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TECHNICAL PAPER

## Evaluation of asbestos-containing products and released fibers in home appliances

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### ABSTRACT

The purpose of this study was to detect asbestos-containing products and released asbestos fibers from home appliances. The authors investigated a total of 414 appliances manufactured between 1986 and 2007. Appliances were divided into three categories: large-sized electric appliances, small-sized electric appliances, and household items. Analysis for asbestos-containing material (ACM) was performed using polarized light microscopy (PLM) and stereoscopic microscopy. Air sampling was performed to measure airborne concentration of asbestos using a phase-contrast microscope (PCM). The results of the analysis for ACM in appliances show that large-sized electric appliances (refrigerators, washing machines, kimchi-refrigerators) and household items (bicycles, motorcycles, gas boilers) contain asbestos material and small-sized electric appliances do not contain asbestos material. All appliances with detected asbestos material showed typical characteristics of chrysotile (7–50%) and tremolite (7–10%). No released fibers of ACM were detected from the tested appliances when the appliances were operating. This study gives the basic information on asbestos risk to people who use home appliances.

*Implications:* All appliances with detected asbestos material showed typical characteristics of chrysotile (7–50%) and tremolite (7–10%). No released fibers of ACM were detected from the tested appliances when the appliances were operating.

### PAPER HISTORY

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### Introduction

Asbestos is a general term for a number of naturally occurring fibrous mineral silicates. It has many advantages, such as low cost, good heating properties, electrical resistance, good wear and friction characteristics, tensile strength, sound insulation, adsorption capacity, and resistance to chemical and biological attacks (Agency for Toxic Substances and Disease Registry [ATSDR], 2001). It is now known that prolonged inhalation of asbestos fibers can cause serious and fatal illnesses, including lung cancer, mesothelioma, and asbestosis (Levin et al., 2000; Hillerdal and Henderson, 1997). The International Agency for Research on Cancer (IARC; Group 1), Ministry of Labor in Korea (MOL; A1), and the American Conference of Governmental Industrial Hygienists (ACGIH; A1) have categorized asbestos as a human carcinogen (IARC, 1987; MOL, 2015; ACGIH, 2015).

The use of asbestos rapidly expanded in Korea during the economic growth that occurred in the 1970s. Asbestos was necessary for shipbuilding and heavy chemical industries to enable heat treatments and for the efficient use of electric power. In May 1997, the manufacture and use of

crocidolite and amosite, commonly known as blue and brown asbestos, were fully banned in South Korea. In January 2009, a full-fledged ban on all types of asbestos occurred when the government banned the manufacture, import, sale, storage, transport, and use of asbestos or any substance containing more than 0.1% asbestos (Kim, 2009). In 2011, South Korea became the world's sixth country to enact an asbestos harm aid act, which entitles any Korean citizen to free lifetime medical care as well as monthly income from the government, if he or she is diagnosed with an asbestos-related disease.

In April 2009, the Korea Food and Drug Administration (KFDA) determined that 11 talc powder products for babies were contaminated with asbestos, presumably from the manufacturing process. Accordingly, KFDA banned the sales of the identified products and called for a halt in the use of talc in other products. Overall, 1122 drugs and medical goods have been confirmed to contain talc contaminated with asbestos. This incident highlights that asbestos can affect not only employees who produce asbestos-containing products and construction workers who are exposed to asbestos, but also residents via environmental exposure (Kim, 2009).

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Home appliances are essential items that accomplish functions and provide comfort and are used in many countries. However, some of these appliances are manufactured with asbestos-containing parts or components. In Japan, since 2005, the Ministry of Environment (MOE) has conducted asbestos-containing material (ACM) research four times on home appliances, for 774 products from 185 companies. They detected asbestos in eight products from six companies, and they suggested that it is likely that asbestos is released into the air when the appliances are in use (MOE, 2005). Thus, it is important to identify household appliances that could contain asbestos and release asbestos fibers during operation. In South Korea, distribution rates of home appliances were obtained from the Korean Power Exchange (Table 1). Distribution rates for essential house appliances, such as electric fans, televisions, and hair dryers were 100%, which means that all households obtained these appliances. Therefore, the purpose of this study was to evaluate ACMs in home appliances and asbestos fibers released in the air from large-sized electric appliances, small-sized electric appliances, and household items manufactured between 1986 and 2007.

## Methods

### Selection of products

The selection of household products suspected to contain asbestos was adjusted to the conditions of our country, with reference to a Japanese study (MOE, 2005). Products suspected to contain asbestos, such as products manufactured for domestic use and imported products, were collected by the recycling center, and subcontractors coordinated the visits. Table 2 lists the three main categories: large-sized electric appliances, small-sized electric appliances, and household items. Large-sized electric appliances comprise five items and 99 samples, small-sized

electric appliances comprise 14 items and 227 samples, and household items comprise eight items and 115 samples.

### Sampling

We dismantled the samples from 27 kinds of appliance and sampled the parts suspected to contain asbestos. The parts of the items suspected to contain asbestos materials were the following: compressor inner packing, break pad, packing, heat wire, motor materials, heat-keeping materials, valve gasket, etc. (listed in Table 3).

### Bulk and air sampling analysis

Analysis for materials suspected to contain asbestos was performed according to U.S. Environmental Protection Agency (EPA) Method 600/R-93-116 using polarized light microscopy (PLM) and stereoscopic microscopy (SMZ645; Nikon, Tokyo, Japan) in a hood attached with high-efficiency filter (Captair Chem, New Jersey, USA). Air sampling was performed while the appliances were in use, and it focused on the appliances that were found to contain asbestos in the bulk analysis (Figure 1). ACM Refrigerators, kimchi-refrigerators, washing machines, bicycles, and motorcycles were evaluated using high-volume pump (model 1532; SKC, New York, USA) with open-face-attached mixed cellulose ester (MCE) filter (25 mm, pore size 0.8  $\mu\text{m}$ ) and air flowing at 10 L/min for 2 hr within a 30-cm distance, while the appliances were in use. Phase-contrast microscopy (PCM) was applied to detect asbestos by National Institute of Occupational Safety and Health (NIOSH) Method 7402.

**Table 1.** Rate (%) of supply of the main appliances per household in Korea.

Product	1994	1996	1997	2000	2002	2004	2006
Air conditioner	9	13	21	29	38	42	48
Microwave	45	53	67	66	74	76	75
Kimchi-refrigerator	—	—	—	—	33	48	63
Washing machine	91	96	95	96	96	96	98
Rice cooker	85	95	87	90	82	83	88
TV	100	100	100	100	100	100	100
Electric fan	100	100	100	100	100	100	100
Stove	12	12	5	12	11	10	3
Toaster	13	21	21	25	25	27	22
Blender	69	66	55	56	49	49	64
Iron	98	98	97	98	96	96	93
Hair dryer	99	100	100	100	100	100	100
Vacuum cleaner	47	63	66	67	80	80	77

**Table 2.** Classification of appliances.

No.	Category	Product (No. of Samples)	
1	Large-sized electric appliances	Refrigerator (20)	Air conditioner (10)
		Kimchi-refrigerator (24)	Washing machine (23)
		TV (22)	Electric oven (15)
2	Small-sized electric appliances	Rice cooker (19)	Electric tool (12)
		Electric fan (19)	Vacuum cleaner (16)
		Stove (16)	Kettle (16)
		Toaster (15)	Desk lamp (15)
		Blender (16)	Heating pad (15)
		Iron (19)	Electric blanket (15)
		Hair dryer (18)	Microwave (18)
3	Household items	Bicycle (16)	Exercise stepping machine (15)
		Motorcycle (22)	
		Exercise cycle (15)	Treadmill (3)
		Butterfly chest exercise device (15)	Gas boiler (15)

**Table 3.** Detailed parts of asbestos-containing materials in appliances.

No.	Product	Asbestos-Containing Material
1	Refrigerator	Compressor inner packing
2	Air conditioner	Compressor inner packing
3	Microwave	Heat wire
4	Kimchi-refrigerator	Compressor inner packing
5	Washing machine	Packing
6	Rice cooker	Power-code protect materials
7	TV	Fan
8	Electric fan	Motor materials
9	Stove	Heat-keeping materials
10	Toaster	Heat-keeping materials
11	Blender	Motor materials
12	Iron	Power-code lagging
13	Hair dryer	Heat-keeping materials
14	Electric tool	Motor materials
15	Vacuum cleaner	Motor insulation materials
16	Kettle	Inner electric wire
17	Electric oven	Pipeline connection, firer, heat-protecting materials
18	Bicycle	Break pad
19	Motorcycle	Break pad, power connection equipment
20	Desk lamp	Inner electronic line
21	Heating pad	Heat materials, heat-keeping materials, inner heat line
22	Electric blanket	Inner heat line, heat materials
23	Gas boiler	Valve gasket, heat-keeping materials
24	Exercise cycle	Spin seat belt, inner electric line
25	Butterfly chest exercise device	Back of chair pad
26	Exercise stepping machine	Inner line, connection materials
27	Treadmill	Motor belt, inner line

## Results

### Asbestos contained in appliances

Table 4 presents the results of ACM analysis in appliances. Asbestos was detected in parts of the large-sized appliances, such as refrigerators, kimchi-refrigerators,

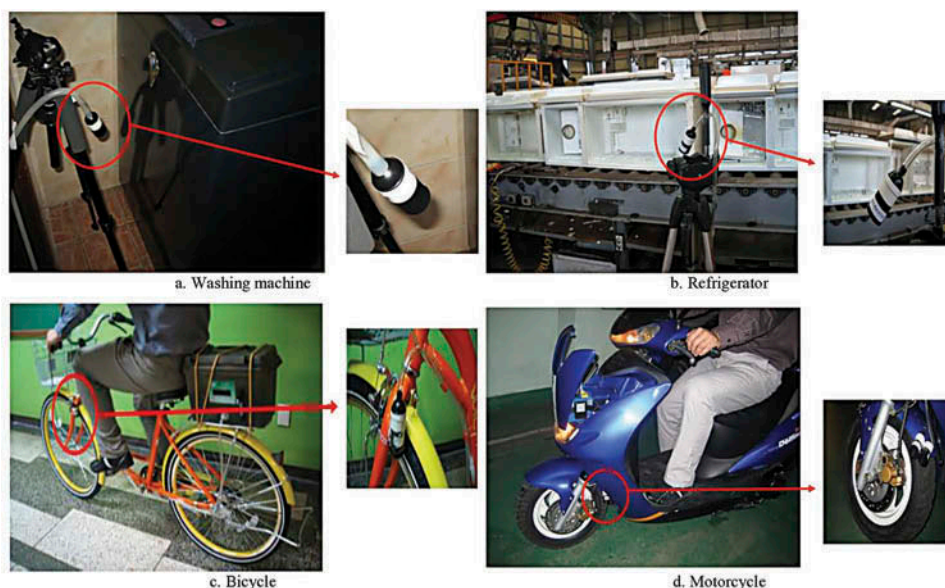
and washing machines. In addition, asbestos was detected in household items, such as bicycles, motorbikes, and gas boilers, whereas it was not detected in small-sized appliances.

Of the five items in large-sized appliances, 99 samples were analyzed for asbestos. Among these samples, 39 samples from three items were found to contain asbestos, with 39.4% detection rate. Chrysotile was detected in refrigerators, ranging from 14% to 50% in 10 out of 20 products, which contain asbestos based on the weight of parts in parts of the inner motor of refrigerators, such as the compressor with gasket. Chrysotile (7–45%) and tremolite (10%) were detected in kimchi-refrigerators in 16 out of 24 products, which contain asbestos in parts of the inner motor of the kimchi-refrigerators, such as the compressor with gasket. Chrysotile was detected in washing machine, ranging from 8% to 20% in 3 out of 23 products, which contain asbestos in parts of the inner clutch with braking and in parts of the packing of the motor in washing machines.

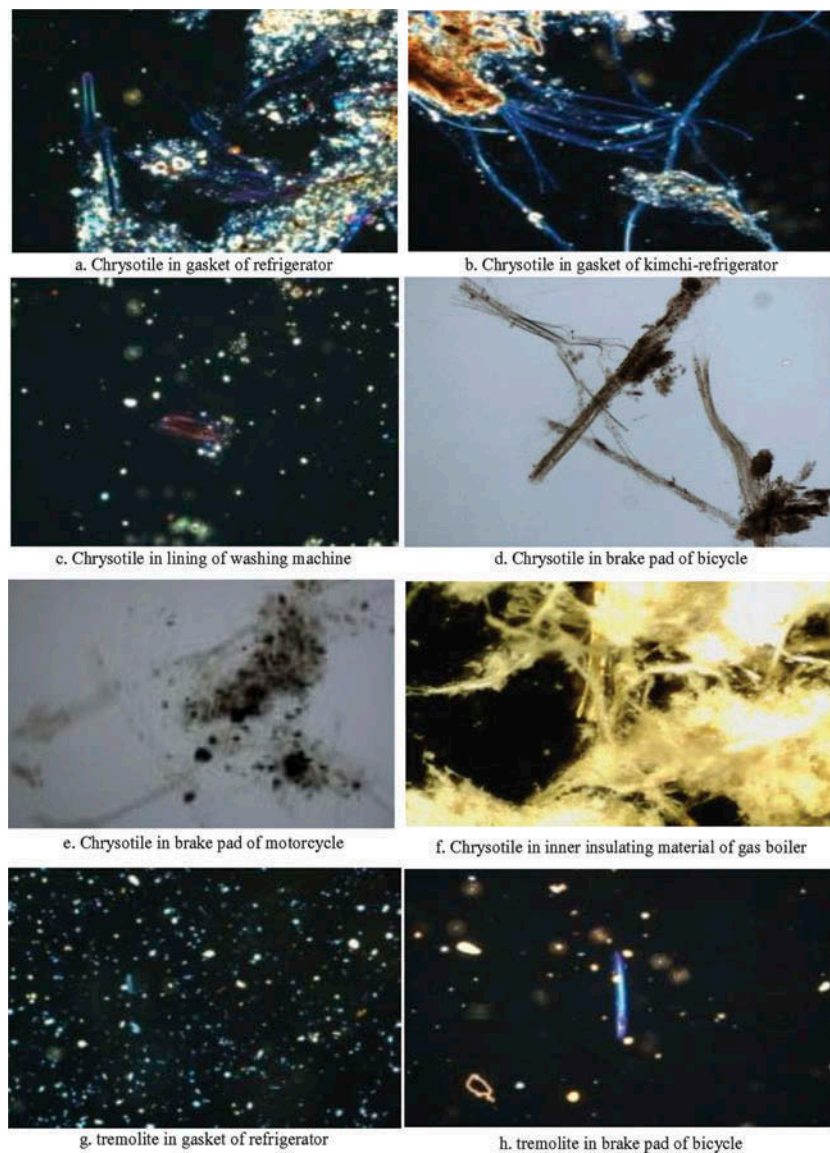
Asbestos was also detected in other types of products, such as bicycles, motorcycles, and gas boilers, in the brake pad, the brake liner, the power connection equipment, and the heat-keeping materials. However, asbestos was not detected in small-sized appliances after analyzing 227 samples from 14 items.

### Annual asbestos detection in appliances

Table 5 presents the results of detected asbestos in appliances per year. Asbestos was detected in 47 of 436 samples from 27 items during 23 years. Table 5



**Figure 1.** Air sampling of asbestos fibers.



**Figure 2.** Micrographs of identified asbestos by PLM.

presents only the samples where we detected asbestos. In large-sized appliances, all products manufactured after 2005 do not contain ACM in their parts, whereas asbestos in household items was detected in items manufactured until 2007.

Chrysotile was detected in 10 products, in parts of refrigerators manufactured in 1991, 1995, 1996–1999, and in 2001. In the case of washing machines, chrysotile was detected in the parts of 16 products manufactured in 1994, 1995, and 1998, whereas no asbestos was detected in products manufactured since 1999. Asbestos was detected in all products manufactured since 1997, except in 2006 and 2007, when asbestos was detected in three products, in parts of the kimchi-refrigerators. Asbestos,

such as chrysotile and tremolite, was also detected in parts of bicycles, motorcycles, and gas boilers.

### ***Comparing ACM in domestic appliances and imported appliances***

We tested for asbestos and obtained the total number of analyzed appliances from domestic and imported samples between 1986 and 2007. A total of 47 products that use asbestos in parts of the product were detected in both domestic and imported appliances. Among these products, 45 products from six items were domestic appliances, and two products from one item were imported appliances.

**Table 4.** Asbestos types by product and asbestos-containing material (ACM) in home appliances.

Product (No. of Samples)	Company	Year	Asbestos type	(%)	Asbestos-Containing Material
Refrigerator (10)	A	1995	Chrysotile	50	Compressor inner gasket
		1996	Chrysotile	40	
		1999	Chrysotile	40	
		2001	Chrysotile	40	
	B	1991	Chrysotile	50	
		1996	Chrysotile	14	
		1997	Chrysotile	30	
		1999	Chrysotile	40	
	C	2001	Chrysotile	40	
		1998	Chrysotile	50	
Washing machine (3)	A	1998	Chrysotile	20	Clutch inner breaking
	B	1994	Chrysotile	8	
	C	1995	Chrysotile	16	
Kimchi-refrigerator (16)	A	1997	Chrysotile	40	Compressor inner gasket
			Tremolite	10	
		1998	Chrysotile	40	
		1999	Chrysotile	40	
		2000	Chrysotile	45	
		2003	Chrysotile	7	
	B	2004	Chrysotile	40	
		1998	Chrysotile	40	
		2001	Chrysotile	45	
		2002	Chrysotile	40	
	C	2001	Chrysotile	45	
		2004	Chrysotile	45	
		2005	Chrysotile	40	
	D	2000	Chrysotile	40	
		2004	Chrysotile	40	
		2002	Chrysotile	40	
E	2005	Chrysotile	40		
	A	2003	Chrysotile	4	Brake pad
		B	2003	Chrysotile	
C		2008	Chrysotile	30	
Motorcycle (7)	A	2004	Chrysotile	10	Brake liner
		2004	Tremolite	3~5	
		2006	Chrysotile	20	
	B	2005	Chrysotile	20	Brake pad
		2005	Chrysotile	20	
	C	2008	Tremolite	3	Power connection equipment
			Chrysotile	10	
Gas boiler (8)	A	2008	Chrysotile	10	Heat-keeping materials
		2002	Chrysotile	25	
		2003	Chrysotile	7	
		2005	Tremolite	2	
	C	2006	Chrysotile	10	
		2003	Chrysotile	20	
		2004	Chrysotile	15	
	D	2005	Tremolite	3	
		2006	Tremolite	2	

Notes: All asbestos concentrations were calculated based on the weight of parts.

**Table 5.** Detected asbestos-containing materials of appliances by year.

Year	Refrigerator	Kimchi-Refrigerator	Washing Machine	Bicycle	Motorcycle	Gas Boiler	Total
1986	0/1	—	—	—	—	—	0/1
1991	1/1	—	0/1	—	—	—	1/2
1992	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—
1994	—	—	1/2	—	—	—	1/2
1995	1/1	—	1/3	—	—	—	2/4
1996	2/2	—	0/2	—	—	—	2/4
1997	1/1	2/2	0/2	—	—	—	3/5
1998	1/1	2/2	1/2	—	—	—	4/5
1999	2/2	1/2	0/2	—	—	—	3/6
2000	0/2	2/2	0/1	—	—	—	2/5
2001	2/2	1/1	0/1	—	—	—	3/5
2002	0/1	2/3	0/1	0/2	0/2	1/2	3/11
2003	—	2/3	0/1	2/2	0/2	2/2	6/10
2004	—	2/2	—	0/2	2/3	1/2	5/9
2005	—	2/2	0/1	0/2	2/5	2/2	6/12
2006	—	0/2	—	0/2	1/4	2/2	3/10
2007	0/6	0/3	0/4	1/6	2/6	0/5	3/30
Total	10/20	16/24	3/23	3/16	7/22	8/15	47/112

In refrigerators, chrysotile was detected in 10 out of 20 products (50%), whereas no asbestos was detected in three imported refrigerators. Chrysotile was also detected in washing machines (16.7%) and kimchi-refrigerators (58.3%), whereas no asbestos was detected in imported washing machines. In bicycles, asbestos was detected in three out of eight domestic products, but it was not detected in eight imported bicycles. Moreover, asbestos was detected in two out of three (67%) imported motorcycles (Figure 1).

### Asbestos detection in the air

The products analyzed for ACM, such as refrigerators, washing machines, kimchi-refrigerators, bicycles, and motorcycles, were evaluated in order to detect airborne asbestos particles during their operating time using PCM. However, no asbestos deriving from any of the tested ACM products was detected in the air.

### Discussion

This study was performed in order to detect ACM in home appliances. Appliances were divided into three categories: large-sized electric appliances, small-sized electric appliances, and household items, and they were manufactured between 1986 and 2007. In addition, we assessed the presence of airborne asbestos fibers during the operation of asbestos-containing appliances. Throughout the study, large-sized electric appliances (refrigerators, washing machines, kimchi-refrigerators) and household items (bicycles, motorcycles, gas boilers) were found to contain asbestos. All appliances in which we detected asbestos material had typical characteristics, such as chrysotile ranging from 7% to 50% (*w/w*) and tremolite ranging from 7% to 10% (*w/w*) (Table 4). Kimchi-refrigerators had the highest ACMs (66.7%) compared with other types of household appliances, such as gas boilers (53.3%), refrigerators (50.0%), motorcycles (31.8%), bicycles (18.8%), and washing machines (13.0%) (Table 5). Kimchi-refrigerator is a refrigerator, which is a unique product of Korea, designed specifically to meet the storage requirements of kimchi types and different fermentation processes. Asbestos was detected in the inner compressor gasket of kimchi-refrigerators manufactured until 2005. Gas boilers, bicycles, and motorcycles in which we detected asbestos were relatively recently manufactured (i.e., manufactured until 2007) compared with washing machines and refrigerators, which were manufactured in 1988 and 2001, respectively. The appliances that were identified to contain asbestos were manufactured from 1991 to 2007, when asbestos was commonly used in Korea. In 2009, all kinds of asbestos, including asbestos gaskets and industrial friction materials,

have been prohibited in Korea (Kim, 2009; Paek et al., 1998). The amendment act, which banned asbestos in 2009, was possibly the reason asbestos was only detected in home appliances manufactured between 1991 and 2007.

This policy that bans manufacture, import, and use of all kinds of asbestos might affect the companies that produce and import asbestos. Previous studies suggest a decline in the production of asbestos after the aforementioned policy was implemented. The amount of the produced asbestos-containing gaskets was 70 tons in 2004, 90 tons in 2005, and 55 tons in 2006, in four companies, and that of asbestos-containing friction materials was 435.5 tons in 2004, 540.4 tons in 2005, and 454.3 tons in 2006, in 10 companies (Ki et al., 2008).

In the United States, where the amount of asbestos used is the largest in the world, and where asbestos has been used for a long time, there were serious damages (Carroll et al., 2005). In 1989, the EPA issued the Asbestos Ban and Phase Out Rule, but in 1991, asbestos industry supporters challenged and overturned the ban in a landmark lawsuit: *Corrosion Proof Fittings v. the Environmental Protection Agency* (EPA, 1999). In Canada, use of asbestos has declined since the mid-1970s and early 1980s. Products containing asbestos are regulated by the Asbestos Products Regulation (SOR 2007/260). In the United Kingdom, blue and brown asbestos materials were banned outright in 1985, whereas the import, sale, and secondhand reuse of white asbestos were outlawed in 1999. The 2012 Control of Asbestos Regulations states that owners of nondomestic buildings (e.g., factories and offices) have a “duty to manage” asbestos on their premises by making themselves aware of its presence and ensuring that the material does not deteriorate, removing it if necessary (Health and Safety Executive [HSE], 2012). In 1971, the Tokyo metropolitan government ordered that companies handling asbestos should install ventilators and conduct health checks on a regular basis; however, the Japanese government did not ban crocidolite and amosite until 1995, but enforced regulation of asbestos to a maximum of 1% *w/w* (Ministry of Health, Labour and Welfare [MHLW], 1995). In May 1997, the manufacture and use of crocidolite and amosite, commonly known as blue and brown asbestos, were fully banned in South Korea, and then a full-fledged ban was implemented on all types of asbestos material containing more than 0.1% asbestos (Kim, 2009).

We performed air sampling to detect airborne asbestos particles during the operating time of products that were found to contain asbestos, such as refrigerators, washing machines, kimchi-refrigerators, bicycles, and motorcycles, using PCM. However, asbestos was detected at a lesser amount than the environmental

exposure limitation (0.01 fibers/cc in South Korea) in the air around all the ACM products. In a previous study, the collected asbestos air sampling data averaged 0.047 fibers/cc in the mechanical parts of the clutch in motor vehicles during their operating time (Cohen and Van Orden, 2008). Blake et al. (2008) showed that the average asbestos concentration for personal breathing zone (PBZ) samples during seam sealant removal was 0.006 fibers/cc, during automotive repair work on vintage vehicles. Many other air samples contained asbestos at or below the analytical limit of detection (LOD). Additionally, the mean PCM and phase-contrast microscopy equivalent (PCME) 8-hr time-weighted average (TWA) concentrations for the samples during the removal and installation of asbestos-containing gaskets on vehicles were 0.0031 and 0.0017 fibers/cc, respectively (Contractors State License Board, 2013).

After the study concerning the release of asbestos in the air from 776 products in Japan, the use of asbestos was not permitted as parts of products, such as for heat-insulating material, pipe joint packing, and inner packing of the compressor in general environments. Moreover, manufacturing of electric foot warmer was banned, due to the possibility of releasing asbestos (MOE, 2005). The Consumer Product Safety Commission tries to identify household appliances that could release asbestos fibers during their use. The commission has reviewed information on the use of asbestos-containing parts in toasters, popcorn poppers, boilers, slow cookers, dishwashing machines, refrigerators, ovens, ranges, cloth dryers, and electric blankets (Contractors State License Board, 2013). The release of asbestos in the environment could have serious consequences. For example, a South Korean study on residents of four towns in south Chung-Cheong Province, where Asia's largest asbestos mine was located, showed that over 50 residents among 200 were diagnosed with asbestosis. It is suspected that this disease was caused by environmental exposure because most of the individuals diagnosed with the disease did not have a history of working in the asbestos mine (Kim, 2009).

In this study, asbestos was not detected in the air around the asbestos-containing products when the products were in use, because ACM was firmly seated in the inner parts of the products and it was covered with a protective film. Thus, there is no released asbestos in the air when using asbestos-containing products, if ACM does not decompose, or artificially operate products, such as refrigerators, kimchi-refrigerators, washing machines, bicycles, motorcycles, and gas boilers. However, there is the potential of environmental exposure to asbestos, and workers may be exposed to asbestos during the decommissioning process of ACM. Therefore, further studies should be conducted to determine the levels of exposure to asbestos in the massive

decommissioning workplaces of ACM. Also, in order to ensure there is no asbestos in products, it is likely that some kind of inspection and certification would be needed in all imported products.

This study did not analyze all the home appliances by year, manufacturer, and type; thus, it is hard to conclude that the products such as refrigerators, kimchi-refrigerators, washing machines, bicycles, motorcycles, and gas boilers are the highest asbestos-containing products in South Korea. Nevertheless, this study shows the status of asbestos-containing home appliances and gives the basic information for asbestos risk to the users of home appliances around the world.

## Conclusion

We investigated a total of 414 appliances. Appliances were divided into three categories: large-sized electric appliances, small-sized electric appliances, and household items. The results of this study were as follows.

- (1) The results of ACM analysis show that large-sized electric appliances (refrigerators, washing machines, kimchi-refrigerators) and household items (bicycles, motorcycles, gas boilers) contain asbestos, but small-sized electric appliances do not. All detected asbestos material showed typical characteristics of chrysotile (7~50%) and tremolite (7~10%).
- (2) It was found that 47 asbestos-containing products from 436 investigated products were manufactured before 2007.
- (3) We tested domestic and imported products for ACM. ACM was detected in 44 products of six items. However, only three imported products of one item were found to contain ACM.
- (4) No released fibers were detected during the operating time of ACM appliances.

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## About the authors

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