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Comparison of Risk Assessment Criteria and Distribution of Asbestos-Containing Materials in School Building

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ABSTRACT: We investigated the distribution of Asbestos containing materials(ACMs) in Korea for 15 school buildings built before and after 1990, including elementary schools, middle schools and high schools. In order to perform risk assessments of samples gathered from the buildings, the study used four different rules as the criteria: results from the AHERA rule, the HSE rule and the ASTM rule on ACMs were measured against the available risk assessment of asbestos in Korea, a rule was proposed based on schools environment and background. In the ACMs aging of the samples before 1990, chrysotile and amosite in the ceiling samples were detected 2-5 % and 2-3 %, respectively. Overall, a higher detection rates was found in samples emanating in baum light (chrysotile 5-8 %) used in a cubicle partition in the bathroom more than ceiling samples (chrysotile 2-5 %) taken from classrooms. As a result of air samples of asbestos, most of the samples had concentration levels below of Indoor Air Quality Management Standards (0.01 fiber/cc), except for two samples in the kindergarten and elementary school. Risk assessment and evaluation of ACMs indicated the similar results in AHERA rule, HSG264 rule and ASTM rule and proposed the new assessment(available risk assessment of asbestos in Korea) was made based on the Korea background.

Key words: Asbestos, Risk assessment, ACMs (Asbestos-Containing Materials), Chrysotile, Amosite

INTRODUCTION

Asbestos is a natural mineral of the form of fibers, which was changed serpentine and amphibole; it has excellent properties of chemical resistance such as non-flammable and abrasion resistance, insulation, sound absorption, thermal insulation, corrosion resistance (Beard and Rook, 2000; Lange, 2001; Williams and Crossman, 2003; Gens *et al.*, 2014). Asbestos has been widely used around the world, including Korea, primarily as roofing and ceiling materials, flooring, partitions, boiler insulation, automotive gaskets and other construction, from the manufacture of cars worth more than 3,000 kinds of products in industry (Daya and David, 2003; Williams and Crossman, 2003; Roh *et al.*, 2007; Karadagli, 2011; Youn, 2011).

Asbestos particles of about 0.1 ~ 10 µm poly filamentous structure have a length and structure that is easily deposited in the lungs through the respiratory tract (Youn, 2011). In particular, they can be particles more than 8 µm length, with a diameter particle size of less than 0.25 µm are primarily related to the incidence of respiratory diseases (Ronald and Samuel; Wagner *et al.*, 1960; Selikoff, 1991; Van Orden *et al.*, 2008; Karadagli, 2011). Since the 1960s, the health hazards of asbestos have been reported and many workers suffered medical conditions as a result of constant exposure to asbestos, mesothelioma, and lung cancer in Italy, England (Michael, 1997; Ilgren, 2001; Lange, 2005; Kim and Hoskins, 2010). Asbestos has a long incubation period (20 to 30 years), depending on the type of hazard characteristics of the substance and the differences. For example, crocidolite rather than chrysotile was hazardous and in case of dust entering the body, especially the organization to go through the pleura or peritoneum mesothelioma causes most death within one year of being diagnosed with a terrible disease.

Currently, any asbestos used is heavily regulated

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by law because asbestos is related to the development of cancers such as breast cancer, ovarian cancer, kidney cancer, pancreatic cancer and testicular cancer reported (Selikoff, 1991; Kane, 1993; Lange, 2005; Hwang and Lee, 2011; Shin *et al.*, 2012). National Institute for Occupational Safety and Health(NIOSH) and the Occupational Safety and Health Administration(OSHA) of the World Health Organization(WHO) under the International Agency for Research on Cancer(IARC) defined asbestos as a first-class carcinogen in 1986 (Beard and Rook, 2000; 2010; Karadagli, 2011). In case of Korea, asbestos was included in the Clean Air Conservation Act as a special toxic substances of air pollutants, in addition as specific waste management in 1991 (Weiss, 1977; 2009; Hwang and Lee, 2011; Kim, 2012). Also, the Department of Labor in Korea released asbestos-related regulations that prohibited the use of crocidolite and amosite; the Occupational Health and Safety Act in Korea also was amended to ban actinolite and anthophylite in 2003 (2009).

Therefore, in this study we investigated the distribution of ACMs and measured the asbestos content and concentrations of airborne asbestos in school buildings located in Seoul, South Korea. In addition, we analyzed the ratings of risk assessment comparing the results of the AHERA rule, HSG-264 rule and ASTM-E2356 rule and proposed the new rule for risk assessment as evaluation method applied to school buildings in Korea.

MATERIALS & METHOD

We investigated the distribution of ACMs in Korea for 15 school buildings built before and after 1990, including elementary schools, middle schools and high schools. We confirmed the history and renovation of facilities in school buildings. In addition, we examined the asbestos content and the material types of the samples on the basis of the availability of "Asbestos-containing products," used in standard presented at the Korea Occupational Safety and Health Agency. 180 suspected ACMs (PACM: Potential Asbestos Containing Materials) were collected to analyze potential ACMs such as ceiling tiles, toilet cubicle, wall materials (plasterboard) and wall finish (outer wall) in the classroom, hallways and toilet of schools. These solid samples was analyzed according to the EPA 600/ R-93/116, solid asbestos standard method, suggested by US EPA (Fig.1, 2). This standard method is the qualitative analysis by Polarized Light Microscopy(PLM) and the quantitative analysis by Stereoscopic Polarized Light Microscopy(SM) (Beard and Rook, 2000; 2010). Samples taken were defined as ACMs in case of containing more than 1% asbestos by the quantitative analysis of Stereo Polarized Light Microscopy(SM) (Beard and Rook, 2000; 2010). In this study, we classified asbestos types and calculated the weight ratio of asbestos by the EPA/600/R-93/116. Also, ACMs were analyzed as Scanning Electron Microscopy(SEM) and Transmission Electron Microscope(TEM) in order to ensure the reliability of the analysis.

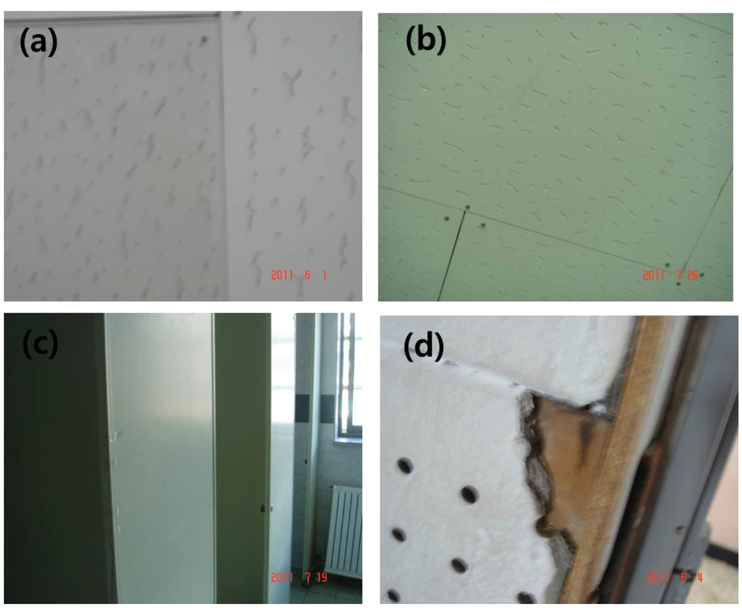

Fig. 1. ACMs in ceiling in a elementary school building (a): Textile ceiling(Chrysotile 2%, Amosite 5%) (b): ceiling of classroom in the elementary school (Chrysotile 5%) (c): partition of toilet in the elementary school (Baum lite, chrysotile 8%) (d):wall finish in the high school

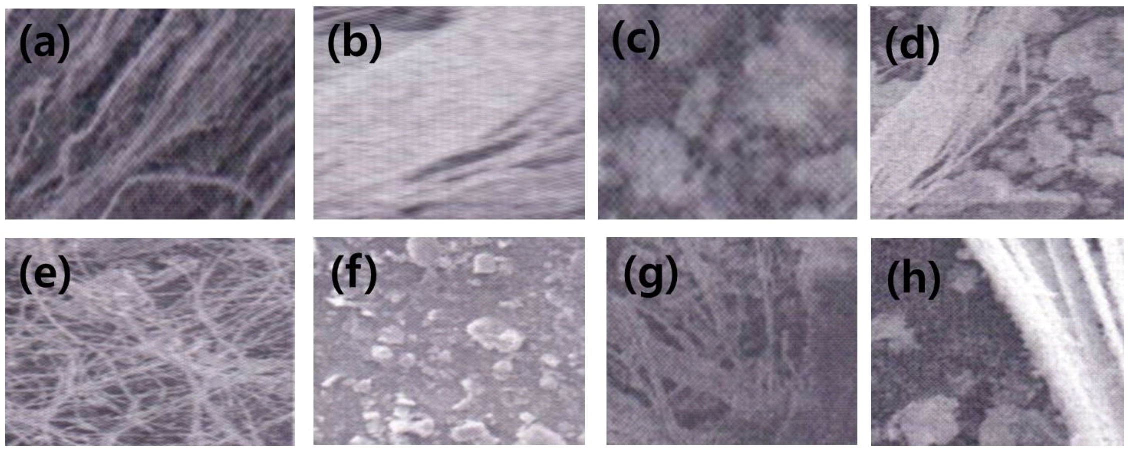

Fig. 2. SEM images for ACMs in schools. ((a), (b): ceiling in the classroom, (c) : celling in dining room, (d): ceiling in the corridor, (e): wall materials, (f): tile in floors in schools, (g): wall finish, (h): duct insulation)

Sampling was conducted in the center of the indoor facilities; this site was chosen in order to ensure no change in wind or air flow in the room and conducted air trapping method at the air a flow rate of 1,200 L / min considering the dust concentration. Z-UTE-IAQ-DC pump (USA) was used for the sampling of airborne asbestos in classrooms. We measured samples accordance with the indoor air quality standard of "Indoor Air how to measure the concentration of asbestos dust and fiber-phase microscopy" by Korea ES 02303.1(Notice of Ministry of Environment No. 2010-24).

Samples were conducted transparency accordance with aceton/triacetin method then expressed as fiber/cc of fiber concentrations in magnification of 400 times by PCM(Phase Contrast Microscopy) inserted into the Walton-Beckett eyepiece graticule (Crump *et al.*, 1991; Lange, 1999; Lange, 2001). In addition, according to standards of NIOSH and OSHA, airborne asbestos was counted as asbestos fiber when sample has the length of over 5 µm and ratio of at least 3:1 in diameter by NIOISH 7400 (NIOSH, 1994).

This assessment rule shows suspected ACMs were evaluated as: current condition, vibration identified by visual inspection, and potential assessment (potential for disturbance, potential contact, potential for air erosion) (Table 1). In addition, the physical assessment of suspected ACMs was evaluated as damaged friable surfacing ACMs, which crashed if we press by hand.

The extent of damage was evaluated as: Significantly Damaged if 1/10 or more damaged, Damaged if less 1/10 damaged, or and Good if there was no damage or wearing only very localized by insulation, surface materials, and other suspicious materials.

The evaluation of potential exposure was conducted by items for the following categories: detail potential for disturbance, potential for air erosion, and frequency of potential contact any of the items 'high' if the final grade to high, and 'high' in the absence of 'normal' if there are any final assessment rating 'Normal', and all three factors are 'low' when the final ratings have been assessed as 'low'. We classified step 7 as a rating these can be divided into three steps such as Significantly Damaged (rank #1), Damaged (rank #2~#4) and Good (rank #5~#7). This evaluation method is simple and applicable to strict standards when building management integration can be managed in a systematic but asbestos investigator and may reflect the subjective opinion of a probability, there may be overestimated (EPA, 1987).

The HSG264 rule was divided into four phases as assessment of the product form, the extent of damage, surface treatment, and depending on type. The priority of administration was decided to the sum of evaluation values after evaluating the possibility whether ACMs is disturbed by operators and residents or not (HSE, 2010). In this study, it was graded as Significantly Damaged, Damaged and Good as more than 10 value, 5~9 value and less 4 value, respectively (Table 3). This evaluation was on the asbestos and ACM particles can be discharged easily to the air and was classified three group such as Significantly Damaged, Damaged and Good including to the damage group as step 2 and 3.

Suspected ACMs were assessed the extent of damage and the exposure potential evaluation during the investigation for possibility of asbestos scattering. Assessment of the state of damage ASTM methods were classified into three groups, and poor group was evaluated as large of damaged surface if exposed to a lot of dust, fair group was evaluated as the damaged

Table 1. Hazard/Risk assessment grade evaluated using standards of AHERA and ASTM

Evaluation Criteria	Classification	
	AHERA	ASTM
Current condition	High, Moderate, Low	Qualitative Ranking : Good, Fair, Poor Numerical Rating : 8~10, 4~7, 1~3 Qualitative Ranking : Low, Medium, High Numerical Rating : 1~3, 4~7, 8~10
Vibration identified by visual inspection	High, Moderate, Low	
Potential for disturbance	SD*, Damage, Good	Physical disturbance : Acc**, Act***, Vib*** Environmental disturbance : air/dust, corrosive, water damage
Potential for air erosion	High, Moderate, Low	
Frequency of potential contact	High, Moderate, Low	

SD*: Significant Damage, Acc**: Accessibility, Act***: Activities, Vib***: Vibration

Table 2. Categories of physical assessment determined by EPA's AHERA rule

Physical Assessment categories
1) Damaged or significantly damaged thermal system insulation ACBM
2) Damaged friable surfacing ACBM
3) Significantly damaged friable surfacing ACBM
4) Damaged or significantly damaged friable miscellaneous ACBM
5) ACBM with potential for damage
6) ACBM with potential for significant damage
7) Any remaining friable ACBM or friable suspected ACBM

Table 3. Material assessment algorithm in HSG264

Sample variable	Score	Example of scores
Product type (or debris from product)	1	Asbestos-reinforced composites (plastics, resins, mastics, roofing felts, vinyl floor tiles, semi-rigid paints or decorative finishes, asbestos cement etc.).
	2	AIB, millboards, other low-density insulation boards, asbestos textiles, gaskets, ropes and woven textiles, asbestos paper and felt.
	3	Thermal insulation (eg pipe and boiler lagging), sprayed asbestos, loose asbestos, asbestos mattresses and packing.
Extent of damage /deterioration	0	Good condition: no visible damage.
	1	Low damage: a few scratches or surface marks, broken edges on boards, tiles etc.
	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres.
	3	High damage or delamination of materials, sprays and thermal insulation. Visible asbestos debris.
Surface treatment	0	Composite materials containing asbestos: reinforced plastics, resins, vinyl tiles
	1	Enclosed sprays and lagging, AIB(with exposed face painted or encapsulated) asbestos cement sheets etc.
	2	Unsealed AIB, or encapsulated lagging and sprays.
	3	Unsealed lagging and sprays.
Asbestos type	1	Chrysotile.
	2	Amphibole asbestos excluding crocidolite
	3	Crocidolite
Total		

Table 4. Comparison of grades of risk assessment assessed by standards of AHERA, ASTM and HSG264

AHERA	HSG264			ASTM	
Significant Damage	Hazard rank #1	= 10	Highly Likely to release asbestos into the air	Poor	Numerical Rating 1,2,3 Qualitative Ranking High
Damage	Hazard rank #2-#4	7-9 5-6	Likely to release asbestos into the air Unlikely to release asbestos into the air	Fair	Numerical Rating 4,5,6,7 Qualitative Ranking Medium
Good	Hazard rank #5-#7	= 4	Highly unlikely to release asbestos into the air	Good	Numerical Rating 8,9,10 Qualitative Ranking Low

surface observed, but not much, good group was evaluated as no observation of damaged surface area or minimal damaged (EPA, 2004). Results of exposure evaluation were conducted to determine whether the grade of the building can be managed (EPA, 1982). The rating which High (8-10), Average (4-7) and Low (1-3) groups were divided indicates three degrees of evaluation on accessibility and physical activity of human, vibration of environmental disturbance, air corrosion and water damage due to flooding conditions affect in the building materials.

RESULTS & DISCUSSION

There were 72 solid samples of suspected ACMs in 15 schools including elementary schools, middle schools and high schools were analyzed 2-5 % chrysotile and 2-3% amosite in 60 textile ceilings (Table 5). Chrysotile was contained from 5% to 8% in the baum light material of toilet cubicle, but asbestos was not detected in case of floor tiles of schools. Ceiling with textiles and gypsum board showed mainly in location-specific detection rate. All ACMs samples of old schools which constructed before 1990s were detected asbestos but, no detected in school buildings constructed after 1990s. Thus, it is necessary investigate the distribution of ACMs by the annual research distinguished before and after the 1990s in the case of a school building in Korea. It will be considered to be needed management more than any other buildings ACMs was mainly used in schools including to the ceiling in the case of school buildings built before the 1990s. Suspected ACMs examined in some high school built since 2000 did not detect by using eco-friendly materials and substitute of asbestos was performed recently for remodelling in the ceiling materials. Thus, in buildings of no-asbestos containing materials before 1990 because there is no textile in the ceiling, so we need more care than other school buildings considered.

Schools have emerged as a key source of asbestos contamination. Asbestos-Containing Materials(ACMs) were found about 75% in 336 Vermont schools constructed or renovated between 1946 and 1976 (Lloyd *et al.*, 1981). For schools with asbestos-containing ceiling tiles, educational officials were advised that vandalism, strong air currents, and movement of the tiles can contribute to concentrations of airborne asbestos. A total of 473 air samples taken from 71 schools scheduled for abatement (328 indoor static samples, 51 personal samples, and 94 outdoor samples) were analyzed by transmission electron microscopy(TEM) techniques(Crump *et al.*, 1991).

Airborne asbestos concentrations were significantly similar in different types of schools (high, intermediate or elementary), or in schools constructed in different time periods (Lloyd *et al.*, 1981; Crump *et al.*, 1991; Kim and Hoskins, 2010) . A study reported that the level of ACMs were investigated in elementary school buildings and public buildings of Korea; ACMs were found in 88.3% of elementary school building and 75% of public buildings (Hwang and Lee, 2011; Kim, 2012). It is extremely important to identify the status of ACMs used in schools considering the characteristics of construction years when use of asbestos was many (87.4 %) of the property before 1990s (SMOE, 2010). The types of ACMs in schools represented as TEM images showed chrysotile,

Table 5. Measurement of suspected ACMs in school buildings

Location	Samples	Detection materials of asbestos	Asbestos
Classroom	5	Ceiling textile	Not detected
Classroom	6	Ceiling textile	Chrysotile 2%, Amosite 2%
Classroom	7	Ceiling textile	Chrysotile 2%, Actinolite 2%
Classroom	7	Ceiling textile	Chrysotile 5%
Corridor	7	Ceiling textile	Chrysotile 2%
Corridor	5	Ceiling textile	Not detected
Corridor	6	Ceiling textile	Chrysotile 2%
Dining room	6	Ceiling textile	Chrysotile 5%, Amosite 3%
Dining room	5	Ceiling textile	Chrysotile 3%
Gym	4	Ceiling textile	Not detected
Auditorium	2	Ceiling textile	Chrysotile 4%
Gym	6	Wall material	Not detected
Music classroom	10	Wall	Chrysotile 5%
Student toilet	20	Baumlite	Chrysotile 5%
Student toilet	11	Baumlite	Chrysotile 8%
Floor	16	Tile	Not detected

actinolite and tremolite (Fig. 3). It is also important to analyze the type of asbestos because of differences in standards on the exposure and hazarous/risk. ACMs samples represented as SEM images show ceiling in the classrooms and corridors, wall, boiler insulation, duct heating pipe lines insulation tile in schools (Fig. 2).

The possibility of asbestos air exposure of ACMs was examined in 16 schools by PCM analysis (Table 6). Samples exceed the asbestos standards showed 28.5 % in the detection rate as showing the detection of two samples in 7 elementary schools. Comprehensive asbestos in air samples showed a detection rate of 13.3 % in all schools.

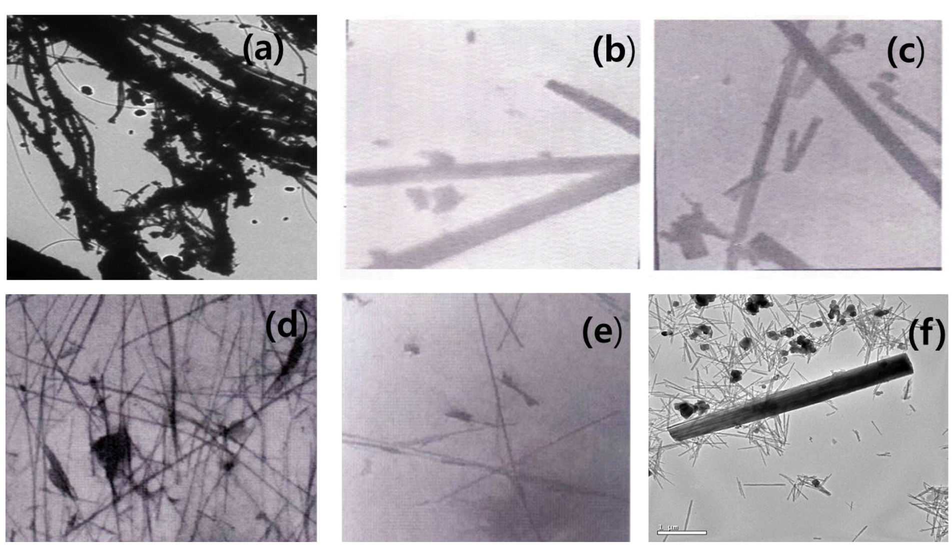

Fig. 3. TEM images for ACMs in schools. (a): chrysotile, (b): actinolite (c): tremolite, (d): 2% chrysotile (e): 5% chrysotile (f): tremolite

Table 6. Concentrations of airborne asbestos based on ACMs (Asbestos Containing Materials) measurements. (A: elementary school, B: middle school, C: high school)

Location	Samples	Concentration (fiber/cc)
A1	3	0.003
A2	2	0.021
B1	7	0.002
B2	1	0.003
B3	6	0.008
B4	1	0.008
C	5	0.002
C	4	0.003

Fig. 4 shows the risk assessment of 150 samples in suspected ACMs represented under different criteria of the AHERA rule, the HSG-264 rule and the ASTM rule. The rating categories used were: Significantly Damaged, Damaged, and Good. In general, risk assessment and management priorities of ACMs can be determined as risk assessment and management priorities as a function of the extent of damage, accessibility, and the scattering of asbestos, rather than merely the types and content of ACMs (Beard and Rook, 2000). The ranking classification was conducted on only three levels, compared to the seven step of the AHERA rule compared to the other rules (e.g., HSG-264 and ASTM rule.) The result of the risk assessment of ACMs according to AHERA rule demonstrated that samples were classified as 67 % Good, 21 % Damaged and 11 % Significantly Damaged. This rule reflects the possibility of contact with air, accessibility and the vibration by the current status of ACMs even though there was the subjective opinion of samplers.

The HSG-264 risk assessment resulted in a ranking of 85 % Good, 11 % Damaged and 5 % Significantly Damaged. Compared with the other rules used in this study, this risk assessment will be added distinct items of the forms and types of asbestos and items related to visible damage and surfacing were reflected in this assessment, even though similar results were showed in most schools,. For this reason, the number of samples evaluated as “Damaged” were less likely for this rule compared to the others.

Using the ASTM criteria, the samples were rated as: 57 % Good, 28 % Damaged and 15 % Significantly Damaged. For this rule, Good levels were lower compared to other rules; samples rated as Damaged or had Significantly Damaged rating were higher than other two rules due to reflection of the current status and the possibility of potential damage.

The ARAK rating of risk assessment showed that samples were classified as 58 % Good, 37 % Damaged and 5 % Significantly Damaged. The results of this assessment reflected that environmental factors of

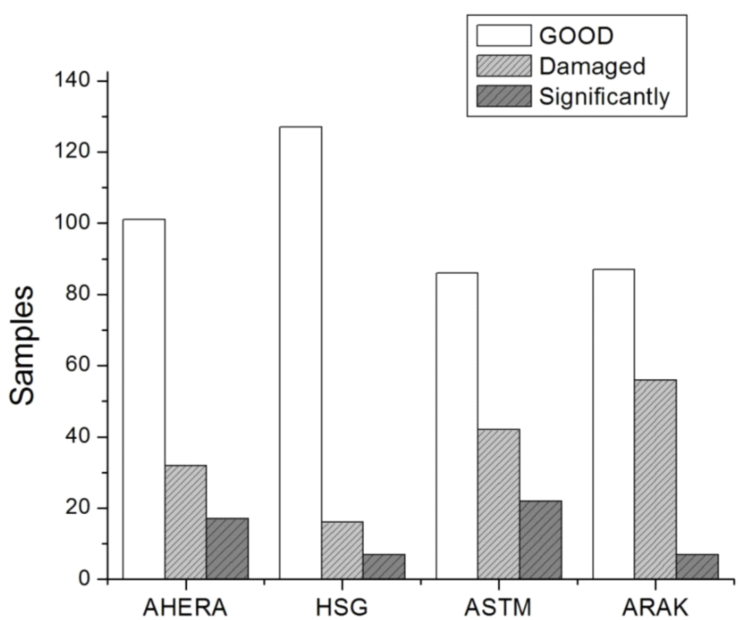

Fig. 4. Comparison of rating scales for the ACMs using risk assessment of the AHERA, HSG264, ASTM and ARAK in schools buildings. (Significantly: Significantly Damaged)

schools would be more effectively and easily managed based on the AHERA-40 CFR rule and ASTM rule. The list management of the available risk assessment of asbestos in Korea is presented in Fig. 4. Asbestos was used in many buildings of all schools in the country built before the 1990s. The assessment list showed numerically according to evaluation of before and after year of construction 1990, the environmental factors and calculated values accordance with used area of suspected ACMs (Table 7).

The available risk assessment of asbestos in Korea classifies samples into a total score based on five different categories: Good as 5th grade (less than 20 points), needs management as 4th grade (21-30 points), periodic management as 3rd grade (31-40 points), required realistically management as 2nd grade (41-50 points) and 1st grade (51 points or more) which is deemed necessary as fully management through renovations and demolition work in school buildings (Table 8).

Table 7. Rating factors for the available risk assessment of asbestos in Korea

Classification	High-Risk (8-10 point)	Middle-Risk (4-7 point)	Low-Risk (1-3 point)
Construction year		1961-1970 (4point) 1951-1960 (5point)	1991-2000(1point) 1981-1990 (2point) 1971-1980 (3point)
Degree of scattering of asbestos	High	Middle	Low
Degree of damage to asbestos materials	Over 20% of total areas	11-20% of total areas	0-10% of total areas
Spatial extent of asbestos use	High	Middle	Low
Space area	$< 25m^2$	$25\text{-}50m^2$	$> 50m^2$
Form of asbestos	Crocidolite	Amosite	Chrysotile
Vibration factors	High	Middle	Low
Air flow	High	Middle	Low
Management system	High	Middle	Low

Table 8. Result of asbestos risk assessment reflected environmental factors in Korea. (A : elementary school, B: middle school, C: high school)

School	Degree of scattering of asbestos	Degree of damage to asbestos materisls	Spatial extent of asbestos use	Space area	Form of asbest-os	Vibration factors	Air flow	Manag-ement system
A1	2	1	3	3	0	1	2	3
A2	1	1	3	3	6	1	1	3
A3	2	2	5	6	4	1	2	3
A4	3	7	4	4	3	1	3	5
A5	4	6	4	4	4	1	4	7
A6	2	3	5	6	4	2	2	5
A7	1	7	4	4	4	1	2	5
B1	2	2	5	6	5	1	2	4
B2	3	6	5	7	3	1	3	6
B3	3	3	5	5	3	1	4	5
B4	2	3	5	6	6	1	2	5
C1	1	5	4	5	5	1	2	4
C2	2	6	5	5	4	1	2	7
C3	2	4	5	6	5	1	2	4
C4	2	1	5	5	0	1	2	2
D4	3	3	4	4	3	4	4	5

CONCLUSION

Overall, 96 suspected ACMs analyzed in 15 schools constructed before 1990 detected asbestos; there was no asbestos detected in school buildings built after 1990. Samples were analyzed mainly using ceiling gypsum and textile; the content of chrisotile was high for toilet cubicles. The results of air samples by PCM analysis appeared to exceed current asbestos criteria in one kindergarten and one elementary school. Asbestos in air samples was not detected in some schools due to the use of alternative materials and remodeling construction. In the case of Korea, the risk assessment determined by checking of the construction year to evaluate suspected ACMs were containing or not.

Compared to other assessments such as the AHERA rule, the HSG264 rule and ASTM rule, we conducted a risk assessment that reflected three different levels of asbestos damaged: Good, Damaged, and Significantly Damaged according to the current status of asbestos, potential contact with air, accessibility, vibration, potential damage and physical evaluation.

The HSE assessment is based on the AHERA rule was evaluated by the form and type of asbestos and showed the detailed assessment as giving a score for each of 12 points by material assessment algorithm. In case of ASTM assessment, risk assessment determined by the potential damage of toilet cubicle reflected itself and affect the grade point. So, the number of samples represented as good grade was less.

In this study, we propose a new evaluation available risk assessment of asbestos in Korea which was considered overall status and evaluation of asbestos in school buildings of Korea and reflected construction year of before and after 1990s, degree of asbestos scattering, degree of asbestos materials, spatial extent of asbestos use, space area and so on. This assessment showed similar results in Significantly Damaged group compared with other assessments but, less in Good group and more in Damaged group.It is possible to manage ACMs in school buildings by assessment of available risk assessment of asbestos in Korea which is deemed necessary as fully management through renovations and demolition work.

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