.97)
Between sex			
1940–9	Men	7.55 (95% CI 5.78–9.86)	1 (ref)
	Women	1 (ref)	0.13 (0.10–0.17)
1955–79	Men	1.91 (0.98–3.72)	1 (ref)
	Women	1 (ref)	0.52(0.27–1.02)

^aEstimated by Poisson regression analysis.

Less than 10% were among persons not born in Sweden, and the cases occurred mostly in the end of the observation period (tables S4 and S5).

Discussion

Our analysis clearly shows that the ban and other restrictions on the use of asbestos in the mid-1970s and early 1980s have decreased the risk of mesothelioma in persons who started their working career during or after this period.

Methodological aspects

It is often of great interest to study the effect of an intervention. Decreasing the use of asbestos through bans and other initiatives in Sweden was a major societal intervention. Studying mesothelioma as a measure of the effect of the intervention has the advantage of mesothelioma being a disease almost

exclusively caused by asbestos. The drawback is that the risk increases some decades from first exposure, meaning that the effect of the intervention can be studied only decades after the intervention. The overall incidence in Sweden, as presented in Figure 2, shows only a very small decrease after the year 2000, while an analysis by birth cohort show a lower risk in younger cohorts (Figure 3). This clearly illustrates that a change in trend in the overall incidence is not a sound indicator for the impact of the asbestos ban. The overall mortality incorporates many birth cohorts, such as those born between 1935 and 1949, with an increasing high risk of mesothelioma with older age that offset the already rapidly decreasing risk of mesothelioma in younger birth cohorts. Mesothelioma depends on the latency period and our analysis assumes that the persons in each birth cohort on average start their exposure at similar ages. Most manual workers start working at 15–20 years of age, meaning that when asbestos exposure was

common they were occupationally exposed first at that age.

Another option is to study the difference between men and women assuming that women have no or very low occupational exposure to asbestos. Our results indicate that there was some occupational exposure in women born 1940–49 (Table II). An analysis of the difference between men and women may underestimate the effect of the intervention.

We have restricted the analysis to persons born in Sweden. Today about 16% of the Swedish population is born in other countries and if they had different exposure patterns to asbestos it could cause some bias in the estimates. The sensitivity analysis showed that immigrants had a lower risk of pleural malignant mesothelioma and that cases occurred mainly in older birth cohorts (tables S4, S5).

The ban

The import of raw asbestos decreased sharply in the mid-1970s due to a combination of some legal restrictions and a negotiated agreement between unions and employers (see Figure 1). The major ban of new use of asbestos was in 1982, but at that time there were some exemptions, e.g. brake linings. There was still a lot of asbestos in buildings and in cars (both in personal cars and trucks). In 1986 there was a law prohibiting selling cars of 1988 models and busses and trucks of 1989 models or later with asbestos brake linings (provision 1986:683). Thus, the total effect of the ban cannot be evaluated by cohorts starting their working career in the mid-1970s, but rather by those starting in the 1990s, i.e. those born 1970 or later. However, we think that the effect of the ban is already obvious in our analysis.

A ban may not just be a legal action, as the findings in Sweden show that there are effects through negotiations between unions and employers and subsequent effects with “power of a well-informed actor on the market”.

Impact

Our analysis shows that the ban has already in 2012 avoided about 12 cases a year (10 in men and two in women) of malignant pleural mesothelioma in ages up to 57 years, i.e. in working ages. This could be compared to the total number of fatal occupational accidents, which was 45 in 2012. Thirteen of these 45 cases occurred in the manufacturing and construction industry, the industry in which most of the asbestos was used. Our estimation of impact only includes pleural malignant mesothelioma. Asbestos is also a cause of other fatal diseases such as lung cancer, mesothelioma

in the peritoneum, and asbestosis. Some studies indicate that the number of lung cancer cases caused by occupational asbestos exposure is of similar size to the number of malignant mesothelioma cases [10]. It would indicate that in 2012 the ban has at least avoided around 24 cases of mesothelioma and lung cancer just in men and women below the age of 57 years. Other studies have indicated a higher proportion of lung cancer than mesothelioma. McCormack et al. [11] found a ratio of about 6 for lung cancer vs. mesothelioma among groups mainly exposed to chrysotile. Most asbestos in Sweden was chrysotile, meaning that “24 cases” may be an underestimation of the impact. Also, family members of exposed workers may gain from a ban as para-occupational exposure will be reduced.

Occupational vs. environmental exposure

Our analysis is focused on the effects on occupational exposure of asbestos. The ban would also cause a decrease in cases due to environmental exposure. That effect is harder to evaluate as it would be based on smaller numbers and changes would be difficult to separate from random variation. Swedish men worked and are working to a much larger extent in industries that used asbestos, e.g. construction industry and shipyards, than Swedish women. However, our analysis indicates that there was a major reduction in women after the ban as the risk decreased by about 50% (Table II). As environmental exposure can occur from birth, the effects of the ban on the risk from environmental exposure would be possible to study in birth cohorts born from 1980 or later. The number of cases in young ages is very low, which indicates that a meaningful analysis cannot be conducted until the late 2020s!

External validity

Our results are based on findings in Sweden. It is reasonable to assume that similar interventions in other countries will decrease the occurrence of pleural mesothelioma. The impact will depend on the proportion of the population that is exposed, the magnitude of the exposure, and age at first exposure. A previous analysis indicated a twofold risk of pleural malignant mesothelioma in The Netherlands compared with Sweden [12]. Thus, the effect of a similar ban and reduction of the use of asbestos in The Netherlands would be about double the effect in Sweden.

In summary, the ban and other initiatives to decrease the occupational exposure to asbestos have had a measurable effect on health.

Acknowledgements

We acknowledge valuable discussions with Anders Englund and Johan Sommar Nilsson.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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