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Environmental asbestos exposure sources in Korea

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Background: Because of the long asbestos-related disease latencies (10–50 years), detection, diagnosis, and epidemiologic studies require asbestos exposure history. However, environmental asbestos exposure source (EAES) data are lacking.

Objectives: To survey the available data for past EAES and supplement these data with interviews.

Methods: We constructed an EAES database using a literature review and interviews of experts, former traders, and workers. Exposure sources by time period and type were visualized using a geographic information system (ArcGIS), web-based mapping (Google Maps), and OpenWeatherMap. The data were mounted in the GIS to show the exposure source location and trend.

Results: The majority of asbestos mines, factories, and consumption was located in Chungnam; Gyeonggi, Busan, and Gyeongnam; and Gyeonggi, Daejeon, and Busan, respectively. Shipbuilding and repair companies were mostly located in Busan and Gyeongnam.

Conclusions: These tools might help evaluate past exposure from EAES and estimate the future asbestos burden in Korea.

Keywords: Modeling, Spatial, Temporal, GIS, Mapping, Reconstruction, Past

Introduction

Asbestos is designated as a Group 1 carcinogen by the International Agency for Research on Cancer.¹ Asbestos causes asbestos-related diseases (ARDs) including malignant diseases such as malignant mesothelioma (MM), lung cancer, laryngeal cancer, and ovarian cancer as well as benign diseases such as asbestosis, pleural plaque, and pleural thickening.¹ The number of MM cases in Korea has risen since 2001,² and environmentally compensated cases of MM have rapidly increased since 2011 after the Asbestos Damage Relief Act (ADRA), which compensates environmental asbestos victims in Korea.³

Because ARDs have long latencies (10–50 years), recent health problems might be caused by past asbestos exposure.⁴ ARDs caused by environmental asbestos exposure sources (EAES) have a longer latency period than those caused by occupational asbestos exposure.⁵ Therefore, individuals, mainly those older than 60 years, who have been compensated by the ADRA might have been exposed to asbestos in their childhood.⁶ To determine the cause, health specialists involved with ARDs need to

be aware of past EAES. Data regarding past EAES can provide not only epidemiological causal relationships at a national level, but also helpful information for individual treatment plans for patients at the clinical level.

EAES data in Korea are very limited.⁷ Because the main time period of asbestos use was 1970 through the early 1990s, when asbestos was used for national industrialization and roof renovation, it is difficult to find data. Furthermore, the majority of asbestos-producing companies are small and do not have accurate records of production data. The purpose of this study was to survey the available data for past EAES and supplement these data with interviews.

Materials and methods

Study scope

The territory of North Korea was excluded. Asbestos source data were collected for the years 1935, which is suspected as the beginning of asbestos production in asbestos mines,⁷ to 2010, just after the asbestos ban in 2009. The study period was 2007–2014.

Literature review

We conducted a broad literature review, from publications of the Japanese Government-General of Choson to recent

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academic publications, reports, newspaper articles, and Internet-based advertisements. The inclusion criterion for the literature review was asbestos source data (factory, mine, shipyard, ship breaking and/or repair, steel mill, petrochemical plant, electric power plant, and town redevelopment area) that had an address, production amount, and/or operational period.

The search for international journals published up to 31 December 2013 was conducted using PubMed with the terms “asbestos and Korea.” Of the 73 papers retrieved, one article was excluded because it lacked information regarding the name, address, and operational period of the asbestos factories.⁸

For the systematic literature review of Korean journals, books, and scientific publications, the search was conducted using the search term which was “asbestos” in the Korean language in the Research Information Sharing Service (www.riss.kr) provided by the Korea Education and Research Information Service. The 2,655 results included 273 theses, 609 journal publications, 1,700 books, and 73 reports. Of the theses and journal papers, one publication was retrieved that initiated this study.⁷ We searched for governmental reports in the national library of Korea (www.nl.go.kr/). The web pages of each industrial association were searched for member status information for shipyards, ship repairs, steel mills, chemical complexes, and power plants. The major literature sources are listed in Table 1.

Interviews

Because accurate and complete records do not exist in Korea, we conducted interviews of former asbestos import and distribution dealers, former asbestos workers, and patients with ARD to verify the company name, location, production amount, and operational period in the author-gathered EAES data, which were provided to the interviewees. In addition, we attempted to find information that was missing from the literature review. As a result, the interviews primarily collected information regarding operational period and production amount. Furthermore, information regarding asbestos shipping and cargo handling was collected through interviews of former workers and residents in the relevant areas.

The two major dealers who managed almost all of the imported raw asbestos material were interviewed twice. In addition, because the ADRA has compensated patients with ARDs caused by environmental exposure since 2011, the authors reviewed the 525 cases of compensated asbestos victims from 2011.³ There are two environmental health centers for asbestos (EHCA) designated by the Ministry of Environment of Korea: SoonChunHyang EHCA, which focuses on asbestos mines in central and western Korea (Seoul, Gyeonggi, Incheon, Daejeon, Chungbuk, and Chungnam), and Pusan National University Yangsan EHCA, which focuses on asbestos factories in southern and Eastern Korea (Daegu, Gyeongbuk, Busan, Ulsan,

Gyeongnam, Gwangju, Jeonbuk, Jeonnam, and Jesu). Since 2011, two EHCAs have conducted health impact assessments of asbestos by each annually surveying approximately 2,000 people who had lived near former asbestos mines or factories; occupational and environmental asbestos exposure history was collected to detect ARDs. The authors analyzed the questionnaires from 2011 to 2013, resulting in data for approximately 12,000 people.

Interviews were conducted with 25 patients with ARD who visited the Yangsan EHCA for the purpose of compensation. Also, approximately 20 former asbestos miners were interviewed by the SoonChunHyang EHCA, and approximately 70 former asbestos workers were interviewed by the Yangsan EHCA. To correct the EAES information and geocode the EHCA location on the geographic information system (GIS) map, two experts who were chief executives of the Korea Land & Housing Corporation were interviewed.

Spatiotemporal visualization

Exposure sources by period and type were visualized using ArcGIS (ESRI, Redlands, CA, U.S.A.). Web-based mapping was conducted using Google Maps (Google, Inc., Mountain View, CA, U.S.A.) and the open application programming interface OpenWeatherMap (Mountain View, CA, U.S.A.).

Results

EAES data by information source

Of the 1,483 EAES, 42 were asbestos mines, 199 were asbestos factories, and 17 were asbestos processing plants. The majority of the data for mines was gathered from the Ministry of Environment ($n = 38$), the majority of the data for factories was from the Ministry of Labor ($n = 81$), and the majority of data for shipbuilding, ship repairs, and steel mills were collected from membership information of the related industrial associations (Table 2). All of the data for town redevelopment were obtained from the literature.

Spatiotemporal distribution

Table 3 shows the regional distribution of the EAES according to source type: asbestos mines, mills, factories (including textile, construction material, and other factory types), shipbuilding and repair companies, steel mills, chemical complexes, power plants, shipping areas, and town redevelopment areas. The number of asbestos mines was highest in Chungnam ($n = 29$). Asbestos factories were located in Gyeonggi ($n = 40$), Busan ($n = 39$), and Gyeongnam ($n = 24$). Shipbuilding and repair companies were concentrated in Busan ($n = 370$), Gyeongnam ($n = 68$), and Jeonnam ($n = 43$). Town redevelopment areas were distributed in Seoul ($n = 248$), Daegu ($n = 48$), and Busan ($n = 46$) (Table 3).

Regional asbestos consumption is shown in Table 3. Of 2,719,241 tons in total, approximately 417,824 tons (15.2% of total consumption) of asbestos were mined, and

Table 1 Major literature sources

Type	Literature	Publisher	Year of publication
Mine and mill	Summary report of investigation of mineral deposit in Chosun (The Mineral Book in Chosun)	The Japanese Government-General of Choson Geological Survey	1923–1942
	Mineral Year Book	U.S. Geological Survey	1932–
	Asbestos Mine	Ministry of Commerce and Industry	1963–1966
	Mining Handbook	Korea Resources Corporation	1981, 1991, 1989
	The Scrutiny of soil contamination in scrap metal mines	Ministry of Environment	2000
	Current status of domestic mine	Korea Resources Corporation	2006.08
	Asbestos Survey Report, Asbestos mining area in Jecheon, Chungbuk	Ban Asbestos Network Korea	2009.02
	Current state of closed asbestos mines in Korea and countermeasure against mine damage	Mine Reclamation Corporation	2009
	Environmental status report around national asbestos mines	Ban Asbestos Network Korea	2009.10
	The summarized and close investigation around national closed asbestos mines	Korea Environment Corporation	2010.10
	The mid- and long-term investigation Plan of Asbestos occurring areas including closed asbestos mines	Ministry of Environment	2011.02
	Status of asbestos mines	Ministry of Environment	2011.03
	Status of asbestos mines	SoonChunHyang Environmental Health Center for Asbestos	2011.04
	Mines and factories	Company list of Factory and Mine	Ministry of Commerce and Industry
Company list of Mining and Manufacturing		Korean Bank	1956
Asbestos factories	Company list of asbestos manufacturing license	Ministry of Labor	1991, 2003–2005, 2007
	Handbook of industrial complex	Korea Industrial Complex Corporation	1980–1996
	Survey and database implementation for Asbestos Contained Materials	Korea Occupational Safety & Health Agency	2007
	Documents of the National Assembly's audit and inspection of state affairs in 2007	Ministry of Labor	2007
Ship building	Members Status	Korea Shipbuilding Industry Cooperative	2011
Ship breaking and repair	Survey of asbestos-related work in the field of ship repair and demolition	Korea Occupational Safety & Health Agency	2011.12
Steel mill	Members Status	Korea Iron & Steel Association	2011
Chemical complex	Members Status	Korea Petrochemical Industry Association	2011
Power plant	Members Status	Korea Electric Association	2011
Harbor		Harbor workers interview	2010
Town redevelopment area	Status of the national urban renewal redevelopment	Korea Land & Housing Corporation	1992.05
	Fact Sheet of Redevelopment and reconstruction	Minister of Land, Infrastructure and Transport	2006.10

approximately 2,324,439 tons (84.8% of total consumption) were used in factories (Table 4).

Asbestos was mined by 42 mines (mean 9,949 tons) and used by 199 factories (mean 11,686 tons) (Table 4). The two asbestos mines with the greatest output were Gwangcheon mine located in Hongseong-gun Gwangcheon-eup Sangjung-ri (190,379 tons) and Hongseong mine located in Hongseong-gun Guhang-myeon Cheonggwang-ri (83,617 tons). The two asbestos factories with the greatest output were KCC in Suwon City Seodun-dong (1,035,742 tons) and Byucksan in Daejeon City Taepyeong-dong (568,933 tons). Detailed data are listed on the homepage of the Environmental Health Center on Asbestos.

EAES are mapped in Figures 1 and 2. Asbestos mines and mills were concentrated in Chungnam, located in direction from west to east. Asbestos factories were concentrated in the capital areas and Busan, Gyeongnam, and Daegu, located in the direction of the Gyeong-Bu line. Shipbuilding and repair companies were concentrated in

Ulsan, Busan, Jinhae, and Geoje in the Dongnam industrial belt.

Figure 2 shows the EAES according to time period. Asbestos has been mined since the 1930s, peaked in the 1970s, and then rapidly decreased until 2006 owing to the exhaustion of asbestos veins and the increase in labor costs, which resulted in increased importing of asbestos.⁷ Asbestos textile factories were operated in the Busan and Gyeongnam area from 1969 until the late 1990s. Friction materials were produced in Daegu-Gyeongbuk and new industrial cities in the capital area. Production of construction materials such as asbestos slate began in Yongsan (Seoul) in 1929 and later expanded to Suwon and Daejeon. Asbestos was also used in shipbuilding (Figure 2).

Discussion

Evaluation of past asbestos exposure is crucial for ARDs because of their long latencies. However, there are limited data regarding past exposure in Korea. In the present

Table 2 Information sources, research methods, and exposure data by industry

Source	Method	Asbestos process-					Redevel-					Total	
		Mine	Factory	Asbestos process-	Ship-	Ship-	Steel mill	Chemical complex	Power plant	Shipping area	Redevel-		
				ing plant	building	repair				ment	opment	area	
Status of asbestos mines (Ministry of Environment)	Literature review	38											38
Status of asbestos mines (SoonChunHyang Environmental Health Center for Asbestos)	Literature review	2		1									3
Asbestos mines (Ministry of Commerce and Industry)	Literature review	2	3										5
Company lists of asbestos manufacturing licenses (Ministry of Labor)	Literature review		81										81
Handbook of industrial complex (Korea Industrial Complex Corporation)	Literature review		57										57
Survey and database implementation for asbestos-contained materials (Korea Occupational Safety & Health Agency)	Literature review		26										26
Status of the national urban renewal redevelopment (Korea Land & Housing Corporation)	Literature review									236			236
Fact sheet of redevelopment and reconstruction (Minister of Land, Infrastructure and Transport)	Literature review									176			176
Environmental status report around national asbestos mines (Ban Asbestos Network Korea)	Literature review		2										2
Dealers	Interview		13										13
Patients	Interview		2									15	17
Asbestos Damage Relief Act	Questionnaire		11	16									30
Health impact assessment	Questionnaire		4									4	13
Related industry association	Search of homepages				23	517	75	94	77				786
Total		42	199	17	23	540	75	94	77	4	412		1483

Table 3 Regional distribution of environmental asbestos exposure sources

Region	Mine	Factory	Asbestos processing plant	Ship-building	Ship repair	Steel mill	Chemical complex	Power plant	Shipping area	Redevelopment area	Total
Seoul		8				5		1		248	262
Gyeonggi	4	40	1		4	3	2	6		5	65
Incheon		7			20	4	3	4	1	5	44
Gangwon	2	1			5	1		15		11	35
Daejeon		2						1		11	14
Chungbuk	2	7			2	4	4	2			21
Chungnam	29	10	16		9	8	6	9		2	89
Daegu		17				1				48	66
Gyeongbuk	3	13				6	3	6			51
Busan		39		7	363	8		8	2	46	473
Ulsan		14		2	22	2	34	2		7	83
Gyeongnam		24		10	58	10		8	1	15	126
Gwangju		3								14	17
Jeonbuk		5		1	9	3	6	5			29
Jeonnam	2	9		3	40	6	36	7			103
Jeju					2			3			5
Total	42	199	17	23	540	75	94	77	4	412	1,483

Table 4 Numbers of asbestos exposure sources and asbestos consumption by region

Type	Region	N	Asbestos consumption amount (metric ton)		
			Sum	Mean	SD
Mine	Gyeonggi	4	6,660	1,665	14
	Gangwon	2	758	379	519
	Chungbuk	2	2,044	1,022	1,400
	Chungnam	29	407,599	14,055	45,620
	Gyeongbuk	3	683	228	261
	Jeonnam	2	98	49	44
	Sub total	42	417,842	9,949	38,837
	Factory	Seoul	8	6,654	832
Gyeonggi		40	1,120,813	28,020	163,479
Incheon		7	3,434	491	723
Gangwon		1	0	0	0
Daejeon		2	568,933	284,467	402,297
Chungbuk		7	4,062	580	725
Chungnam		10	129,252	12,925	27,078
Daegu		17	75,737	4,455	14,220
Gyeongbuk		13	35,402	2,723	4,802
Busan		39	137,668	3,530	9,550
Ulsan		14	19,594	1,400	2,398
Gyeongnam		24	92,143	3,839	13,447
Gwangju		3	0	0	0
Jeonbuk		5	129,473	25,895	48,631
Jeonnam		9	2,274	253	277
Sub total		199	2,325,439	11,686	84,203

study, in addition to gathering available EAES by literature review and interviews, the database was mounted in GIS for use by clinicians, epidemiologists, and environmental health experts. The total asbestos consumption in this study was 2,719,241 tons, including 417,842 tons of mined asbestos and 2,324,439 tons of asbestos used in factories. In comparison, a previous study in Korea estimated a total of 2.0–2.2 million tons, including 145,000 tons of mined asbestos and 1,698,188 tons of imported asbestos.^{7,9} There are several possible explanations for the higher estimate in the present study. First, raw materials from mines and imports that undergo an initial production process might be used again to make a second product, which could result in double counting. However, underestimation is

also possible. Asbestos import statistics are available from 1975, when 74,206 tons were reportedly consumed, suggesting that the amount of imports before 1975 could be considerable. We attempted to gather all possible data and validate those data by interviewing individuals who could recall the situation in the past, which might have reduced the estimation errors that occurred in previous studies. However, it is possible that all of the literature, and formal and informal data were not included. The mined asbestos data in this study had been validated by government officials from the Ministry of Environment and municipal governments through field surveys, which provided additional previous data. Furthermore, more recent factory data had been added to the literature review through the

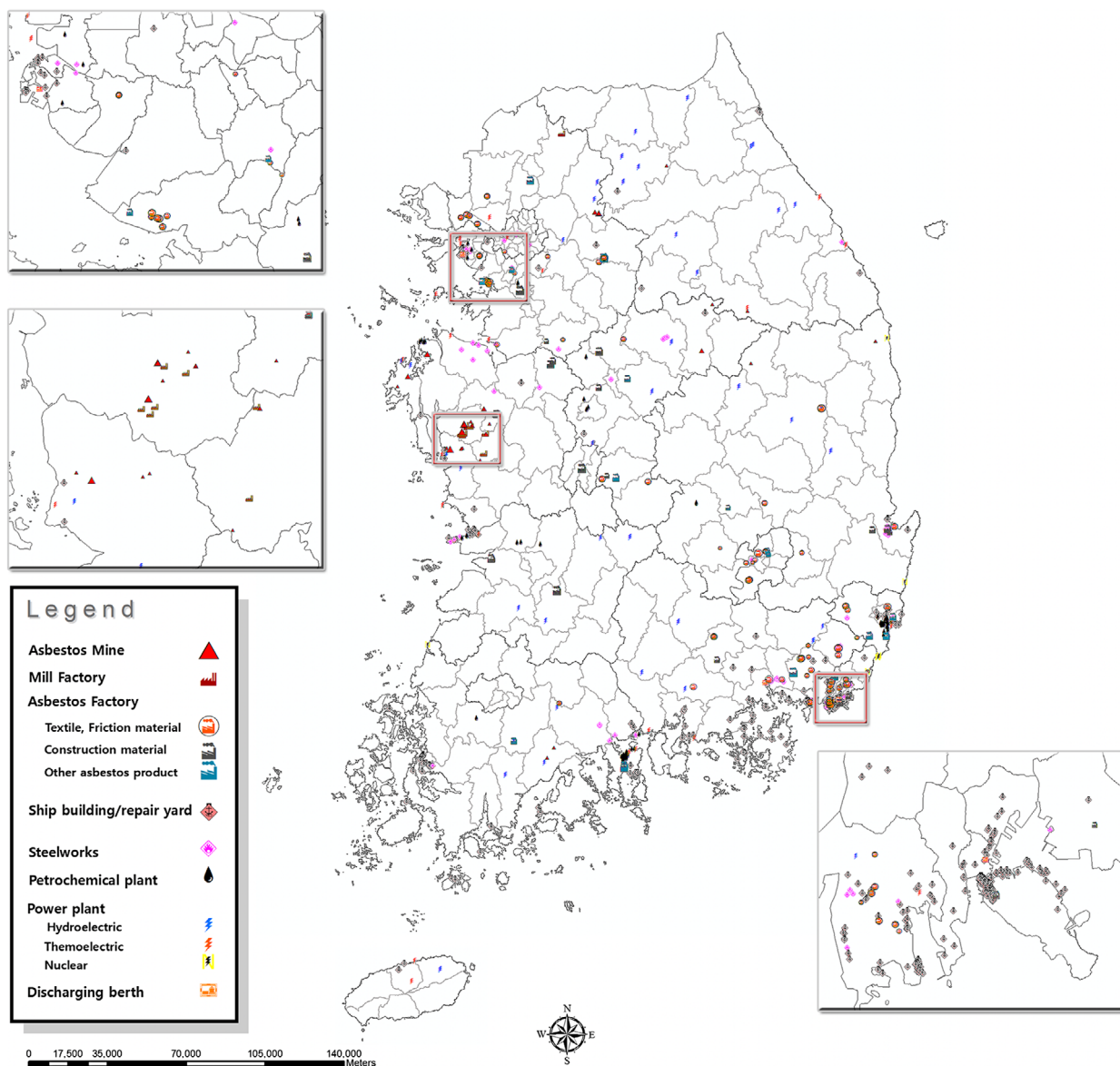


Figure 1 Environmental asbestos sources in Korea.

validation process. Despite these efforts to reduce errors, this study depended on limited data and memory, limiting the accuracy and validity and potentially either under or overestimating the results. For example, if the majority of the records and recall was restricted to relatively large facilities, this study could underestimate the real situation. However, the potential double counting already described could result in overestimation. Hence, the possible asbestos consumption in Korea, including mined and imported asbestos, might be 2.0–2.8 million tons.

It is estimated that more than 107,000 people die each year from ARDs resulting from exposure at work.¹⁰ Although this estimate is focused on occupational exposure, the actual incidence of ARDs, including those caused by environmental exposure, might be higher. ARDs caused by asbestos from various environmental sources including mines, factories, shipyards, and power plants have been studied in other countries.¹¹ The

incidence of MM in Korea is very low, approximately two cases per million people per year (approximately 100 cases among a population of 50 million), compared with that in industrialized countries (14–35 cases per million people per year).^{2,12} Whereas Korea used asbestos at a rate of 4.0–5.6 kg per capita per year according to this study, industrialized countries used asbestos at 2.0–5.5 kg per capita per year approximately 25 years before the increase in the MM incidence. Hence, we could expect a trend of increasing MM in Korea until it is 5–10 times higher than the present level. In other words, assuming at least one MM for every 170 tons of asbestos consumption¹² and considering the 2.0–2.8 million tons of asbestos consumed in Korea, we could expect 11,765–16,471 total MM cases. Because asbestos causes at least a two-fold higher incidence of lung cancer than MM, the ARD incidence will be much higher when all ARDs are considered.¹³



Figure 2 Environmental asbestos sources by product and period in Korea.

A lack of data regarding EAES in Korea has made it difficult to determine exposure sources for epidemiologic studies or clinical purposes for individual patients. The results of this study might be helpful for researchers and clinicians. Because the basic information we evaluated, such as location, operational period, and amounts, is insufficient to estimate past exposure, further studies on emission rates from exposure sources and ambient air

concentrations are necessary. This study and further studies on environmental asbestos exposure might be helpful for both evaluating past asbestos exposure and estimating future asbestos burden.

Disclosure statement

No potential conflict of interest was reported by the authors.

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