Journal of Environmental Management 204 (2017) 82–91

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Treatments of asbestos containing wastes

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ARTICLE INFO

Article history:
Received 18 April 2017
Received in revised form
12 August 2017
Accepted 23 August 2017

Keywords:
Asbestos containing waste
Waste treatment
Chrysotile
Asbestos detoxification

ABSTRACT

Since the second half of the twentieth century, many studies have indicated inhalation of asbestos fibers as the main cause of deadly diseases including fibrosis and cancer. Consequently, since the beginning of the 80s, many countries started banning production and use of asbestos containing products (ACP), although still present in private and public buildings. Due to some extraordinary catastrophic events and/or the aging of these products, people's health and environmental risk associated with the inhalation of asbestos fibers keeps being high even in those countries where it was banned. For these reasons, many communities are developing plans for an environmental and sanitary safe asbestos removal and management. Asbestos containing wastes (ACW) are usually disposed in controlled landfills, but this practice does not definitively eliminate the problems related with asbestos fiber release and conflicts with the ideas of sustainable land use, recycling, and closing material cycles. Consequently, many scientific papers and patents proposed physical, chemical, and biological treatments aimed to the detoxification of ACW (or the reduction of their health effects) and looking for the adoption of technologies, which allow the reuse of the end-products. By including recent relevant bibliography, this report summarizes the status of the most important and innovative treatments of ACW, providing main operating parameters, advantages, and disadvantages.

Contents

1. Introduction . . . 82
2. Solidification and stabilization . . . 83
3. Vitrification . . . 84
4. Thermal treatments . . . 84
5. Mechanical treatments . . . 86
6. Chemical treatments . . . 86
7. Biological treatments . . . 88
8. Conclusions . . . 89
Acknowledgements . . . 89
Supplementary data . . . 89
References . . . 89

1. Introduction

Asbestos is a group of six naturally-occurring fibrous silicate minerals (chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite) which has been widely used because of its low thermal conductivity, high mechanical strength, resistance to chemical and biological attacks, and low cost (Dellisanti et al., 2009). Asbestos was already used in ancient times to produce materials resistant to fire, as described by Pliny the Elder (Røe and Stella, 2015). However, the industrial exploitation of this resource

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http://dx.doi.org/10.1016/j.jenvman.2017.08.038

for the fabrication of spun products, rope packings, and heat-insulating boards began between 1860 and 1875 (Skinner et al., 1988). Once these new goods were presented at the Paris Universal Exposition in 1878, the world production of ACP raised (Degiovanni et al., 2004). As a result, asbestos extraction continued to grow steadily, peaking in 1977 at 4.8×10^6 tons (Park et al., 2012), but successively it declined since the use and extraction of asbestos started being forbidden, mainly in European countries, because of its negative effects on human health (Stayner et al., 2013; Tossavainen, 2004).

In particular, Iceland (1983), Norway (1984), Denmark (1986), Sweden (1986), Austria (1990), The Netherlands (1991), Finland (1992), Italy (1992), and Germany (1993) were the first countries to restrict and ban asbestos uses (Kazan-Allen, 2003). Nowadays, asbestos mining and use in 2015 was still equal to 2.0×10^6 tons (U.S. Geological Survey, 2016), although 58 countries have banned the production and consumption of all forms of asbestos (Kazan-Allen, 2016). In particular, the major asbestos producers in 2015 (U.S. Geological Survey, 2016) and consumers in 2012 (Frank and Joshi, 2014) are reported in Fig. 1.

In the peak period of asbestos consumption, more than 3000 types of ACP have been used in schools, hospitals, gyms, cinemas, and industrial plants (Paglietti et al., 2012). Nowadays, most of these applications have been abandoned (Virta, 2002), but a few non-limiting examples of the remainder are reported in Table 1S.

The main asbestos production is now based on chrysotile, since the production of amosite and crocidolite ceased in the mid-1900s (Pye, 1979; Virta, 2011). However, physical and chemical properties of chrysotile, amosite, and crocidolite are reported in Table 2S.

By considering that, from 1900 to 2015, 2.1×10^8 tons of asbestos fibers were produced and used all over the world and by taking into account the worldwide pandemic of asbestos-related diseases, the management of ACP and ACW is an issue of global concern. Indeed, although ACP are still used in Eastern Europe and Asia, in many countries where asbestos has been already banned a significant background level of asbestos still remains in close contact with the population (in the environment, buildings and devices). For instance, it has been evaluated that in Italy the amount of ACW can reach 30×10^6 tons (Plescia et al., 2003). Similarly, the authority for waste management and soil remediation in Flanders reported that the amount of ACP is equal to 3.7×10^6 tons, more specifically, 1.9×10^6 tons in buildings and 1.8×10^6 tons in utility pipelines (OVAM, 2016).

Many papers justify the use or the presence of chrysotile in non-friable ACP in public buildings, since in this condition it is not dangerous for human health (Bernstein et al., 2013; Lee and Van Orden, 2008; Whysner et al., 1994; Chesson et al., 1990). Indeed, the hazard generated by ACP is associated to the inhalation of asbestos airborne (Donaldson et al., 2013; Ansari et al., 2007; Nel et al., 2006). On the other hand, in North America a significant portion of the water distribution through asbestos cement pipes is still in service and it has been reported that some water samples, withdrawn in 1991, contained between 1.4×10^3–2.6×10^5 million asbestos fibers per liter (Webber and Covey, 1991). Unfortunately, like inhalation, also the ingestion of asbestos fibers can cause fatal diseases (Kjaerheim et al., 2005; Van Kesteren et al., 2004).

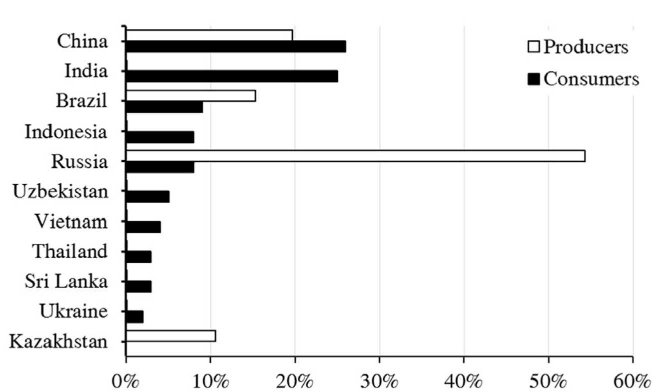

Fig. 1. Producers (2015) and consumers (2012) of asbestos fiber.

Furthermore, during natural and made-man disasters, both friable and non-friable ACP present in buildings and utilities contribute to the generation of large volumes of debris characterized by high environmental and public health impacts (Brown et al., 2011). Specifically, it occurred after 2005 Katrina hurricane (Luther, 2008; Brandon et al., 2011), 2011 Fukushima earthquake (Kashimura et al., 2015), and after the terroristic attack to the World Trade Center in 2001 when analysis in settled dust highlighted the presence of asbestos fibers at the concentration of $0.8\%_{w/w}$ - $3.0\%_{w/w}$ (Landrigan et al., 2004). Moreover, both non-friable and friable ACP could generate hazardous dusts during a whole-building demolition by heavy equipment and/or explosives (Perkins et al., 2007; Stefani et al., 2005). In any case, it has been estimated that 125×10^6 people are occupationally exposed to asbestos (Linton et al., 2012) and it has been reported that asbestos-related illnesses cause 1.07×10^6 deaths per year (Frank and Joshi, 2014; Marsili and Comba, 2013).

As a consequence, to overcome all the environmental and health problems associated to the presence of ACP and ACW, on the 30th of January 2013, the European Parliament (Resolution EU-P7_TA, 2013) encouraged the EU "*to work with the social partners and other stakeholders at European, national and regional levels to develop and share action plans for asbestos removal and management*".

Actually, ACW are generally bagged, labelled, and deposited in controlled landfill (Paglietti et al., 2016). For example, according to the Italian Environment Ministry Decree of the 6th of September 1994 and related acts, ACP have to be sealed in double polyethylene bags (2 mm thick), labeled and deposited in controlled landfills. This practice is cheap, but it does not eliminate the problems related to asbestos fiber release, which is merely postponed to the future generations (Leonelli et al., 2006). In fact, it represents only a temporary solution since weathering through rain, wind, or mechanical action would result in the release of fibers, raising a potential health risk (Promentilla and Peralta, 2003). Furthermore, landfilling is conflicting with the idea of sustainable land use, recycling, and closing material cycles (Scharff, 2014; Tam and Tam, 2006).

Consequently, the European Parliament "*points out that, as regards the management of asbestos waste, measures must also be taken – with the consensus of the populations concerned – to promote and support research into, and technologies using, eco-compatible alternatives, and to secure procedures, such as the inertisation of waste-containing asbestos, to deactivate active asbestos fibers and convert them into materials that do not pose public health risks*" (Resolution EU-P7_TA, 2013).

For this purpose, many papers and patents have been devoted to physical, chemical, and biological treatments aimed to the detoxification of asbestos fibers or to the reduction of their health effects. These studies, in some cases, have already led to pilot installations or even full-scale operational treatment-plants. In the present review, an attempt is made to describe all these ACW treatment processes by focusing on the environmental and economic advantages and disadvantages, as briefly summarized in Table 3S.

2. Solidification and stabilization

The landfilling of hazardous waste following the solidification