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Original Article

건축물에 사용된 석면함유물질(ACMs)의 조사 및 위해성 평가

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Investigation and Risk Assessment of Asbestos-Containing Materials used in Buildings

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ABSTRACT

Objectives: The objectives of this study are to research the usage characteristics of asbestos-containing building materials and to conduct exposure risk assessment by applying no. 2016-230 "Methods of Risk Assessment of Asbestos-Containing Buildings" from the Ministry of Environment.

Methods: One hundred buildings located in the Seoul and Gyeonggi-Incheon area were chosen, with 29 in Seoul, 20 in Incheon, and 51 in Gyeonggi-do Province. The year of construction was divided between three buildings in the 1970s, 11 buildings in the 1980s, 42 buildings in the 1990s, and 44 buildings in the 2000s. The bulk samples were analyzed by using a polarizing microscope after a pre-process using a stereomicroscope in a hood with an HEPA filter. This study defined ACMs(asbestos-containing materials) as asbestos when the content percentage was over 1% in the analysis result. Methods and standards of risk assessment of asbestos-containing building materials were conducted by refering to no. 2016-230 "Method of Risk Assessment of Asbestos-Containing Buildings" from the Ministry of Environment. The risk of exposure to ACMs was rated by a score based on three categories(high, middle, low risk of asbestos exposure).

Results: In this study, 30 of the 100 buildings and 36 of the 416 bulk samples(8.6%) were found to have had asbestos. Asbestos was detected at a high rate, in 18 out of 42, in buildings constructed in the 1990s and at the lowest rate(7 out of 44) for buildings constructed in the 2000s. As a result of the evaluation according to no. 2016-230 "Method of Risk Assessment of Asbestos-Containing Buildings" of the Ministry of Environment, the risk assessment level of two asbestos-containing building materials was found to be "Medium", and 28 buildings materials were found to be at the "Low" level.

Conclusion: As asbestos is regulated by the government, it is required to conduct active management and implemention by introducing methods of risk assessment of asbestos exposure that are supported by data from various situations. In the case of buildings owned by individuals, building owners should be aware of the risk of exposure to asbestos.

Key words: asbestos, asbestos-containing materials(ACMs), building material, building owner, risk assessment

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Objectives: 본 연구의 목적은 석면함유물질의 사용 특성을 조사하고, “환경부고시 제2016-230호 석면건축물의 위해성 평가 방법”을 적용하여 위해성평가를 실시하였다.

Methods: 서울 및 경인지역에 위치한 건축물 100개소를 선정하였으며, 지역의 구분은 서울 29개, 인천 20개, 경기 51개이다. 건축연도는 1970년대 3개, 1980년대 11개, 1990년대 42개, 2000년대 44개로 구분하여 조사하였다. 고형시료의 분석은 고효율 필터가 부착된 후드 내에서 입체현미경을 이용하여 전처리 과정을 거쳐 편광현미경으로 분석하였으며, 분석결과가 함유율 1% 초과인 경우에 석면함유물질(Asbestos-Containing Materials, ACMs)을 석면으로 규정하였다. 석면건축자재의 위해성 평가 방법 및 기준은 “환경부고시 제2016-230호 석면건축물의 위해성 평가 방법”을 참고하여 석면함유물질에 노출된 위해성 등급은 세 가지 단계(높음, 중간, 낮음)로 평가하였다.

Results: 건축물 100개소 중 30개소, 고형시료 416개 중 36개(8.6%)에서 석면함유물질이 있는 것으로 나타났다. 1990년대에 지어진 건축물 42개 중 18개에서 석면이 높은 비율로 검출되었으며, 2000년대에 지어진 건물 44개 중 7개에서 가장 낮은 비율로 검출되었다. “환경부고시 제2016-230호 석면건축물의 위해성 평가 방법”에 따라 평가를 실시한 결과, 2개 건축자재의 위해성평가 등급은 “중간”으로 나타났으며, 28개의 건축자재는 “낮음” 으로 나타났다.

Conclusion: 석면은 정부에 의해 규제되고 있어 적극적으로 관리를 하여야 하고, 다양한 상황에서 얻은 데이터가 뒷받침하는 석면 노출 위해성 평가방법을 도입하여 시행이 필요할 것이다. 개인이 소유하고 있는 건물의 경우 건축주가 석면 노출의 위해성을 인지하고 있어야 할 것이다.

Key words: 석면, 석면함유물질, 건축자재, 건축주, 위해성평가

I. Introduction

Asbestos can be categorized into six mineral types (chrysotile, amosite, crocidolite, anthophyllite, actinolite, and tremolite) in two mineralogical classes of serpentines and amphiboles. Chrysotile is the only serpentine mineral and accounts for 95% of the total asbestos used commercially. Asbestos has been classified as a carcinogen because its inhalation can cause diseases in humans, such as malignant mesothelioma and lung cancer (Lee et al., 2014).

Asbestos has been widely used around the world, including in South Korea, primarily as chrysotile cement for roofing and ceiling materials, wall materials, floor materials, partitions, boiler pipes, gaskets, and other construction materials(Nam et al., 2015). It is recognized as being extremely cancerous, however, and is currently considered one of the most important toxic wastes that have to be remediated in most countries and by National Institute for Occupational Safety and Health(NIOSH) and Occupational Safety and Health Administration(OSHA) of World Health Organization(WHO) under the International Agency for Research on Cancer(IARC) (Beard, 1999; Karadagli, 2011). The asbestos-containing materials(ACMS) that are in place in buildings are currently health threats for the maintenance and construction workers(Dumortier & De Vuyst, 2011). The asbestos types were classified as Class 1 carcinogens in 1986(IARC, 1987). Occupational exposure to asbestos can cause four types of disorders: asbestosis; lung cancer; mesotheliomas of the pleura, pericardium, and peritoneum; and benign changes in the pleura(Mossman et al., 1990). Asbestosis, a pulmonary interstitial fibrosis with excessive deposition of collagen, caused progressive lung stiffening, impaired gas exchange, disability, and death in many workers who had been exposed to asbestos before the enforcement of occupational standards. Lung cancers－i.e., tumors arising in the tracheobronchial or alveolar epithelial cells－have occurred in asbestos workers, in most cases 20 or more years after their first exposure to asbestos. In general, lung cancers have been found in asbestos workers who are smokers, and only rarely in non-smokers(Saracci, 1987). Asbestos-containing floor tiles and mastic have been identified by regulatory agencies as hazardous materials. They are commonly used building components in the U.S(Lange, 2005). The WHO 1986 report notes that at that time, “the second largest industry”(WHO, 2002). Regulatory agencies have identified floor tiles as hazardous materials, and require special precautions in their removal or installation(Lange & Thomulka, 2000). In South Korea, asbestos has been imported since the 1960s, with the highest record of import(95,000 metric tons) in 1992; since then, however, its use has been continuously declining(Kim et al., 2009). The asbestos hazards have been studied, and the government has pursued “Comprehensive Measures for

Asbestos Management" jointly with the related departments. As a part of the plan, the Ministry of Environment is to introduce the legislation Asbestos Safety Management Act through Environment Announcement No. 2010-108 (Kim et al., 2011).

In the case of South Korea, it had a higher use of building containing asbestos building materials from the 1970s. In the late 1970s, however, concerns were raised about the significance of asbestos in buildings (Lee & Van Orden, 2008). Since recently, in the repair or remodeling of the existing buildings, it has become necessary to take measures to prevent the scattering of asbestos. There have been many studies on school or public buildings, but there has been less research on privately owned buildings. Research on privately owned buildings is required. In this study, the year of construction of the building and the ownership type(for management) of the building were made the bases of the investigation that was conducted to confirm the features of ACMs and the risk of exposure to them.

Ⅱ. Research and Methods

1. Sampling and Analysis of Asbestos

1) Investigation of asbestos-containing materials(ACMs)

The investigation was conducted by asbestos analysts according to the asbestos analysis and quality control rule and the samples taken from the buildings were sorted by homogeneous area. The homogeneous areas were classified based on the similar visible properties and textures, and the analysts took samples of the suspected ACMs within the homogeneous areas(Figure 1). The samples were defined as ACMs if they contained more than 1% asbestos.

The typical building materials that were suspected to be ACMs were the ceiling tiles, ceiling panels, wall panels, floor tiles, calking materials for window cracks, pipe insulations if there was a boiler room, joints, gaskets, patches, etc(Figure 2).

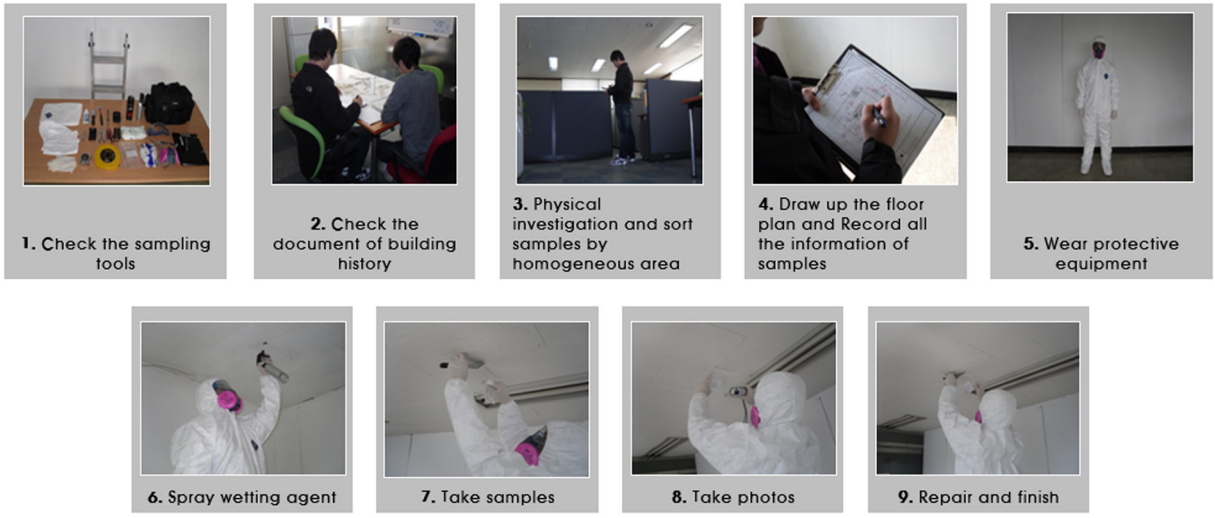

Figure 1. Sampling Process

Figure 2. Onsite investigation

2) Analysis of the samples

The asbestos analysis was done by asbestos analysts who had completed the asbestos analyst training conducted by Korea Occupational Safety and Health Agency. The samples were pre-processed with stereomicroscope in a hood with an HEPA(High efficiency particulate air) filter, and were analyzed with a polarizing microscope according to the analysis method of bulk samples for the asbestos sampling of buildings(Article 38-2 of the Occupation Safety and Health Act, and Article 80-5 of the same act's enforcement regulations).

3) Risk assessment of ACMs

The analysis assessed the samples according to the Risk Assessment Standard for ACMs presented by the Ministry of Environment(Ministry of Environment Notice No. 2016-230). They categorized the samples into four different categories, and each category had detailed evaluation items.

- Physical assessment(score: 0-3)

The physical assessment was evaluated based on three items: damage condition, scattering condition, asbestos content

- Potential possibility of damage due to vibration, airflow or water leakage(score: 0-2)

ACMs have the potential to be damaged by environmental effects like the location of the building, the installation locations of facilities, and the vibration, airflow, or water leakage. The vibration, airflow, and water leakage were determined to environmental factors and were evaluated by factor.

- Possibility of damage due to the building maintenance (score: 0-3)

The possibility of asbestos scattering due to the building maintenance was evaluated.

- Possibility of human exposure assessment(score: 0-2)

The possibility of human exposure to ACMs was evaluated by category, such as by the number of residents, the frequency of use, and the average usage hours.

- Rating the risk of ACMs exposure

The risk of ACMs exposure was rated by giving a score for above four categories. Each category required action.

Table 1. ACM exposure risk scores

Rate of the risk	Score
High	20 or more
Middle	Between 12 and 19
Low	11 or less

Ⅲ. Results and Discussion

1. Condition of the subjected building and number of samples

The buildings were categorized year, and the exact building year was confirmed by the building register document. The building year categories were the 1970s, 1980s, 1990s, and 2000s, and the numbers were 3, 11, 42, and 44, respectively. The number of buildings built after the 1990s was more than 85% of the total number of buildings. The buildings were categorized into four types: isolated building, attached building, apartment,

Table 2. Numbers of buildings by building year and type

Category	Isolated		Attached		Apartment		Villa		Total	
	Private	State-owned	Private	State-owned	Private	State-owned	Private	State-owned	Private	State-owned
1970s	-		3	0/3	-		-		3	0/3
1980s	5	4/1	3	2/1	2	2/0	1	1/0	11	9/2
1990s	17	14/3	13	8/5	10	10/0	2	1/1	42	33/9
2000s	11	8/3	15	10/5	18	16/2	-		44	34/10
Total	33	26/7	34	20/14	30	28/2	3	2/1	100	76/24

and villa. These types were confirmed by building documents and the facility officials(Table 2).

2. Sampling bulk samples

The number of bulk samples suspected of containing asbestos was 416, and only the buildings that contained asbestos were subjected to risk assessment(Table 3). The numbers of samples of constructed buildings by building year and type were as follow: 302 of the 416 samples (72% of the total samples) were taken from among the private buildings, and 114 samples(28% of the total samples) were taken from among the state-owned buildings. Also, 346 samples(84% of the total samples) were taken from the buildings that had been built in the 1990s and 2000s.

The same numbers of building material type samples were taken from the ceiling and the floor, and 166 samples(39% of the total samples) were taken from the floor materials. Also, samples were taken from the outside of the buildings, such as the slates(Table 4).

Table 3. Samples categorized by building year and ownership/ building type

Category	1970s	1980s	1990s	2000s	Total
Ownership					
Private	0	48	118	136	302
State-owned	14	8	59	33	114
Building type					
Isolated	-	31	75	46	152
Attached	14	15	65	64	158
Apartment	-	6	34	59	99
Villa	-	4	3	-	7
Total	14 (3%)	56 (13%)	177 (43%)	169 (41%)	416 (100%)

Table 4. Samples categorized by building year and building material type

Category	1970s	1980s	1990s	2000s	Total
Ceiling materials	3	17	62	55	137(32%)
Wall materials	5	14	42	47	108(26%)
Floor materials	6	24	70	66	166(39%)
Roofing materials	-	1	-	-	1(0.2%)
Gaskets	-	-	-	1	1(0.2%)
Partitions	-	-	3	-	3(0.7%)
Total	14 (3%)	56 (13%)	177 (43%)	169 (41%)	416 (100%)

3. Results of the bulk sample assessment

Twenty-nine office buildings in Seoul, 20 in Incheon, and 51 in Gyeonggi were analyzed. The buildings were categorized as private and state-owned, and the numbers were 76 and 24, respectively. Thirty of the 100 buildings had ACMs, and 15 buildings in Gyeonggi had ACMs, the largest number by region. Seven of the 20 buildings in Incheon had ACMs, accounting for 35% of the buildings in the province, the largest rate(Table 5).

Table 5. Detection results by number of buildings categorized by ownership and region

Category	Private	State-owned	Total
Seoul	4/21	4/8	8/29
Incheon	6/15	1/5	7/20
Gyeonggi	10/40	5/11	15/51
Total	20/76	10/24	30/100

Asbestos was detected in 18 of the 42 buildings that had been built in the 1990s, with the highest detection rate, and also in 7 of the 44 buildings that had been built in the 2000s, with the lowest detection rate.

Asbestos was detected in 4 of the 15 attached buildings, and also in two isolated buildings and one apartment. No asbestos was detected in the villas(Table 6).

Table 6. Detection results by building year and ownership /building type

Category	1970s	1980s	1990s	2000s	Total
Ownership					
Private	-	3/9	10/31	7/36	20/76
State-owned	1/3	1/2	8/11	0/8	10/24
Building type					
Isolated	-	2/5	5/17	2/11	9/33(27%)
Attached	1/3	2/3	10/13	4/15	17/34(50%)
Apartment	-	0/2	3/10	1/18	4/30(13%)
Villa	-	0/1	0/2	-	0/3(-%)
Total	1/3 (33%)	4/11 (34%)	18/42 (43%)	7/44 (16%)	30/100 (30%)

Table 7. Detection results by building and material type

Category	Ceiling materials	Wall materials	Floor materials	Roofing materials	Gaskets	Partitions
Isolated	7	1	-	1	-	1
Attached	18	1	-	-	1	1
Apartment	3	-	-	-	-	1
Villa	-	-	-	-	-	-
Total	28/137 (20%)	2/108 (2%)	0/166 (0%)	1/1 (100%)	1/1 (100%)	3/3 (100%)

The building materials were categorized by building type, and asbestos was detected in 28 of the 137 ceiling material samples taken from the attached buildings, with the largest detection rate. It was detected in one slate roofing material from an isolated buildings, and in one gasket from an attached building. No asbestos was detected in the floor materials(Table 7).

The asbestos type was categorized by building year and type, as shown in Table 8. Chrysotile was detected in 36 samples, and amosite in 5 samples, taken from the buildings that had been built in the 1980s. In another study, 72 bulk samples of suspected ACMs were found in 15 schools(elementary, middle, and high schools), and 2-5% chrysotile and 2-3% amosite were found in 60 textile ceilings(Nam et al., 2015). Chrysotile is the only serpentine mineral and is the most common asbestos variety(Nicholson, 1991). Chrysotile Institute distinguishes between the chrysotile and amphibole forms of asbestos, contending that the former is not very dangerous and can be safely used(Burki, 2010). Chrysotile accounts for over 95% of the world production, and is being exploited in more than 40 countries. The most important products based on chrysotile fibers are asbestos cement(AC) sheets, AC pipes, vinyl asbestos floor tiles, brake linings and clutch facings, thermal and electrical insulation boards, asbestos textiles, asbestos ropes, asbestos paper and felt, etc(Bhagia et al., 2010). In an old buildings, however, there is a greater risk of exposure due to the damage to the ACMs.

The samples were categorized by type, as shown in Table 9. Overall, asbestos was detected in 35 of the 416 samples, and the detection rate was 8%. It was detected in 28 of the 137 samples taken from the ceilings, with

Table 8. Types of asbestos detected in buildings

Category	Isolated		Attached		Apartment		Villa		Total
	Chrysotile	Amosite	Chrysotile	Amosite	Chrysotile	Amosite	Chrysotile	Amosite	
1970s	-	-	1	-	-	-	-	-	1
1980s	2	-	6	5	-	-	-	-	13
1990s	4	-	13	-	2	-	-	-	19
2000s	2	-	5	-	1	-	-	-	8
Total	8	-	25	5	3	-	-	-	41

Table 9. Types and contents of asbestos detected in the buildings

Category	No. of samples	No. of asbestos-detected samples	Rate of asbestos detected in the sample	Asbestos type/content
Ceiling materials	137	28	20%	Chrysotile 2-7% Amosite 1-4%
Floor materials	166	0	0%	ND*
Wall materials	108	2	1.85%	Chrysotile 5-8%
Gaskets	1	1	100%	Chrysotile 15%
Roofing materials	1	1	100%	Chrysotile 10%
Partitions	3	3	100%	Chrysotile 8%
Total	416	35	8.4%	Chrysotile 2-15% Amosite 1-4%

* ND : None Detected

the largest detection rate. This result was caused by the use of textile and cement boards. It was also found in one cement slate roof. Another study confirmed and quantified asbestos fibers released from asbestos-cement slate roofs due to weathering, and three houses selected based on the building year(1960s, 1970s, and 1980s) were investigated. The ranges of the asbestos fibers that were counted from the samples collected in the buildings built in the 1960s, 1970s, and 1980s were 10,406.3-55,575.6, 5,218.8-38,126.2, and 2,906.3-7,798.6 f/L, respectively. This means that weathering can be a significant factor in the release of asbestos fibers from the asbestos cement products(Kim, 2010). In this study, no asbestos was detected in the floor materials. It is guessed that the frequent change of the floor materials caused this result.

4. Risk assessment of ACMs

ACMs exposure risk assessment was conducted in used buildings. Two of 30 private and state-owned buildings were evaluated as middle grade. The score details are shown in Table 10. According to the Risk Assessment Standard for ACMs presented by the Ministry of Environment, ACM exposure risk assessment was conducted. The riskiness was also assessed based on four different categories. The total score of each category was the assessment score of the building materials.

Table 10. Risk assessment scores

Category	Private	State-owned	Total
High (20 or more)	-	-	-
Middle (12-19)	2	-	2
Low (11 or less)	18	10	28
Total	20	10	30

Ⅳ. Conclusion

The presence of asbestos in buildings does not mean that the people who reside in or are the users of such buildings have higher health risks due to their exposure to asbestos than those who live in buildings where there is no asbestos. If the building materials to be used will be managed in any place quantitatively and safely, the health risk from exposure to asbestos will be reduced. Now is the time for actively managing asbestos in South Korea, and an asbestos exposure risk assessment method supported by the data from various situations should be introduced and implemented. In particular, the management of asbestos should be a priority in the case of buildings with ACMs where children and adolescents reside. The results of the sampling of bulk samples from the buildings are shown below.

1. In this study, 30 of the 100 offices were found to possibly have ACMs, and 35 of the 416 bulk samples (8.4%) were found to have had asbestos.

2. By building year, asbestos was detected in 18 of the 42 buildings built in the 1990s, with the highest detection rate.

3. By building type, asbestos was detected in 17 of the 34 attached buildings, and in two isolated buildings and one apartment. No asbestos was detected in the villas.

4. It was also detected in 28 of the 137 samples taken from the ceilings.

5. By asbestos type, chrysotile was detected in 36 samples, and amosite in 5 samples.

6. By building material type, asbestos was detected in 28 the 137 ceiling material samples from attached buildings, the largest detection rate. It was also detected in one slate roofing material from an isolated buildings, and in one gasket from an attached buildings. It was not detected in the floor materials.

7. Asbestos was detected in 30 of the 100 samples of possible ACMs, and two of the samples got the grade “middle-higher chance of potential damage” while 28 got the grade “low-lower change of potential damage.”

By ownership type, the private building owners need to have a correct understanding of the dangers of asbestos exposure, and that an awareness campaign about the riskiness of asbestos of asbestos is required. Based on the results of this study, it is considered that there is a need to control each building material type. Asbestos is currently being regulated by the government in South Korea. The national and public buildings, including the

schools built with asbestos, are being managed well by the government. In the case of the privately owned buildings, the owners should be aware of the dangers of asbestos exposure.

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