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Recent Scientific Evidence Regarding Asbestos Use and Health Consequences of Asbestos Exposure

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Abstract To justify the continuous use of two million tons of asbestos every year, it has been argued that a safe/controlled use can be achieved. The aim of this review was to identify recent scientific studies that present empirical evidence of: 1) health consequences resulting from past asbestos exposures and 2) current asbestos exposures resulting from asbestos use. Articles with evidence that could support or reject the safe/controlled use argument were also identified. A total of 155 articles were included in the review, and 87 % showed adverse asbestos health consequences or high asbestos exposures. Regarding the safe/controlled use, 44 articles were identified, and 82 % had evidence suggesting that the safe/controlled use is not being achieved. A large percentage of articles with evidence that support the safe/controlled use argument have a conflict of interest declared. Most of the evidence was developed in high-income countries and in countries that have already banned asbestos.

Keywords Asbestos · Safe/controlled use · Conflict of interest · Scientific evidence

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Introduction

There are two main groups of asbestos fibers, amphiboles and serpentines [1–4]. Amphiboles include amosite, crocidolite, tremolite, actinolite, and anthophyllite [2–6]. Chrysotile is the only type of asbestos in the serpentine group [1–3, 5]. Asbestos has several physicochemical characteristics, including tensile strength and resistance to heat, fire, and corrosion, which result in multiple industrial applications [1, 7]. Therefore, asbestos has been and is still used in a large number of industrial products [1, 4, 6–8].

All forms of asbestos are carcinogenic to humans (Group 1) [1, 2, 9, 10]. Asbestos, including chrysotile, causes mesothelioma, cancer of the lung, larynx, and ovary [1, 2, 9, 10]. The scientific evidence suggests that there is no threshold for the carcinogenic effect of asbestos exposure [1, 4, 5, 9]. Because of its negative health effects, since the 1980s, different countries, especially high-income countries, began to restrict and ban the use of asbestos [2, 11]. The first country to implement a complete ban on asbestos was Iceland in 1983 [12], and by September 2015, 57 countries have banned the production and consumption of all forms of asbestos [13].

Asbestos has been used since ancient times [7], but its consumption markedly increased from the 1920s until the 1980s [2]. At the global scale, the highest level

of asbestos consumption occurred in 1977, when approximately 4.7 million tons were reached [6, 11, 12]. Then, asbestos health risks triggered country-wide bans and stringent regulations, which resulted in a worldwide asbestos consumption decline until the late 1990s, when it leveled at two million tons, a consumption level that has been maintained since then with some minor fluctuations [2, 4, 6, 11, 12]. Most of the asbestos currently used is chrysotile (95-100 %) [1, 6, 7, 9], and low- and middle-income countries have a major share in the consumption and production of asbestos at a global scale [1, 2, 4, 9, 11]. Furthermore, in some parts of the world consumption is increasing, especially in Asia [2, 12, 14]. In 2012, 60 % of the global asbestos consumption was concentrated in China (26 %), India (25 %), and Brazil (9 %) [4]. It is estimated that 125 million people in the world are occupationally exposed to asbestos [3, 9], and each year 107,000 people die from asbestos related diseases (i.e., mesothelioma, lung cancer, and asbestosis) [2, 4, 11, 14].

One argument that has been used to justify the continued use of asbestos is that chrysotile asbestos is safe to use because it has a lower cancer potency compared to other asbestos types [15–18]. Although there is some evidence of a potency difference for mesothelioma [3, 4, 16, 19, 20], for lung cancer this potency difference is controversial [3, 5, 18, 19, 21, 22], and for both mesothelioma and lung cancer the potency difference has been strongly contended. Additional arguments to justify the use of chrysotile include that exposure is prevented because chrysotile-containing products are high-density (i.e., non-friable) [16] and that control interventions can be implemented to achieve a safe/controlled use [17, 18]. In many of the studies that argue in favor of a safe/controlled use of asbestos, conflicts of interest of the authors have been identified [1].

This review considers scientific publications over the last 5.5 years (Jan 2010 - Jul 2015), identifying studies that analyze health impacts associated with asbestos exposure, including studies that report no adverse health outcomes. The review also identifies studies that analyze asbestos exposures derived from the use of both asbestos and asbestos-containing products. The primary aim of this review is to determine among recently published scientific studies, how many studies show evidence of asbestos adverse health effects or high asbestos exposures compared to those that show no evidence of asbestos health effects or low asbestos exposures. The distribution of studies that either support or oppose the safe/controlled use argument is also identified. During the review process, for each study it was determined if a conflict of interest was reported and the income level of the country where the study was conducted.

Methods

The search process was conducted using PubMed. Keywords for the search were: asbestos + country name, safe use + asbestos, and controlled use + asbestos. Name of the countries were identified using the list of The World Bank income economy classification, consulted on December 1st, 2015. To be included in the review, articles should have been published between January 1st, 2010 and July 31st, 2015, and only articles written in English were considered. The search process of the keywords involving countries was finalized on January 22nd, 2016. The search process of the keywords involving safe and controlled use was conducted on March 15th, 2016. Once an article was identified, it was downloaded for free through multiple databases with which our institution, Universidad de los Andes, is affiliated.

From the list of titles of the articles that could not be accessed for free, articles that could be relevant for the review were selected. This list of articles was requested through Celsius Network, a software that, among other things, gives access to published articles in libraries that are member of Library Linkage. Because of budget constraints, articles that could not be accessed for free through Celsius Network were not included in the review. Furthermore, some articles that were requested through Celsius Network were not found by the system.

Articles identified in the search process by the country of origin were distributed based on this classification between six readers. There were no specific criteria for this distribution. Since sometimes PubMed classifies articles in a wrong country, the same article may have been included in more than one country and because of this some articles were read by more than one reader.

Since the purpose of the review was to identify empirical evidence regarding asbestos exposures resulting from asbestos use or health consequences derived from the use of asbestos, our readers classified the articles based on pre-established criteria. Three groups of studies were identified:

1) Epidemiological studies presenting evidence of the presence or absence of adverse health consequences in populations exposed to asbestos. In this category, studies addressing the following health outcomes were the only ones included: mesothelioma, asbestosis, pleural plaques, lung opacities and thickening, and cancer of the lung, larynx, and ovaries.
2) Exposure assessment studies that reported air asbestos concentrations or asbestos exposures resulting from the use of either asbestos or asbestos containing products. Regulatory compliance was also considered in this group of studies if it was explicitly discussed. In some studies, regulatory compliance was determined based on local regulations, which could be different from the

international reference value for asbestos air concentration of 0.1 f/cc.

3) Review articles and meta-analysis, if asbestos exposure was assessed in the study.

Articles focused on the following topics were excluded:

- Theoretical and simulation studies.
- Toxicological studies involving animals or in vitro studies.
- Studies analyzing the mode of action by which asbestos induce disease, including studies of genotoxicity.
- Studies presenting treatment options or prognostic methodologies for asbestos-related diseases (ARD).
- Studies that use projections to estimate future number of ARD cases.
- Studies stating that no exposure to asbestos occurred or that asbestos exposure could not be proven.
- Studies in which asbestos exposure was not assessed or determined.
- Studies involving environmental exposure produced by naturally occurring asbestos.
- Studies in which asbestos exposures occurred because of contamination of a material and not because of asbestos use (e.g., diamond mine, talc industry).
- Studies addressing multiple contaminants without individual conclusions for asbestos.
- Studies focused on methods for fiber counting.
- Studies that use information and surrogates constructed in countries or regions different from the one where the study was conducted, to estimate number of people occupationally exposed to asbestos.
- Studies analyzing potential and not validated biomarkers of disease presence or progression.
- Letters to the editor, editorials, responses, or commentaries.

For all the articles included, the following characteristics were determined: 1 – Country where the study was conducted, based on the geographical region of the study, and not the nationality of authors or institutions involved (i.e., if more than one country was involved, it was classified as either regional or global); 2 – Based on the World Bank country income classification (i.e., consulted on December 1st, 2015), the income level of each country was established (i.e., high, upper-middle, lower-middle, or low); 3 – Type of asbestos identified in the study; 4 – Conflict of interest reported by the authors of the study. If at least one author reported a conflict of interest, the article was classified as having a conflict of interest. Conflict of interest was solely determined based on what was reported by the authors in the article, and the researchers involved in this review made no changes on what was reported. If there was no specific report of either presence or absence of conflict of interest, it was classified as *Not Reported* (NR).

Because of the extremely low number of studies identified in the initial search with evidence of either no asbestos health consequences or compliance of asbestos exposure limits (i.e., eight articles), an additional search was conducted using as keywords the names of some authors whose research has been sponsored by the industry. Three additional studies were identified. This search was conducted between March 27th and April 1st, 2016.

In some studies that complied with the inclusion criteria, it was difficult to define if the results could be used to determine elevated health risks or high air asbestos concentrations or exposures. In such cases, the study was classified as ambiguous.

We also tried to determine if the safe/controlled use concept could be assessed in some of the articles that complied with the inclusion criteria. In this case, studies included were not restricted to those that explicitly analyzed the presence or absence of a safe/controlled use. Thus, studies that did not have as explicit aim an analysis of the safe/controlled use were also included. For this, two types of studies were included in this classification:

1 Recent asbestos exposure studies (i.e., considering only asbestos sampling conducted after the year 2000) that found high asbestos concentrations resulting from asbestos use or absence of exposure controls (i.e., which can be considered evidence of lack of safe/controlled use), and recent studies that found no or low asbestos exposure (i.e., which support the safe/controlled use). When an exposure assessment article was not explicit about the year in which sampling was conducted, the corresponding author was contacted to confirm the year of the study.

2 Epidemiological studies of populations exposed to chrysotile, that found adverse health effects, not necessarily because of recent exposures, to take into consideration the latency of ARD (i.e., which argues against the safe/controlled use), and studies that, based on epidemiological data, concluded that chrysotile does not cause disease or is less toxicologically potent than amphiboles (i.e., which supports the safe/controlled use).

During a period of 10 weeks, weekly meetings were held between all readers to discuss studies that were difficult to classify, and to verify that the inclusion and exclusion criteria were consistently applied.

A final discussion of all the articles that were included in the review was conducted with all the readers, to verify one more time how each article was classified.

Results

A total of 1516 articles were identified through the search process. After applying the inclusion and exclusion criteria, 155 articles were included in the review. Looking at the consistency of the classification of articles that were read by two or more members of the research team (i.e., 231 articles), 206 articles with multiple readers were classified in similar groups (89 %). For the remaining 25 articles with unmatched classification (11 %), each article was discussed and a classification was determined by consensus.

Articles that were excluded from the review because they could not be accessed for free (n = 44), are included in Supplementary Material 1, Table S1. These 44 articles represent 3 % of the total number of articles initially identified.

Table 1 presents a classification of all the articles published between January 1st, 2010 and July 31st, 2015. Table 1 presents both epidemiological and exposure assessment studies as defined above, including all types of asbestos (i.e., amphiboles or chrysotile), and without restricting the moment in time when exposures occurred. Thus, Table 1 could include the analysis of morbidity or mortality of populations exposed to asbestos several decades ago, which is consistent with the latency period of many asbestos related diseases. Table 1 groups articles in three categories, based on asbestos health consequences (i.e., present or absent), asbestos exposure levels (i.e., compliant or non-compliant), and ambiguous when a study could not be classified based on the information it presented.

Most of the studies published in the period analyzed (n = 134; 87 %) present evidence of adverse health consequences resulting from asbestos exposures, or extremely high asbestos exposures of people using either asbestos or asbestos containing products. Only 11 (7 %) studies in the period analyzed presented evidence of no or reduced health consequences resulting from asbestos exposure or low asbestos concentrations associated with asbestos use. Ten studies were also classified as ambiguous. Regarding the conflict of interest, most of the studies (69 %) that report adverse health consequences or high asbestos exposures reported no conflict of interest, 8 % of the studies declared a conflict of interest, and 23 % of the studies do not report if there was a conflict of interest. For studies reporting no health effect or exposures in compliance with asbestos exposure limits, 70 % had a conflict of interest, 10 % reported no conflict of interest, and 20 % did not report if there was a conflict of interest.

There were also important differences in terms of the characteristics of the income levels of the countries that produced the scientific evidence. From the 155 articles included in the review, 63 % were conducted in countries with high economies, 21 % in countries with upper-middle economies, and less than 1 % were conducted in countries with lower-middle economies. In the period analyzed, no studies were conducted in countries with low economies. Fifteen percent of the studies included more than one country, and for these studies an income-economy group could not be specified.

Analyzing in more detail the distribution of studies according to the income level of the countries, not considering studies classified as ambiguous, 145 studies were included in the review. From this, 22 studies were regional (i.e., Asia, Europe) or global, and could not be assigned to a specific country. Thus, 123 studies conducted in a specific country were identified. From these 123 studies, 91 (74 %) were conducted in countries with high economies, 31 (25 %) in countries with upper-middle economies, one (1 %) in a country with a lower-middle economy, and no studies were conducted in countries with low economies. Furthermore, 65 of the 123 studies (53 %) were conducted in countries that have already banned asbestos (i.e., Australia, Belgium, Denmark, Finland, France, Germany, Greece, Israel, Italy, Japan, Netherlands, New Caledonia, Poland, South Korea, Spain, Sweden, and the United Kingdom) [13]. Thus, only 58 studies were identified in countries that currently use asbestos, including 16 studies in the United States and eight studies in Canada, both high economy countries with stringent regulations for asbestos. Consequently, only 34 studies were identified over a period of more than 5 years in countries that use asbestos and do not have high economies. This is an extremely low number, considering that only 57 countries have banned asbestos. In Supplementary Material 2, Table S2 details the percent distribution of income levels of the countries where the studies were conducted.

Table 2 identifies and classifies studies depending on whether the evidence presented supports or not the safe/controlled use. Two types of studies were included in this classification, based on exposure assessment studies that presented evidence of high or low asbestos exposure (i.e., with samples collected after 2002), and epidemiological studies that presented evidence of presence or absence of health effects on populations exposed to chrysotile. All the studies shown in Table 2 were also included in Table 1. Table 2 does not include ambiguous studies.

As shown in Table 2, 44 studies had evidence that either supported or did not support the safe/controlled use argument. Thirty-six studies (82 %) had evidence against the safe/controlled use argument, and eight studies (18 %) had evidence that supported the safe/controlled use argument. Focusing on the studies that did not support the safe/controlled use argument, 11 % reported a conflict of interest, 64 % had no conflict of interest, and 25 % did not reported if a conflict of interest was present. For the eight studies with evidence that support the safe/controlled use argument, four (50 %) had a conflict of interest, one (12 %) had no conflict of interest, and three (38 %) did not report if a conflict of interest existed. For studies that present recent evidence of asbestos exposure as a consequence of the use of either asbestos or

Table 1 Scientific evidence of asbestos health effects or asbestos exposures resulting from asbestos use

Income-Economy group	Country/Region	Evidence of presence of adverse asbestos health consequences or high/non-compliant asbestos exposures					Evidence of no asbestos health consequences or compliance of asbestos exposure limits					Ambiguous				
		#	Reference	% With conflict of interest			#	Reference	% With conflict of interest			#	Reference	% With conflict of interest		
				Yes	No	NR			Yes	No	NR			Yes	No	NR
High	Australia	3	[23–25]	-	67 %	33 %	0	-	-	-	-	0	-	-	-	-
High	Belgium	3	[26–28]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
Upper-middle	Brazil	1	[29]	100 %	-	-	0	-	-	-	-	0	-	-	-	-
High	Canada	8	[30–37]	13 %	62 %	25 %	0	-	-	-	-	0	-	-	-	-
Upper-middle	China	14	[38–51]	-	93 %	7 %	0	-	-	-	-	0	-	-	-	-
Upper-middle	Colombia	3	[52–54]	-	67 %	33 %	0	-	-	-	-	0	-	-	-	-
High	Denmark	3	[55–57]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
High	Finland	0	-	-	-	-	0	-	-	-	-	1	[58]	-	100 %	-
High	France	9	[59–67]	-	67 %	33 %	0	-	-	-	-	0	-	-	-	-
High	Germany	4	[68–71]	-	75 %	25 %	0	-	-	-	-	1	[72]	-	-	100 %
High	Greece	1	[73]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
High	Hong Kong	2	[74, 75]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
Lower-middle	India	1	[76]	-	-	100 %	0	-	-	-	-	0	-	-	-	-
Upper-middle	Iran	7	[77–83]	-	14 %	86 %	0	-	-	-	-	0	-	-	-	-
High	Israel	1	[84]	100 %	-	-	0	-	-	-	-	0	-	-	-	-
High	Italy	15	[85–99]	-	67 %	33 %	0	-	-	-	-	0	-	-	-	-
Upper-middle	Jamaica	0	-	-	-	-	0	-	-	-	-	1	[100]	-	-	100 %
High	Japan	6	[101–106]	-	83 %	17 %	0	-	-	-	-	0	-	-	-	-
Upper-middle	Malaysia	1	[107]	-	100 %	-	0	-	-	-	-	1	[108]	-	-	100 %
Upper-middle	Mexico	2	[109, 110]	-	-	100 %	0	-	-	-	-	0	-	-	-	-
Upper-middle	Mongolia	2	[111, 112]	50 %	50 %	-	0	-	-	-	-	0	-	-	-	-
High	Netherlands	2	[113, 114]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
High	New Caledonia	0	-	-	-	-	0	-	-	-	-	1	[115]	-	100 %	-
High	Poland	2	[116, 117]	-	50 %	50 %	2	[118, 119]	-	-	100 %	1	[120]	-	-	100 %
High	South Korea	2	[121, 122]	-	100 %	-	1	[123]	-	-	100 %	0	-	-	-	-
High	Spain	1	[124]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
High	Sweden	4	[125–128]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
High	Taiwan, China	4	[129–132]	-	75 %	25 %	0	-	-	-	-	0	-	-	-	-
Upper-middle	Thailand	1	[133]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
High	United Kingdom	2	[134, 135]	-	-	100 %	0	-	-	-	-	0	-	-	-	-
High	United States	12	[136–147]	34 %	58 %	8 %	4	[148–151]	100 %	-	-	2	[152, 153]	100 %	-	-

Table 1 (continued)

Income-Economy group	Country/Region	Evidence of presence of adverse asbestos health consequences or high/non-compliant asbestos exposures					Evidence of no asbestos health consequences or compliance of asbestos exposure limits					Ambiguous				
		#	Reference	% With conflict of interest			#	Reference	% With conflict of interest			#	Reference	% With conflict of interest		
				Yes	No	NR			Yes	No	NR			Yes	No	NR
-	Asia	1	[14]	-	-	100 %	0	-	-	-	-	0	-	-	-	-
-	Europe	2	[154, 155]	-	100 %	-	0	-	-	-	-	0	-	-	-	-
-	Global	15	[2–6, 12, 19–22, 156–160]	13 %	80 %	7 %	4	[18, 161–163]	75 %	25 %	-	2	[164, 165]	100 %	-	-
Subtotal		134	-	8 %	69 %	23 %	11	-	64 %	9 %	27 %	10	-	40 %	20 %	40 %
Total		87 %					7 %					6 %				

asbestos containing products, 15 studies (79 %) identified extremely high exposures that do not support the safe/controlled use concept. From these 15 studies, one reported a conflict of interest, seven had no conflict of interest, and seven did not report if a conflict of interest existed. Four studies (21 %) reported recent evidence of low or no asbestos exposures (i.e., supporting the safe/controlled use argument), in which two had a conflict of interest, and two did not report if a conflict of interest existed. Thus, there were no studies with recent evidence of low or no asbestos exposure with no conflict of interest.

In terms of the income level of the countries where the 44 studies were conducted (Table 2), 36 % were done in countries with high-economies, 55 % in countries with upper-middle economies, 2 % in countries with low-middle economies, and no studies were conducted in countries with low economies. Three of the studies involved multiple countries, and income level could not be determined. All the studies that had evidence to support the safe/controlled use argument were conducted in countries with either high economies (six; 75 %) or in multiple countries (two; 25 %). In Supplementary Material 2, Table S3 details the percent distribution of income levels of the countries where the studies were conducted.

Discussion and Conclusions

This review analyzed scientific studies published between January 1st, 2010 and July 31st, 2015, that presented empirical evidence of either health consequences associated with asbestos exposure or asbestos exposure assessments in occupational or general population settings in which asbestos or asbestos-containing products are used.

Overall, recent scientific evidence confirms once again the devastating effects of asbestos use in the health of populations at the global scale. Most of the studies included in the review had evidence of either adverse health effects or high asbestos exposures (Table 1). Furthermore, we identified 44 studies that had evidence that support or contradict the safe/controlled use argument (Table 2), and most of these studies presented evidence that did not support the achievement of a safe/controlled use of asbestos. Advocates of the safe/controlled use argument could debate that the health effects observed in some of the 44 studies included populations exposed to high asbestos concentrations, which would not comply with the conditions of a safe/controlled use. Thus, we did an independent analysis to identify articles with recent evidence of asbestos exposure resulting from the use of the material (Table 2), and most of them showed that there was no safe/controlled use of asbestos because of high exposures. There were five articles in this group in which the year of the sampling campaign was not explicit. We asked the corresponding authors about the year when sampling was

Table 2 Scientific publications with evidence that supports or rejects the safe/controlled use

Income-Economy group	Country/Region	Evidence of absence of asbestos safe/controlled use					Evidence that supports asbestos safe/controlled use				
		Recent high asbestos exposure					Recent low/No asbestos exposure				
		#	Reference	% With conflict of interest			#	Reference	% With conflict of interest		
				Yes	No	NR			Yes	No	NR
High	Belgium	1	[28]	-	1	-	-	-	-	-	-
Upper-middle	Colombia	3	[52–54]	-	2	1	-	-	-	-	-
Lower-middle	India	1	[76]	-	-	1	-	-	-	-	-
Upper-middle	Iran	6	[77–82]	-	1	5	-	-	-	-	-
Upper-middle	Mongolia	1	[111]	1	-	-	-	-	-	-	-
High	Poland	0	-	-	-	-	1	[118]	-	-	1
High	South Korea	0	-	-	-	-	1	[123]	-	-	1
Upper-middle	Thailand	1	[133]	-	1	-	-	-	-	-	-
High	United States	1	[146]	-	1	-	2	[149, 150]	2	-	-
-	Global	1	[12]	-	1	-	-	-	-	-	-
Subtotal		15		1	7	7	4		2	0	2
Income-Economy group	Country/Region	Adverse health effects of chrysotile					Health effects of chrysotile revised/Questioned				
		#	Reference	% With conflict of interest			#	Reference	% With conflict of interest		
				Yes	No	NR			Yes	No	NR
High	Canada	1	[34]	-	-	1	-	-	-	-	-
Upper-middle	China	12	[38–46, 48, 49, 51]	-	12	-	-	-	-	-	-
High	Italy	1	[94]	-	-	1	-	-	-	-	-
Upper-middle	Mongolia	1	[112]	-	1	-	-	-	-	-	-
High	Poland	0	-	-	-	-	1	[119]	-	-	1
High	South Korea	1	[122]	-	1	-	-	-	-	-	-
High	United States	5	[136, 140, 141, 143, 144]	3	2	-	1	[151]	1	-	-
-	Global	0	-	-	-	-	2	[18, 163]	1	1	-
Subtotal		21		3	16	2	4		2	1	1
Total		# [%] of studies absence of controlled use		% With conflict of interest			# [%] of studies that support controlled use		% With conflict of interest		
				Yes	No	NR			Yes	No	NR
		36	82 %	11 %	64 %	25 %	8	18 %	50 %	12 %	38 %

conducted, and we received confirmation about the year of the study from four authors. Thus, for only one study [81] and based on the content of the article, we assumed that the asbestos exposure assessment was recent. Since occupational exposure limits can change between countries, exposures classified as in compliance in a country based on local regulations, could have been classified as not in compliance if the international standard of 0.1 f/cc had been used.

Among the 15 recent articles included in Table 2 that reported extremely high asbestos exposure, one article was from Belgium and included exposure to friable asbestos during a renovation of an old building in 2007 [28].This would not correspond with the conditions of the safe/controlled use. However, Belgium has strict regulations for this type of job and is a high economy country with the financial and technical resources to enforce these regulations, and this study was included because it presents evidence of how difficult it is to control asbestos exposure resulting from the legacy of past asbestos use. This would be more critical in upper-middle, lower-middle, and low economies.

Some of the studies included in the review that analyzed incidence and prevalence of asbestos related diseases, estimated asbestos exposure using asbestos consumption or the location of the asbestos industry as surrogates. We recognize that this could lead to an ecological fallacy.

Most of the studies that presented evidence of no or little health effects resulting from asbestos exposure, or studies presenting low or no asbestos exposures, had a conflict of interest declared. Contrary to that, most studies presenting evidence of adverse health effects resulting from asbestos exposure or high asbestos exposures had no conflict of interest to declare (69 % vs. 9 %, Table 1). This has been observed in other areas of research. For example, two studies analyzing the association between sponsorship and research outcome in the development of new drugs and medical devices found that the results of studies funded by industry were more likely to favor the product of the sponsor, compared to studies with other funding sources [166, 167]. In a recent review of the potential effect of sponsorship in animal studies analyzing the effects of Atrazine, the authors found that studies that were not funded by industry were more likely (p-value 0.07) to conclude that atrazine had adverse effects compared to studies funded by industry [168].

We also identified some studies (n = 4) in which the authors declared they had no conflict of interest, but this declaration was followed by an acknowledgement of funding that clearly created a financial conflict of interest. For the purposes of this review, the declaration of the authors of the study (i.e., no conflict of interest) was maintained, but this is something that requires further discussion. A conflict of interest exists and must be declared if the authors have received funding that could potentially compromise the design and implementation of the study, as well as their judgment, recognizing that declaring a conflict of interest does not necessarily mean that the study has been compromised. However, this is not a decision that the authors can make, and if a financial conflict of interest exists, it must be declared. The declaration of conflict of interest by authors should be verified with diligence by all journals, to prevent situations like the ones described above. Furthermore, from the original 155 articles identified, 38 did not report if a conflict of interest existed. All journals should have a mandatory requirement for a disclaimer of conflict of interest, especially in controversial topics like asbestos health consequences and use.

One concerning aspect of this review is the extremely low number of articles published in upper-middle, lower-middle, and low economy countries. Since most of the studies included in the review have been conducted in countries that have already banned asbestos or have stringent regulations on the material, exposure levels identified in this review could underestimate actual asbestos exposures occurring in low- and middle-income countries.

Regarding the countries that are the major producers (Russia, China, Brazil, Canada, Zimbabwe, Colombia) and consumers (China, India, Brazil, Russia, Indonesia, Kazakhstan, Thailand, Ukraine, Uzbekistan) of asbestos in the world [1, 2, 11], no studies were found for this review from Russia, Zimbabwe, Indonesia, Kazakhstan, Thailand, Ukraine, and Uzbekistan. Furthermore, three major players of the asbestos global trade, China, India, and Brazil, had what seems to be a rather low number of studies considering the volume of asbestos these countries produce and consume. Brazil and India only had one study each, and China had 14 studies. Thus, it is intriguing how with such a low number of scientific studies, especially in countries that use asbestos and in some cases in extremely large volumes, it could be argued that the material can be sold because there is a safe/controlled use. In fact, the majority of the little evidence that has been produced in countries that consume and produce asbestos suggests that a safe/controlled use of the material is not happening.

As authors we applied several quality control strategies to conduct the review. We specified in the framework of our aims clear inclusion and exclusion criteria. We held regular meetings to discuss those articles that were difficult to classify and the classification was reached by consensus. We had a percentage of articles (i.e., 231, 15 %) read by more than one person (i.e., blinded) to double check the way studies were classified, and for 89 % of the articles with two or more readers there was coincidence in the classification made. Finally, when closing the review, we did a group discussion, one by one, of the 155 articles included in the review. However, we acknowledge that there is always the possibility of human error in a review of this size. We may have missed articles that should have been included in the review, and we may have misclassified some articles in the process. Thus, we

invite other authors to build on the work we are presenting in the current review, to improve if necessary what we have done.

In closing, the scientific literature published in recent years confirms the negative consequences derived from the historical use of asbestos. Moreover, most of the studies that could be used to determine if a safe/controlled use of asbestos is being achieved suggest that current asbestos use is resulting in high asbestos exposures. We also found very few studies analyzing the use of asbestos containing construction products, which is one of the categories of asbestos products with the highest production and consumption at a global scale. The scientific literature does not seem to support the safe/controlled use concept, and we join other authors, once again, in a call for a global ban of asbestos.

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Compliance with Ethical Standards

Conflict of Interest Manuela Valenzuela, Margarita Giraldo, Sonia Gallo-Murcia, Juliana Pineda, Laura Santos, and Juan Pablo Ramos-Bonilla have no conflict of interest to declare.

Humans and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

1. Ramazzini C. Asbestos is still with us: repeat call for a universal ban. Am J Ind Med. 2010;7(5):57–61.
2. Stayner L, Welch LS, Lemen R. The worldwide pandemic of asbestos-related diseases. Annu Rev Public Health. 2013;34:205–16.
3. Linton A, Vardy J, Clarke S, van Zandwijk N. The ticking time-bomb of asbestos: its insidious role in the development of malignant mesothelioma. Crit Rev Oncol Hematol. 2012;84(2):200–12.
4. Frank AL, Joshi TK. The global spread of asbestos. Ann Glob Health. 2014;80(4):257–62.
5. Nielsen LS, Bælum J, Rasmussen J, Dahl S, Olsen KE, Albin M, et al. Occupational asbestos exposure and lung cancer—a systematic review of the literature. Arch Environ Occup Health. 2014;69(4):191–206.
6. Park E-K, Takahashi K, Jiang Y, Movahed M, Kameda T. Elimination of asbestos use and asbestos-related diseases: an unfinished story. Cancer Sci. 2012;103(10):1751–5.
7. Røe OD, Stella GM. Malignant pleural mesothelioma: history, controversy and future of a manmade epidemic. Eur Respir Rev. 2015;24(135):115–31.
8. Bang KM, Mazurek JM, Wood JM, Hendricks SA. Diseases attributable to asbestos exposure: years of potential life lost, United States, 1999–2010. Am J Ind Med. 2014;57(1):38–48.
9. LaDou J, Castleman B, Frank A, Gochfeld M, Greenberg M, Huff J, et al. The case for a global ban on asbestos. Environ Health Perspect. 2010;118(7):897–901.
10. Arsenic, metals, fibres, and dusts. IARC monographs on the evaluation of carcinogenic risks to humans [Internet]. 2012. Available from: http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C.pdf.
11. Marsili D, Comba P. Asbestos case and its current implications for global health. Ann Ist Super Sanita. 2013;49(3):249–51.
12. Choi Y, Lim S, Paek D. Trades of dangers: a study of asbestos industry transfer cases in Asia. Am J Ind Med. 2013;56(3):335–46.
13. Laurie Kazan-Allen, International Ban Asbestos Secretariat [Internet]. Available from: http://www.ibasecretariat.org/alpha_ban_list.php.
14. Le GV, Takahashi K, Park EK, Delgermaa V, Oak C, Qureshi AM, et al. Asbestos use and asbestos-related diseases in Asia: past, present and future. Respirology. 2011;16(5):767–75.
15. Chrysotile Institute. 9 questions and answers on chrysotile and health [Internet]. Available from: http://www.chrysotile.com/en/chrysotile/hltsfty/quest1.aspx.
16. Chrysotile Institute. Guidelines for a regulation on the Safe and Responsible use of chrysotile [Internet]. Available from: http://www.chrysotile.com/en/sfuse/guide.aspx.
17. Chrysotile Institute. Safe use of chrysotile [Internet]. Available from: http://www.chrysotile.com/en/sfuse/.
18. Bernstein D, Dunnigan J, Hesterberg T, Brown R, Velasco JAL, Barrera R, et al. Health risk of chrysotile revisited. Crit Rev Toxicol. 2013;43(2):154–83.
19. Lenters V, Vermeulen R, Dogger S, Stayner L, Portengen L, Burdorf A, et al. A meta-analysis of asbestos and lung cancer: is better quality exposure assessment associated with steeper slopes of the exposure-response relationships? Environ Health Perspect. 2011;119(11):1547–55.
20. McCormack V, Peto J, Byrnes G, Straif K, Boffetta P. Estimating the asbestos-related lung cancer burden from mesothelioma mortality. Br J Cancer. 2012;106(3):575–84.
21. Van der Bij S, Koffijberg H, Lenters V, Portengen L, Moons KGM, Heederik D, et al. Lung cancer risk at low cumulative asbestos exposure: meta-regression of the exposure-response relationship. Cancer Causes Control. 2013;24(1):1–12.
22. Lenters V, Burdorf A, Vermeulen R, Stayner L, Heederik D. Quality of evidence must guide risk assessment of asbestos. Ann Occup Hyg. 2012;56(8):879–87.
23. Reid A, Franklin P, Olsen N, Sleith J, Samuel L, Aboagye-Sarfo P, et al. All-cause mortality and cancer incidence among adults exposed to blue asbestos during childhood. Am J Ind Med. 2013;56(2):133–45.
24. Berry G, Reid A, Aboagye-Sarfo P, de Klerk NH, Olsen NJ, Merler E, et al. Malignant mesotheliomas in former miners and millers of crocidolite at Wittenoom (Western Australia) after more than 50 years follow-up. Br J Cancer. 2012;106(5):1016–20.
25. Olsen NJ, Franklin PJ, Reid A, de Klerk NH, Threlfall TJ, Shilkin K, et al. Increasing incidence of malignant mesothelioma after exposure to asbestos during home maintenance and renovation. Med J Aust. 2011;195(5):271–4.
26. 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(2):134–40.
27. 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(6):e007384.

28. Dumortier P, De Vuyst P. Asbestos exposure during uncontrolled removal of sprayed-on asbestos. Ann Occup Hyg. 2012;56(1):49–54.
29. Terra-Filho M, Bagatin E, Nery LE, Nápolis LM, Neder JA, De Meirelles GSP, et al. Screening of miners and millers at decreasing levels of asbestos exposure: comparison of chest radiography and thin-section computed tomography. PLoS ONE. 2015;10(3): e0118585.
30. Carrillo MC, Alturkistany S, Roberts H, Nguyen E, Chung TB, Paul N, et al. Low-dose computed tomography (LDCT) in workers previously exposed to asbestos: detection of parenchymal lung disease. J Comput Assist Tomogr. 2013;37(4):626–30.
31. Adib G, Labrèche F, De Guire L, Dion C, Dufresne A. Short, fine and WHO asbestos fibers in the lungs of Quebec workers with an asbestos-related disease. Am J Ind Med. 2013;56(9):1001–14.
32. Villeneuve PJ, Parent M, Harris SA, Johnson KC. Occupational exposure to asbestos and lung cancer in men: evidence from a population-based case-control study in eight Canadian provinces. BMC Cancer. 2012;12:595.
33. Verma DK, Clark NE. Asbestos fiber burden in lung tissues of occupationally exposed workers. J Occup Environ Hyg. 2012;9(10):D177–82.
34. Egilman D, Menéndez LM. A case of occupational peritoneal mesothelioma from exposure to tremolite-free chrysotile in Quebec, Canada: a black swan case. Am J Ind Med. 2011;54(2):153–6.
35. Finkelstein MM. Absence of radiographic asbestosis and the risk of lung cancer among asbestos-cement workers: extended follow-up of a cohort. Am J Ind Med. 2010;53(11):1065–9.
36. Krupoves A, Camus M, De Guire L. Incidence of malignant mesothelioma of the pleura in Québec and Canada from 1984 to 2007, and projections from 2008 to 2032. Am J Ind Med. 2015;58(5):473–82.
37. Koné Pefoyo AJ, Genesove L, Moore K, Del Bianco A, Kramer D. Exploring the usefulness of occupational exposure registries for surveillance. J Occup Environ Med. 2014;56(10):1100–10.
38. Wang X, Lin S, Yu I, Qiu H, Lan Y, Yano E. Cause-specific mortality in a Chinese chrysotile textile worker cohort. Cancer Sci. 2013;104(2):245–9.
39. Lin S, Wang X, Yu ITS, Yano E, Courtice M, Qiu H, et al. Cause-specific mortality in relation to chrysotile-asbestos exposure in a Chinese cohort. J Thorac Oncol. 2012;7(7):1109–14.
40. Du L, Wang X, Wang M, Lan Y. Analysis of mortality in chrysotile asbestos miners in China. J Huazhong Univ Sci Technol Med Sci. 2012;32(1):135–40.
41. Wang X, Yano E, Qiu H, Yu I, Courtice MN, Tse LA, et al. A 37-year observation of mortality in Chinese chrysotile asbestos workers. Thorax. 2012;67(2):106–10.
42. Wang XR, Yu ITS, Qiu H, Wang MZ, Lan YJ, Tse LY, et al. Cancer mortality among Chinese chrysotile asbestos textile workers. Lung Cancer. 2012;75(2):151–5.
43. Wang X, Lin S, Yano E, Qiu H, Yu ITS, Tse L, et al. Mortality in a Chinese chrysotile miner cohort. Int Arch Occup Environ Health. 2012;85(4):405–12.
44. Yano E, Wang X, Wang M, Qiu H, Wang Z. Lung cancer mortality from exposure to chrysotile asbestos and smoking: a case-control study within a cohort in China. Occup Environ Med. 2010;67(12):867–71.
45. Wang X, Yano E, Lin S, Yu ITS, Lan Y, Tse LA, et al. Cancer mortality in Chinese chrysotile asbestos miners: exposure-response relationships. PLoS ONE. 2013;8(8):e71899.
46. Deng Q, Wang X, Wang M, Lan Y. Exposure-response relationship between chrysotile exposure and mortality from lung cancer and asbestosis. Occup Environ Med. 2012;69(2):81–6.
47. Courtice MN, Lin S, Wang X. An updated review on asbestos and related diseases in China. Int J Occup Environ Health. 2012;18(3):247–53.
48. Gao Z, Hiroshima K, Wu X, Zhang J, Shao D, Shao H, et al. Asbestos textile production linked to malignant peritoneal and pleural mesothelioma in women: analysis of 28 cases in Southeast China. Am J Ind Med. 2015;58(10):1040–9.
49. Wang X, Lin S, Yano E, Yu ITS, Courtice M, Lan Y, et al. Exposure-specific lung cancer risks in Chinese chrysotile textile workers and mining workers. Lung Cancer. 2014;85(2):119–24.
50. Wang X, Wang M, Qiu H, Yu I, Yano E. Longitudinal changes in pulmonary function of asbestos workers. J Occup Health. 2010;52(5):272–7.
51. Wang X, Courtice MN, Lin S. Mortality in chrysotile asbestos workers in China. Curr Opin Pulm Med. 2013;19(2):169–73.
52. Cely-Garcia MF, Torres-Duque CA, Durán M, Parada P, Sarmiento OL, Breysse PN, et al. Personal exposure to asbestos and respiratory health of heavy vehicle brake mechanics. J Expo Sci Environ Epidemiol. 2015;25(1):26–36.
53. Salazar N, Cely-García MF, Breysse PN, Ramos-Bonilla JP. Asbestos exposure among transmission mechanics in automotive repair shops. Ann Occup Hyg. 2015;59(3):292–306.
54. Cely-Garcia MF, Sanchez M, Breysse PN, Ramos-Bonilla JP. Personal exposures to asbestos fibers during brake maintenance of passenger vehicles. Ann Occup Hyg. 2012;56(9):985–99.
55. Langhoff MD, Kragh-Thomsen MB, Stanislaus S, Weinreich UM. Almost half of women with malignant mesothelioma were exposed to asbestos at home through their husbands or sons. Dan Med J. 2014;61(9):4902.
56. Skammeritz E, Omland LH, Johansen JP, Omland Ø. Asbestos exposure and an occupational clinic. Int J Occup Environ Med. 2011;2(4):224–36.
57. Skammeritz E, Omland O, Hansen J, Johansen JP. Regional differences in incidence of malignant mesothelioma in Denmark. Dan Med J. 2013;60(3):A4592.
58. Vierikko T, Järvenpää R, Toivio P, Uitti J, Oksa P, Lindholm T, et al. Clinical and HRCT screening of heavily asbestos-exposed workers. Int Arch Occup Environ Health. 2010;83(1):47–54.
59. Lacourt A, Gramond C, Rolland P, Ducamp S, Audignon S, Astoul P, et al. Occupational and non-occupational attributable risk of asbestos exposure for malignant pleural mesothelioma. Thorax. 2014;69(6):532–9.
60. Clin B, Andujar P, Abd Al Samad I, Azpitarte C, Le Pimpec-Barthes F, Billon-Galland MA, et al. Pulmonary carcinoid tumors and asbestos exposure. Ann Occup Hyg. 2012;56(7):789–95.
61. Wild P, Gonzalez M, Bourgkard E, Courouble N, Clément-Duchêne C, Martinet Y, et al. Occupational risk factors have to be considered in the definition of high-risk lung cancer populations. Br J Cancer. 2012;106(7):1346–52.
62. Lacourt A, Leffondré K, Gramond C, Ducamp S, Rolland P, Gilg Soit Ilg A, et al. Temporal patterns of occupational asbestos exposure and risk of pleural mesothelioma. Eur Respir J. 2012;39(6):1304–12.
63. Gonzalez M, Vignaud J-M, Clement-Duchene C, Luc A, Wild P, Bertrand O, et al. Smoking, occupational risk factors, and bronchial tumor location: a possible impact for lung cancer computed tomography scan screening. J Thorac Oncol. 2012;7(1):128–36.
64. Ameille J, Rosenberg N, Matrat M, Descatha A, Mompoint D, Hamzi L, et al. Asbestos-related diseases in automobile mechanics. Ann Occup Hyg. 2012;56(1):55–60.
65. Clin B, Morlais F, Launoy G, Guizard A-V, Dubois B, Bouvier V, et al. Cancer incidence within a cohort occupationally exposed to asbestos: a study of dose-response relationships. Occup Environ Med. 2011;68(11):832–6.
66. Rolland P, Gramond C, Lacourt A, Astoul P, Chamming's S, Ducamp S, et al. Occupations and industries in France at high risk for pleural mesothelioma: a population-based case-control study (1998-2002). Am J Ind Med. 2010;53(12):1207–19.

67. Lacourt A, Rolland P, Gramond C, Astoul P, Chamming's S, Ducamp S, et al. Attributable risk in men in two French case-control studies on mesothelioma and asbestos. Eur J Epidemiol. 2010;25(11):799–806.
68. Pesch B, Taeger D, Johnen G, Gross IM, Weber DG, Gube M, et al. Cancer mortality in a surveillance cohort of German males formerly exposed to asbestos. Int J Hyg Environ Health. 2010;213(1):44–51.
69. Schneider J, Brückel B, Fink L, Woitowitz H-J. Pulmonary fibrosis following household exposure to asbestos dust? J Occup Med Toxicol. 2014;9(1):39.
70. Eisenhawer C, Felten MK, Tamm M, Das M, Kraus T. Radiological surveillance of formerly asbestos-exposed power industry workers: rates and risk factors of benign changes on chest X-ray and MDCT. J Occup Med Toxicol. 2014;9(1):18.
71. Schonfeld SJ, McCormack V, Rutherford MJ, Schüz J. Regional variations in German mesothelioma mortality rates: 2000–2010. Cancer Causes Control. 2014;25(5):615–24.
72. Ramroth H, Ahrens W, Dietz A, Becher H. Occupational asbestos exposure as a risk factor for laryngeal carcinoma in a population-based case–control study from Germany. Am J Ind Med. 2011;54(7):510–4.
73. Zarogoulidis P, Orfanidis M, Constadinidis TC, Eleutheriadou E, Kontakiotis T, Kerenidi T, et al. A 26-year-old male with mesothelioma due to asbestos exposure. Rep Med. 2011;2011:951732.
74. Chen M, Tse LA, Au RKF, Yu ITS, Wang XR, Lao XQ, et al. Mesothelioma and lung cancer mortality: a historical cohort study among asbestosis workers in Hong Kong. Lung Cancer. 2012;76(2):165–70.
75. Tse LA, Yu ITS, Goggins W, Clements M, Wang XR, Au JSK, et al. Are current or future mesothelioma epidemics in Hong Kong the tragic legacy of uncontrolled use of asbestos in the past? Environ Health Perspect. 2010;118(3):382–6.
76. Bhagia LJ, Vyas JB, Shaikh MI, Dodia SL. Chrysotile asbestos exposure in the manufacturing of thermal insulating boards. Environ Monit Assess. 2010;167(1-4):559–64.
77. Panahi D, Kakooei H, Marioryad H, Mehrdad R, Golhosseini M. Evaluation of exposure to the airborne asbestos in an asbestos cement sheet manufacturing industry in Iran. Environ Monit Assess. 2011;178(1-4):449–54.
78. Marioryad H, Kakooei H, Shahtaheri SJ, Yunesian M, Azam K. Assessment of airborne asbestos exposure at an asbestos cement sheet and pipe factory in Iran. Regul Toxicol Pharmacol. 2011;60(2):200–5.
79. Kakooei H, Hormozy M, Marioryad H. Evaluation of asbestos exposure during brake repair and replacement. Ind Health. 2011;49(3):374–80.
80. Kakooei H, Marioryad H. Evaluation of exposure to the airborne asbestos in an automobile brake and clutch manufacturing industry in Iran. Regul Toxicol Pharmacol. 2010;56(2):143–7.
81. Azari MR, Nasermoaddeli A, Movahadi M, Mehrabi Y, Hatami H, Soori H, et al. Risk assessment of lung cancer and asbestosis in workers exposed to asbestos fibers in brake shoe factory in Iran. Ind Health. 2010;48(1):38–42.
82. Kakooei H, Normohammadi M. Asbestos exposure among construction workers during demolition of old houses in Tehran, Iran. Ind Health. 2014;52(1):71–7.
83. Najmi K, Khosravi A, Seifi S, Emami H, Chaibakhsh S, Radmand G, et al. Clinicopathologic and survival characteristics of malignant pleural mesothelioma registered in hospital cancer registry. Tanaffos. 2014;13(2):6–12.
84. Bitchatchi E, Kayser K, Perelman M, Richter ED. Mesothelioma and asbestosis in a young woman following occupational asbestos exposure: short latency and long survival: case Report. Diagn Pathol. 2010;16(5):81.
85. Barbieri PG, Mirabelli D, Somigliana A, Cavone D, Merler E. Asbestos fibre burden in the lungs of patients with mesothelioma who lived near asbestos-cement factories. Ann Occup Hyg. 2012;56(6):660–70.
86. Mensi C, Bonzini M, Macchione M, Sieno C, Riboldi L, Pesatori AC. Differences among peritoneal and pleural mesothelioma: data from the Lombardy Region Mesothelioma Register (Italy). Med Lav. 2011;102(5):409–16.
87. Gatto MP, Di Tanna GL. Distribution and trends in mesothelioma mortality in Italy from 1974 to 2006. Int Arch Occup Environ Health. 2013;86(4):489–96.
88. Corfiati M, Scarselli A, Binazzi A, Di Marzio D, Verardo M, Mirabelli D, et al. Epidemiological patterns of asbestos exposure and spatial clusters of incident cases of malignant mesothelioma from the Italian national registry. BMC Cancer. 2015;15:286.
89. Mensi C, Riboldi L, De Matteis S, Bertazzi PA, Consonni D. Impact of an asbestos cement factory on mesothelioma incidence: global assessment of effects of occupational, familial, and environmental exposure. Environ Int. 2015;74:191–9.
90. De Matteis S, Consonni D, Lubin JH, Tucker M, Peters S, Vermeulen RC, et al. Impact of occupational carcinogens on lung cancer risk in a general population. Int J Epidemiol. 2012;41(3):711–21.
91. Bianchi C, Bianchi T, Bucconi S. Malignant mesothelioma of the pleura in nonagenarian patients. Tumori. 2011;97(2):156–9.
92. Chellini E, Martino G, Grillo A, Fedi A, Martini A, Indiani L, et al. Malignant mesotheliomas in textile rag sorters. Ann Occup Hyg. 2015;59(5):547–53.
93. Bianchi C, Bianchi T. Mesothelioma among shipyard workers in Monfalcone, Italy. Indian J Occup Environ Med. 2012;16(3):119–23.
94. Nemo A, Silvestri S. Mesothelioma in a wine cellar man: detailed description of working procedures and past asbestos exposure estimation. Ann Occup Hyg. 2014;58(9):1168–74.
95. Fazzo L, Minelli G, De Santis M, Bruno C, Zona A, Marinaccio A, et al. Mesothelioma mortality surveillance and asbestos exposure tracking in Italy Lucia. Ann Ist Super Sanita. 2012;48(3):300–10.
96. Mensi C, Pellegatta M, Sieno C, Consonni D, Riboldi L, Bertazzi PA. Mesothelioma of tunica vaginalis testis and asbestos exposure. BJU Int. 2012;110(4):533–7.
97. Girardi P, Bressan V, Merler E. Past trends and future prediction of mesothelioma incidence in an industrialized area of Italy, the Veneto Region. Cancer Epidemiol. 2014;38(5):496–503.
98. Fazzo L, De Santis M, Minelli G, Bruno C, Zona A, Marinaccio A, et al. Pleural mesothelioma mortality and asbestos exposure mapping in Italy. Am J Ind Med. 2012;55(1):11–24.
99. Bianchi C, Bianchi T. Shipbuilding and mesothelioma in Monfalcone, Italy. Indian J Occup Environ Med. 2012;16(1):14–7.
100. Scarlett HP, Delzell E, Sathiakumar N, Oestenstad RK, Postlethwait E. Exposure to airborne asbestos in Jamaican hospitals. West Indian Med J. 2010;59(6):668–73.
101. Fujimoto N, Kato K, Usami I, Sakai F, Tokuyama T, Hayashi S, et al. Asbestos-related diffuse pleural thickening. Respiration. 2014;88(4):277–84.
102. Fujimoto N, Aoe K, Gemba K, Kato K, Yamazaki K, Kishimoto T. Clinical investigation of malignant mesothelioma in Japan. J Cancer Res Clin Oncol. 2010;136(11):1755–9.
103. Kishimoto T, Gemba K, Fujimoto N, Onishi K, Usami I, Mizuhashi K, et al. Clinical study of asbestos-related lung cancer in Japan with special reference to occupational history. Cancer Sci. 2010;101(5):1194–8.
104. Kishimoto T, Gemba K, Fujimoto N, Aoe K, Kato K, Takeshima Y, et al. Clinical study on mesothelioma in

Japan: relevance to occupational asbestos exposure. Am J Ind Med. 2010;53(11):1081–7.
105. Gemba K, Fujimoto N, Kato K, Aoe K, Takeshima Y, Inai K, et al. National survey of malignant mesothelioma and asbestos exposure in Japan. Cancer Sci. 2012;103(3):483–90.
106. Tomioka K, Natori Y, Kumagai S, Kurumatani N. An updated historical cohort mortality study of workers exposed to asbestos in a refitting shipyard, 1947–2007. Int Arch Occup Environ Health. 2011;84(8):959–67.
107. Safitri Zen I, Ahamad R, Gopal Rampal K, Omar W. Use of asbestos building materials in Malaysia: legislative measures, the management, and recommendations for a ban on use. Int J Occup Environ Health. 2013;19(3):169–78.
108. Latif MT, Baharudin NH, Velayutham P, Awang N, Hamdan H, Mohamad R, et al. Composition of heavy metals and airborne fibers in the indoor environment of a building during renovation. Environ Monit Assess. 2011;181(1-4):479–89.
109. Aguilar-Madrid G. Case–control study of pleural mesothelioma in workers with social security in Mexico. Am J Ind Med. 2010;53(3):241–51.
110. Méndez-Vargas MM, López-Rojas P, Campos-Pujal GA, Marín-Cotoñieto IA, Salinas-Tovar S, Fernández-Muñoz MJ. Pleural mesothelioma in paraoccupational, environmental and occupational patients exposed to asbestos. Rev Med Inst Mex Seguro Soc. 2010;48(4):361–6.
111. Damiran N, Silbergeld EK, Frank AL, Lkhasuren O, Ochir C, Breysse PN. Exposure to airborne asbestos in thermal power plants in Mongolia. Int J Occup Environ Health. 2015;21(2): 137–41.
112. Damiran N, Davaajav K, Erdenebayar E, Gomboloi B, Frank AL. Mesothelioma in Mongolia: case report. Int J Occup Environ Health. 2015;21(2):166–8.
113. Offermans NSM, Vermeulen R, Burdorf A, Goldbohm RA, Kauppinen T, Kromhout H, et al. Occupational asbestos exposure and risk of pleural mesothelioma, lung cancer, and laryngeal cancer in the Prospective Netherlands Cohort Study. J Occup Environ Med. 2014;56(1):6–19.
114. Driece HAL, Siesling S, Swuste PHJJ, Burdorf A. Assessment of cancer risks due to environmental exposure to asbestos. J Expo Sci Environ Epidemiol. 2010;20(5):478–85.
115. Baumann F, Maurizot P, Mangeas M, Ambrosi J-P, Douwes J, Robineau B. Pleural mesothelioma in New Caledonia: associations with environmental risk factors. Environ Health Perspect. 2011;119(5):695–700.
116. Świątkowska B, Szubert Z, Sobala W, Szeszenia-Dąbrowska N. Predictors of lung cancer among former asbestos-exposed workers. Lung Cancer. 2015;89(3):243–8.
117. Świątkowska B, Sobala W, Szubert Z. Progression of small, irregular opacities in chest radiographs of former asbestos workers. Int J Occup Med Environ Health. 2012;25(4):481–91.
118. Szeszenia-Dąbrowska N, Sobala W, Swiątkowska B, Stroszejn-Mrowca G, Wilczyńska U. Environmental asbestos pollution—situation in Poland. Int J Occup Med Environ Health. 2012;25(1):3–13.
119. Szeszenia-Dabrowska N, Swiatkowska B, Sobala W, Szubert Z, Wilczyhska U. Asbestos related diseases among workers of asbestos processing plants in relation to type of production and asbestos use. Med Pr. 2015;66(1):1–9.
120. Buczaj A, Brzana W, Tarasińska J, Buczaj M, Choina P. Study on the concentration of airbone respirable asbestos fibres in rural areas of the Lublin region in south-east Poland. Ann Agric Environ Med. 2014;21(3):639–43.
121. Jung S-H, Kim H-R, Koh S-B, Yong S-J, Chung MJ, Lee C-H, et al. A decade of malignant mesothelioma surveillance in Korea. Am J Ind Med. 2012;55(10):869–75.
122. Park S-H, Kang D-M, Koo B-H, Kim Y-K, Kim J-E. Risk assessment of gastric cancer associated with asbestosis: a case report. Ann Occup Environ Med. 2015;27(1):9.
123. Choi S, Suk M, Paik NW. Asbestos-containing materials and airborne asbestos levels in industrial buildings in Korea. J UOEH. 2010;32(1):31–43.
124. López-Abente G, García-Gómez M, Menéndez-Navarro A, Fernández-Navarro P, Ramis R, García-Pérez J, et al. Pleural cancer mortality in Spain: time-trends and updating of predictions up to 2020. BMC Cancer. 2013;13:528.
125. Järvholm B, Burdorf A. Emerging evidence that the ban on asbestos use is reducing the occurrence of pleural mesothelioma in Sweden. Scand J Public Health. 2015;43(8):875–81.
126. Järvholm B, Åström E. The risk of lung cancer after cessation of asbestos exposure in construction workers using pleural malignant mesothelioma as a marker of exposure. J Occup Environ Med. 2014;56(12):1297–301.
127. Andersson E, Westberg H, Bryngelsson IL, Magnuson A, Persson B. Cancer incidence among Swedish pulp and paper mill workers: a cohort study of sulphate and sulphite mills. Int Arch Occup Environ Health. 2013;86(5):529–40.
128. Järvholm B, Englund A. The impact of asbestos exposure in Swedish construction workers. Am J Ind Med. 2014;57(1):49–55.
129. Wu W-T, Lin Y-J, Li C-Y, Tsai P-J, Yang C-Y, Liou S-H, et al. Cancer attributable to asbestos exposure in shipbreaking workers: a matched-cohort study. PLoS ONE. 2015;10(7):e0133128.
130. Te Wu W, Lin YJ, Shiue HS, Li CY, Tsai PJ, Yang CY, et al. Cancer incidence of Taiwanese shipbreaking workers who have been potentially exposed to asbestos. Environ Res. 2014;132:370–8.
131. Lin CK, Chang YY, Wang JD, Lee LJH. Increased standardised incidence ratio of malignant pleural mesothelioma in Taiwanese asbestos workers: a 29-year retrospective cohort study. Biomed Res Int Hindawi Publishing Corporation. 2015;2015:678598.
132. Yang HY, Der Wang J, Chen PC, Lee JJ. Pleural plaque related to asbestos mining in Taiwan. J Formos Med Assoc. 2010;109(12):928–33.
133. Phanprasit W, Sujirarat D, Musigapong P, Sripaiboonkij P, Chaikittiporn C. Asbestos exposure among mitering workers. Saf Health Work. 2012;3(3):235–40.
134. Frost G. The latency period of mesothelioma among a cohort of British asbestos workers (1978–2005). Br J Cancer Nature Publishing Group. 2013;109(7):1965–73.
135. Harding AH, Darnton AJ. Asbestosis and mesothelioma among British asbestos workers (1971–2005). Am J Ind Med. 2010;53(11):1070–80.
136. Meisenkothen C. Malignant mesothelioma, airborne asbestos, and the need for accuracy in chrysotile risk assessments. New Solutions J Environ Occup Health Policy. 2013;23(2):389–405.
137. Roelofs CR, Kernan GJ, Davis LK, Clapp RW, Hunt PR. Mesothelioma and employment in Massachusetts: analysis of cancer registry data 1988–2003. Am J Ind Med. 2013;56(9):985–92.
138. Cole SR, Richardson DB, Chu H, Naimi AI. Analysis of occupational asbestos exposure and lung cancer mortality using the G formula. Am J Epidemiol. 2013;177(9):989–96.
139. Thomas D, Geck R, Rozas D, Muro-cacho C, Rumbak M. Mesothelioma: a soon to be forgotten disease in the United States? J Bronchol Interv Pulmonol. 2012;19(3):258–61.
140. Loomis D, Dement JM, Elliott L, Richardson D, Kuempel ED, Stayner L. Increased lung cancer mortality among chrysotile asbestos textile workers is more strongly associated with exposure to long thin fibres. Occup Environ Med. 2012;69(8):564–8.
141. Elliott L, Loomis D, Dement J, Hein MJ, Richardson D, Stayner L. Lung cancer mortality in North Carolina and South Carolina

chrysotile asbestos textile workers. Occup Environ Med. 2012;69(6):385–90.
142. Haber SE, Haber JM. Malignant mesothelioma: a clinical study of 238 cases. Ind Health. 2011;49(2):166–72.
143. Finkelstein MM, Meisenkothen C. Malignant mesothelioma among employees of a connecticut factory that manufactured friction materials using chrysotile asbestos. Ann Occup Hyg. 2010;54(6):692–6.
144. Loomis D, Dement J, Richardson D, Wolf S. Asbestos fibre dimensions and lung cancer mortality among workers exposed to chrysotile. Occup Environ Med. 2010;67(9):580–4.
145. Welch L, Dement J, West G. Mortality among sheet metal workers participating in a respiratory screening program. Am J Ind Med. 2015;58(4):378–91.
146. Cowan DM, Cheng TJ, Ground M, Sahmel J, Varughese A, Madl AK. Analysis of workplace compliance measurements of asbestos by the U.S. Occupational Safety and Health Administration (1984–2011). Regul Toxicol Pharmacol. 2015;72(3):615–29.
147. Egilman D, Bird T, Lee C. Dust diseases and the legacy of corporate manipulation of science and law. Int J Occup Environ Health. 2014;20(2):115–25.
148. Moolgavkar SH, Anderson EL, Chang ET, Lau EC, Turnham P, Hoel DG. A review and critique of U.S. EPA's risk assessments for asbestos. Crit Rev Toxicol. 2014;44(6):499–522.
149. Finley BL, Pierce JS, Paustenbach DJ, Scott LLF, Lievense L, Scott PK, et al. Malignant pleural mesothelioma in US automotive mechanics: reported vs expected number of cases from 1975 to 2007. Regul Toxicol Pharmacol. 2012;64(1):104–16.
150. Phelka AD, Finley BL. Potential health hazards associated with exposures to asbestos-containing drywall accessory products: a state-of-the-science assessment. Crit Rev Toxicol. 2012;42(1):1–27.
151. Goodman JE, Peterson MK, Bailey LA, Kerper LE, Dodge DG. Electricians' chrysotile asbestos exposure from electrical products and risks of mesothelioma and lung cancer. Regul Toxicol Pharmacol. 2014;68(1):8–15.
152. Franke K, Paustenbach DJ. Government and Navy knowledge regarding health hazards of asbestos: a state of the science evaluation (1900 to 1970). Inhal Toxicol. 2011;23(S3):1–20.
153. Wylie AG, Candela PA. The hobbit: the desolation of Smaug. J Toxicol Environ Health B. 2015;18(1):1–42.
154. Kameda T, Takahashi K, Kim R, Jiang Y, Movahed M, Park E, et al. Asbestos: use, bans and disease burden in Europe. Bull World Health Organ. 2014;92(11):790–7.
155. La Vecchia C, Boffetta P. Role of stopping exposure and recent exposure to asbestos in the risk of mesothelioma. Eur J Cancer Prev. 2012;21(3):227–30.
156. Reid A, de Klerk NH, Magnani C, Ferrante D, Berry G, Musk AW, et al. Mesothelioma risk after 40 years since first exposure to asbestos: a pooled analysis. Thorax. 2014;69(9):843–50.
157. Moon EK, Son M, Jin Y-W, Park S, Lee WJ. Variations of lung cancer risk from asbestos exposure: impact on estimation of population attributable fraction. Ind Health. 2013;51(1):128–33.
158. Park EK, Takahashi K, Hoshuyama T, Cheng TJ, Delgermaa V, Le GV, et al. Global magnitude of reported and unreported mesothelioma. Environ Health Perspect. 2011;119(4):514–8.
159. Ngamwong Y, Tangamornsuksan W, Lohitnavy O, Chaiyakunapruk N, Scholfield CN, Reisfeld B, et al. Additive synergism between asbestos and smoking in lung cancer risk: a systematic review and meta-analysis. PLoS ONE. 2015;10(8):e0135798.
160. Delgermaa V, Takahashi K, Park E-K, Le GV, Hara T, Sorahan T. Global mesothelioma deaths reported to the World Health Organization between 1994 and 2008. Bull World Health Organ. 2011;89(10):716–24.
161. Donovan EP, Donovan BL, McKinley MA, Cowan DM, Paustenbach DJ. Evaluation of take home (para-occupational) exposure to asbestos and disease: a review of the literature. Crit Rev Toxicol. 2012;42(9):703–31.
162. Finley BL, Pierce JS, Phelka AD, Adams RE, Paustenbach DJ, Thuett KA, et al. Evaluation of tremolite asbestos exposures associated with the use of commercial products. Crit Rev Toxicol. 2012;42(2):119–46.
163. Bernstein DM. The health risk of chrysotile asbestos. Curr Opin Pulm Med. 2014;20(4):366–70.
164. Goswami E, Craven V, Dahlstrom DL, Alexander D, Mowat F. Domestic asbestos exposure: a review of epidemiologic and exposure data. Int J Environ Res Public Health. 2013;10(11):5629–70.
165. Case BW, Abraham JL, Meeker G, Pooley FD, Pinkerton KE. Applying definitions of "asbestos" to environmental and "low-dose" exposure levels and health effects, particularly malignant mesothelioma. J Toxicol Environ Health B Crit Rev. 2011;14(1-4):3–39.
166. Lexchin J, Bero LA, Djulbegovic B, Clark O. Pharmaceutical industry sponsorship and research outcome and quality: systematic review. Br Med J. 2003;326(7400):1167–70.
167. Lundh A, Sismondo S, Lexchin J, Busuioc OA, Bero L. Industry sponsorship and research outcome. JAMA Intern Med. 2012;12:MR000033.
168. Bero L, Anglemyer A, Vesterinen H, Krauth D. The relationship between study sponsorship, risks of bias, and research outcomes in atrazine exposure studies conducted in non-human animals: systematic review and meta-analysis. Environ Int. 2016;92-93:597–604.