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Evaluating the efficiency of an asbestos stabilizer on ceiling tiles and the characteristics of the released asbestos fibers

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HIGHLIGHTS

- The efficiencies of asbestos stabilizers were evaluated for ceiling tiles.
- Asbestos concentrations decreased by 69.5–84.4% for damaged/treated ceiling tiles.
- The reliability of the factors affecting the concentration was estimated as 58.3%.
- The inorganic stabilizers were more efficient for the damaged ceiling tiles.

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ABSTRACT

The efficiency of asbestos stabilizers and their adaptability were evaluated by investigating the characteristics of asbestos fibers released from ceiling tiles. The impact of such variables as the wind speed or vibration conditions was also studied along with the asbestos stabilizers. The concentrations of the asbestos fibers released from damaged ceiling tiles treated with stabilizers decreased by 69.5–84.4% compared with those of untreated tiles for all variables, with a statistically significant difference ($p < 0.001$). The effects of the environmental factors on the asbestos concentrations were analyzed through a multiple regression analysis. It was determined that the surface status of the ceiling tiles and stabilizers were the main factors affecting the concentration, and the reliability of these factors was estimated as 58.3%. The lengths of the chrysotile fibers released from the damaged ceiling tiles were in the range of 0.991–79.1 μm for the untreated tiles and 3.74–35.6 μm for the tiles treated with inorganic stabilizers. It was confirmed that inorganic stabilizers are more efficient for damaged ceiling tiles. The results of this study also show that the asbestos concentrations are greatly reduced after treating damaged ceiling tiles with a stabilizer.

1. Introduction

Asbestos has been widely used for many decades in a large range of building products (ceiling tiles, roofing slates, wall boards, and heat insulators) and automobile products (brake linings and clutch facing) because of the many advantages such as their durability, low maintenance fees [1], resistance to heat and fire, high insulating properties [2], high mechanical strength, and low thermal conductivity [3–5]. The asbestos use in Korea gradually increased during the period of 1970 to 1995, and the total amount of usage during 1971 to 2007 was 2.1-million tons. The amounts of asbestos imported in Korea were 0.57-million tons during the 1970s, 0.62-million tons during the 1980s, and 0.7-million tons during the 1990s. About 82% of these imports were used in producing roofing slates, building inner-decorative materials, and ceiling tiles, and 96% of the roofing slates were used as building materials during the 1970s [6].

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The dangers of asbestos fibers have been reported since the 1950s. Asbestos is known to be extremely carcinogenic, especially causing severe respiratory diseases such as pulmonary asbestosis, lung cancer, and malignant mesothelioma [3,7,8]. Cancers of the intestine [9], larynx [10], breast, ovaries, kidneys [11], pancreas [12], testicles [13], and lymph nodes [14] have also been reported. In addition, collapsed lungs and pleurisy [15] have been known to occur among asbestos miners and processing workers. A dose–response relationship was reported between the occurrence of diseases and asbestos fibers [16]. Physical properties such as the thickness, length, and shape of the asbestos fibers, along with their chemical properties, are intimately related to the occurrence of lung cancer and mesothelioma [17].

Ever since the promulgation of the "Comprehensive Asbestos Management Plan" in Korea, it has been reported that 488 out of 737 public facilities use asbestos-containing materials [18]. In addition, the roofing slates in 28.9% of farming areas and fishing communities, and 13.6% of urban areas, use such materials [19]. Unlike the comprehensive regulations of asbestos management in buildings in the USA and Japan [20–22], which focus on safe and continuous usage followed by complete removal, the management status in Korea has focused solely on the dismantling and removal of asbestos.

In the USA, AHERA (Asbestos Hazard Emergency Response Act – 40CFR 763) requires local education agencies to identify friable and non-friable asbestos containing materials in schools by visually inspecting school buildings for such materials and analyzing the samples through appropriate techniques. AHERA also requires the local education agencies to submit management plans and complete their implementation in a timely fashion. In addition, local education agencies are required to conduct inspections every six months and re-inspections every three years for safe and continuous building use [21]. In addition, ASHARA (Asbestos School Hazard Abatement Reauthorization Act) regulations recommend inspecting and managing commercial and public facilities, the inspection and management of which are conducted based on the AHERA regulations. In the ASTM (American Society for Testing and Materials) guidelines, encasement and encapsulation methods are recommended for asbestos management. Testing criteria (ASTM E 1494-92) have been presented for a stabilization of the spray coating material, although they are not operated as a certification system [23].

In Japan, a certification scheme for asbestos stabilizers was enacted through the Building Standard Law by the Ministry of Land and Transportation in 2006, and regulations regarding the use of spray coating materials for the appropriate management of asbestos release are stated within the relevant acts and are currently being enforced [24–31]. Through a certification system, 39 species of asbestos stabilizers have been enrolled thus far. In Australia, performance evaluation criteria for the products used in asbestos containing slates are stated in the APAS (Australian Paint Approval Scheme) Specification 1720 [32]. In Korea, the use of asbestos stabilizers has been long considered. The Korea Institute of Construction Technology (KICT) developed inorganic asbestos stabilizers using nano-silica and alkali-ions in 2009, and has conducted research on their use [33].

Spurny [34] conducted a study to develop a method for sampling and measuring asbestos fibers from cement products and to develop the methods for studying the physical and chemical changes and carcinogenic potency of the emitted fibers. Brown and Martin [1] conducted a field and laboratory investigation to restore the weathered surfaces of asbestos cement roofing by applying biocidal washes or penetrating stabilizer systems. Brown and Angelopoulos [5] also conducted a study on developing test methods to measure the release of asbestos fibers from the surfaces of asbestos building products using nine species of stabilizers when subjected to an airstream (air erosion) or contact with a light brush (brush erosion).

A number of studies were conducted regarding asbestos treatment using a variety of methods. Thermal treatments were mostly used for the treatment of waste asbestos: transformation of asbestos to a mixture of non-hazardous silicate phases by thermal decomposition [35], thermal modification of Chrysotile asbestos by high temperature calcination [36], melting treatment of waste asbestos using mixture of hydrogen and oxygen (Brown's gas) as a fuel [37], hydrothermal conversion of Chrysotile asbestos into an anhydrous magnesium silicate using supercritical steam [38]. The behavior of antigorite dehydroxylation was examined by the experimental conditions and mineral preparation [39] and the kinetics of the dehydroxylation of Chrysotile asbestos was investigated [40]. Chemical treatments were also employed for the decomposition of Chrysotile–asbestos fibers by $CHClF_2$-decomposed acidic gas [41] and for the chemical breakdown of the Chrysotile fibers with HCl, Na_2CO_3, and CO_2-saturated water [42]. Mechanochemical transformation was also applied to modify the fibrous structure of asbestos into an inert substance [43]. Averroes et al. used the atmospheric microwave air plasma for the treatment of asbestos-like microfiber particles and they found that the plasma-treated microfiber particles were spheroidized and agglomerated by SEM images [44]. Asbestos-cement waste was treated by means of a high energy ring mill [45] and high pressure carbonization of asbestos containing material was also performed [46].

The above described methods are applied mainly to the treatment of asbestos-containing wastes for the reduction of the fiber release. However, the method using stabilizers has a benefit to fundamentally prevent the fiber release by applying a stabilizer to its surface, embedding the asbestos fibers in an adhesive matrix. This method has also advantages that can be directly applied in the field and it can be an alternative maintenance method to substitute the dismantling process of asbestos-containing materials.

The Architectural Institute of Japan carried out a wind test for 17 species of spray coating for materials treated and untreated with asbestos stabilizers, which were certified by the quality management regulations in the Standard Architecture Act [47]. Kim et al. [48] conducted a study to analyze the rain or snow-melt water collected from asbestos-cement slate roofs, and they reported that a significant amount of asbestos fibers such as chrysotile fibers were found in the water samples. Song et al. [49] investigated the applicability of four different dust suppressants to prevent asbestos from flying off of fire-resistant coating under various wind speeds and vibration conditions. Kim et al. [50] conducted a study to assess the asbestos scattering properties for plate-type asbestos building materials and found that the asbestos scattering level increased according to the intensity of the vibrations and air inflow up to a certain level.

In this study, the efficiencies of the stabilizers were evaluated for asbestos-containing ceiling tiles that have been used in public facilities or urban or rural buildings in Korea, and the characteristics of the released asbestos fibers were evaluated under various wind speeds and vibration conditions.

2. Experimental methods

2.1. Asbestos stabilizers

Ceiling tiles, greater than ten years in age, collected at the asbestos dismantling sites in Seoul, were selected as the testing materials. For the testing, a total of eight different commercial stabilizers were purchased locally or from abroad: six (two inorganic and four organic/synthetic resins) from Japan, one (inorganic) from Australia, and one (inorganic) from Korea, as summarized in Table 1.