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Optimal management program for asbestos containing building materials to be available in the event of a disaster

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ABSTRACT

The safe management and disposal of asbestos is a matter of considerable importance. A large number of studies have been undertaken to quantify the issue of waste management following a disaster. Nevertheless, there have been few (if any) studies concerning asbestos waste, covering the amount generated, the cost of disposal, and the degree of hazard incurred. Thus, the current study focuses on developing a program for the management of Asbestos Containing Building Materials (ACBMs), which form the source of asbestos waste in the event of a disaster. The study will also discuss a case study undertaken in a specific region in Korea in terms of: (1) the location of ACBM-containing buildings; (2) types and quantities of ACBMs; (3) the cost of ACBM disposal; (4) the amount of asbestos fiber present during normal times and during post-disaster periods; (5) the required order in which ACBM-containing buildings should be dismantled; and (6) additional greenhouse gases generated during ACBM removal. The case study will focus on a specific building, with an area of 35.34 m^2, and will analyze information concerning the abovementioned points. In addition, the case study will focus on a selected area (108 buildings) and the administrative district (21,063 buildings). The significance of the program can be established by the fact that it visibly transmits information concerning ACBM management. It is a highly promising program, with a widespread application for the safe management and optimal disposal of asbestos in terms of technology, policy, and methodology.

1. Introduction

Asbestos has been used since ancient times because it is heat-resistant, has antiseptic and insulating properties, and is highly economical (Becklake, 1976; Bourgault et al., 2014). Following the 1940s, there was a rapid global increase in the use of asbestos, which peaked in the 1980s (Virta, 2006; Kim et al., 2015). Asbestos has been used in nearly 3000 different Asbestos Containing Materials (ACM) (Zaremba and Peszko, 2008). One study suggests that over 90% of asbestos previously used has been in asbestos cement sheets, pipes, and other construction materials (Ramazzini, 2010). A study conducted in the 1960s identified asbestos as a carcinogen that, following an incubation period of 20–50 years from the time of exposure, causes malignant mesothelioma (i.e., respiratory diseases, such as lung cancer, which has a poor prognosis) and pulmonary asbestosis (Selikoff et al., 1964; Mossman et al., 1996). There has been consistent research on the pathways of human exposure to asbestos, and the human toxicity arising from the length and frequency of exposure (Wagner, 1965; Kamp, 2009). The International Agency for Research on Cancer under the World Health Organization classifies asbestos as a Group 1 carcinogen, while the American Conference of Governmental Industrial Hygienists classifies it as A1 (i.e., a confirmed human carcinogen), and the National Toxicology Program classifies it as Group 1 (i.e., known to be a human carcinogen) (Doll et al., 1985; Bahk et al., 2013). Such toxicity has prompted developed countries to either ban or restrict the use of asbestos from the early 1990s (Kane, 1996; Nicholson, 2001), and ongoing efforts have been made to compensate for asbestos-related damage from the 2000s (Harris and Kahwa, 2003). However, there remains a considerable amount of asbestos in use, particularly in developing countries, such as China and other countries in Southeast Asia, Africa, and South America (Bhagia et al., 2010; Kazan-Allen, 2005). One study notes that asbestos remains in 840,000 educational, public, and commercial buildings in the USA (Powell et al., 2015). A detoxification mechanism for asbestos is currently under development (Yoshikawa et al., 2015). However, poverty prevents its widespread application, and therefore the safe management and the correct handling

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of any remaining asbestos remains a matter of considerable importance.

Korea began to import asbestos in the 1960s, with its use peaking at 95,000 tons in 1992, following which it has declined (Kim et al., 2009). Its use was subject to regulation in 1990, when the revised Occupational Safety and Health Act added asbestos as a toxic material requiring government permission prior to use (Kim et al., 2015). The use of asbestos was completely banned in 2009, following the revision of the Enforcement Decree of the same Act (Kim et al., 2014). In 2010, the Asbestos Victims' Compensation Act was passed, stipulating compensation for harm caused by asbestos, and the Asbestos Safety Management Act was enacted in 2012 to ensure the safe management of existing asbestos (Kim et al., 2016a). Approximately 96% of the asbestos imported into Korea was used in slate, which is employed as a roofing material. This is consistent with the government-led project during the 1970s to redevelop old buildings (Paek et al., 1998). There is a high proliferation of Asbestos Containing Building Materials (ACBMs) in Korea, as evidenced by the fact that 82% of the imported asbestos was used as part of construction materials during the 1990s (Zhang et al., 2016). ACBMs can be broadly divided into outdoor materials (i.e., slate), indoor materials (i.e., textiles), and facility materials (i.e., gaskets) (The Ministry of Environment, 2009). Once stabilized, ACBMs are not toxic to the human body (U.S. Environmental Protection Agency, 1990). However, outdoor materials cause harm to the human body with the passage of time, as weathering and erosion can cause exposure of asbestos fibers, releasing them into the surroundings (Bornemann and Hildebrandt, 1986). The asbestos density around buildings that have a slate roof (i.e., outdoor materials: all slates made in Korea contain asbestos fiber) is higher than the permissible level (Spurny, 1989) and slate damage (e.g. caused by shock) has the potential to release asbestos fibers and cause serious harm to residents (Pastuszka, 2009). One previous study in Korea noted that a resident who had not worked in an asbestos-exposed environment, and who lived in a building that used only slate as its roofing material, was diagnosed with malignant mesothelioma (Jung et al., 2006), thus suggesting that the toxicity of ACBMs is related to slate.

Disasters normally produce large amounts of debris waste (Deshmukh and Hastak, 2012). Previous work has emphasized the importance of waste management in the event of a disaster. Issues such as (1) the problem of huge amount of waste disaster (construction debris) management (EPA, 2008); (2) the problem of high vulnerable buildings (Zanini et al., 2016; Argyroudis et al., 2015); and (3) the problem of temporary debris management sites (Hu and Sheu, 2013; Swan, 2000) have been addressed. Above all, the evaluation of the amount and type of waste is important for the optimal disposal of disaster waste (Brown et al., 2011). Poor waste management not only causes environmental pollution in water, soil, and air, but also causes harm to human health, particularly that of workers (Giusti, 2009). It has been found that nearly 5000 tons of ACBMs were released during the collapse of the World Trade Centre in 2001, and the amount of asbestos fibers discharged was 555 times greater than the permissible level (Klotter, 2002). A number of studies have been undertaken to quantify disaster waste (Luther, 2006), but these studies have had shortcomings due to the absence of accurate data (Lin Moe, 2010). The disposal and recycling of asbestos waste is also a serious issue, because it can easily be amalgamated with other waste when a disaster takes place (Brown and Milke, 2016). It is therefore critical to ensure the management and optimal disposal of ACBM waste. There are a large number of studies relating to asbestos toxicity, but only a few have investigated the safe management and optimal disposal of ACBMs, and no studies have been undertaken that focus on developing a program for ACBM management. In this context, the current study aims to develop a program conducive to the effective management and optimal disposal of ACBMs. In an earlier study, applying the Delphi technique, Beak et al. (2013) determined the required elements for the safe management and optimal disposal of ACBMs during normal times, and following a disaster. The management elements identified consist of: (1) the location of the ACBM-containing buildings; (2) types and quantities of ACBMs; (3) cost of ACBM disposal cost; (4) amount of asbestos fiber during normal times and during post-disaster periods; (5) the optimum order in which ACBM-containing buildings should be dismantled. At the same time, this study adds to the Delphi technique the greenhouse gas (GHG) generated when removing ACBMs, in relation to Korean regulations concerning ACBM removal (as described in detail in Section 2.3). Based on the program to manage all the foregoing six elements, the study investigated the type and characteristics of ACBMs, analyzed building registers (which form the foundation for the program), and created an inventory of manpower, equipment, and materials needed for optimal ACBM removal. The evaluation model for each of the six elements of ACBM management was then developed, and building registers, digital maps, land register maps, and building topographic information were combined to create a GIS-based Shape (SHP) file. Finally, the study developed a program enabling integrated asbestos management based on computer language (C, VC++, C#). Fig. 1 demonstrates the flow of this study. The new program is expected to play a significant role in the safe management and optimal disposal of ACBMs. At the same time, it will have a broad methodological contribution, particularly due to the lack of such studies globally.

2. Theoretical consideration and application

In order to achieve the objective of the current study, this section will focus on outlining the types and characteristics of ACBMs used in Korea, based on an extensive literature review. It will also consider the feasibility of the application of building registers, which form the basis for the program database (DB), as a building's summary information. The methods employed to remove ACBMs are also described in order to create an inventory that supports the optimal removal of these materials.

2.1. Overview of ACBMs used in Korea

The amount of asbestos imported annually into Korea steadily increased from 74,000 tons in 1976 to 88,000 tons in 1995. This trend was then reversed, with imports declining to only 6500 tons in 2005 (The Ministry of Environment, 2009). Imports were completely banned in 2009, and the focus subsequently transferred to the safe management and optimal disposal of the asbestos already in use (Kim et al., 2016a,b). According to previous studies: 82.3% of the ACMs used in the 1990s consisted of ACBMs (e.g., slate); 10.5% consisted of friction materials (e.g., brake lining and pads); 5.5% consisted of asbestos spinning products (e.g., asbestos cloth); and 1.7% consisted of insulators (e.g., gaskets) (Jeong et al., 2012). This suggests a high ratio of ACBMs in ACMs (Paek et al., 1998). The Asbestos Safe Management Act defines ACBMs as construction materials whose asbestos content exceeds 1% of the total weight (Korea Ministry of Environment, 2012). ACBMs are used extensively as: (1) outdoor materials (e.g., for roofs and exterior walls); (2) indoor materials (e.g. for walls, ceilings, and floors); and (3) facility materials (e.g., pipes and boilers) (The Ministry of Environment, 2009). In particular, 43% of ACBMs in Korea are used for slate (an outdoor material), 49% for textiles, (an indoor material), and the rest for facility materials (Hong et al., 2014). Chrysotile comprises the major portion of ACBMs, while anthophyllite or amosite comprise a smaller fraction (Kim et al., 2016a,b). The