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ScienceDirect
Regulatory Toxicology and Pharmacology 52 (2008) S97–S109
Regulatory Toxicology and Pharmacology
www.elsevier.com/locate/yrtph

Exposure to airborne amphibole structures and health risks: Libby, Montana

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Received 5 September 2007
Available online 10 October 2007

Abstract

Libby, Montana is the site of a large vermiculite deposit that was mined between 1920 and 1990 to extract vermiculite for commercial applications such as insulation, gardening products, and construction materials. The Libby vermiculite deposit also contains amphibole minerals including tremolite, actinolite, richterite, and winchite. Historically, Libby mine workers experienced high exposures to amphibole structures, and, as a group, have experienced the health consequences of those occupational exposures. It has been suggested that Libby residents also have been and continue to be exposed to amphibole structures released during the vermiculite mining operations and therefore are at increased risk for disease. The Agency for Toxic Substance and Disease Registry (ATSDR) conducted two epidemiological-type studies of residents living in Libby and the surrounding areas to assess these risks. The Environmental Protection Agency (EPA) collected and analyzed exposure data in Libby and used those data to project risks of asbestos-associated disease for Libby residents. The EPA has placed the Libby Asbestos Site, which includes the mine and the town of Libby, on its National Priority List of hazardous waste sites in need of clean up. This article presents a review of the exposure studies conducted in Libby and an analysis of health risks based on the data collected in those studies. Libby mine workers have experienced elevated levels of asbestos-associated disease as a consequence of their occupational exposures to amphibole structures. Libby residents' exposures typically are substantially lower than mine workers' historical exposures, and the health risk projections for residents are, accordingly, substantially lower.

Keywords: Libby; Montana; Vermiculite; Amphibole minerals; Asbestos; Asbestos-associated disease

1. Introduction

Libby, Montana gained the attention of the U.S. government health agencies in 1999 when the Seattle Post Intelligencer ran an article by Andrew Schneider titled "A town left to die". The article associated high rates of respiratory disease in Libby with exposure to amphibole particles released into the air from the vermiculite mine located in Libby.

Vermiculite is the mineralogical name given to hydrated laminar magnesium–aluminum–iron silicate that resembles mica in appearance. When subjected to heat, vermiculite has the unusual property of exfoliating or expanding into worm-like pieces. This characteristic of exfoliation is the basis for commercial use of vermiculite in applications such as insulation, gardening products, and construction materials.

Commercially useful vermiculite is found in Australia, Brazil, China, Kenya, South Africa, the U.S., and Zimbabwe. In the U.S., vermiculite is mined at Enoree, South Carolina and Libby, Montana. The Libby mine, which operated from 1920 to 1990, may have produced as much as 80% of the world's supply of vermiculite.

The Libby vermiculite deposit contains amphibole minerals. It has been suggested that the amphibole component of the ore deposits at the vermiculite mine has unique characteristics that make its potency for asbestos-associated disease different than other asbestos minerals. "Libby Asbestos" (LA), a term coined by the United States Environmental Protection Agency (EPA) and the Agency for Toxic Substance Disease Registry (ATSDR), is a collection

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0273-2300/$ - see front matter © 2008 Published by Elsevier Inc.
doi:10.1016/j.yrtph.2007.09.015

of amphibole minerals including tremolite, actinolite, anthophylite, richterite, and winchite. LA is a combination of asbestiform structures (i.e., fibers) and non-asbestiform structures known also as cleavage fragments.

High-level exposure to LA has been associated with various diseases including lung cancer, mesothelioma, asbestosis, and other non-malignant respiratory diseases (McDonald et al., 1986; Amandus et al., 1987a; Amandus and Wheeler, 1987b). This article presents a review of the exposure studies conducted in Libby and an analysis of health risk based on the data collected in those studies. Libby mine workers have experienced elevated levels of asbestos-associated disease as a consequence of their occupational exposures to amphibole particles. Libby residents' exposures typically are substantially lower than mine workers' historical exposures and the health risk projections for residents are, accordingly, substantially lower.

2. Chronology of health studies and regulatory actions in Libby

The vermiculite mining operation in Libby between 1920 and 1990 consisted of ore extraction, processing, and shipping. Until the 1960s, mine workers often were exposed to high levels of LA, which co-existed with the vermiculite ore. In the mid-1980s, W.R. Grace and the National Institute for Occupational Safety and Health (NIOSH) conducted separate epidemiology studies of mine workers to assess heath risks associated with exposure to LA in vermiculite mining (McDonald et al., 1986; Amandus et al., 1987a; Amandus and Wheeler, 1987b). ATSDR and EPA initiated studies of respiratory disease among Libby residents in 1999. In 2000, ATSDR released a report describing the results of its study of asbestosis mortality in Libby (ATSDR, 2000). The report stated that the asbestosis mortality rate in Libby was 40–60 times greater than the national average asbestosis mortality rate. During the summer of 2000, ATSDR initiated a medical testing program and Screening Study. ATSDR's report on the Screening Study, released in 2001, stated that Libby residents experienced a high rate of pleural abnormalities (ATSDR, 2002b). Also in 2001, the EPA summarized an exposure analysis it had conducted in Libby stating that exposure to asbestos in Libby constituted an "imminent and substantial endangerment to public health" (Weis, 2001). In 2002, EPA placed Libby on the National Priorities List of the Superfund Program, which established it as a hazardous waste site requiring clean-up. Also in 2002, ATSDR revised its asbestosis mortality study, updated its Screening Study, reported on a pilot study of environmental cases of pleural abnormalities, and issued a Public Health Assessment for vermiculite (ATSDR, 2002a; ATSDR, 2002b; ATSDR, 2002c; ATSDR, 2002d). The studies addressing the rate of pleural abnormalities among Libby residents were summarized and published with comments in Environmental Health Perspectives (Peipins et al., 2003a,b; Price, 2004). The remainder of this article contains a review of the mine worker and Libby resident studies and regulatory actions concerning Libby. Included are re-analyses of data in order to evaluate concerns about the health risk of low-level environmental exposure to LA.

3. Morphology characterization of LA

LA is a collection of amphibole minerals that have been identified as tremolite, actinolite, soda tremolite, richterite, and winchite (Meeker et al., 2001). A typical sample of LA also contains acicular cleavage fragments. Because LA is a mixture of pure fibers and acicular morphologies, in the remainder of this report LA particles are referred to as structures rather than fibers. The toxicities of the mineral components of LA have not been thoroughly studied. Cleavage fragments, in particular, are at the center of a controversy concerning their toxicity for asbestos-associated disease. Currently, The Occupational Safety and Health Administration (OSHA), excludes cleavage fragments from the mineral fibers it regulates under its asbestos exposure standard (57 FR 24310). The relative toxicity of cleavage fragments, which tend to be thicker and shorter than fibers, although uncertain, is generally considered to be less than the asbestiform analogue (Ilgren, 2004; Davis et al., 1991; Wylie et al., 1993; ATS, 1990). Notwithstanding the specific toxicity uncertainties associated with cleavage fragments, it is generally accepted that inhalation of long, thin fibers (longer than 5 μm with diameters less than 0.50 μm) have greater potential to cause disease than shorter, thicker fibers (ATSDR, 2003a; EPA, 2003).

Table 1 contains a summary of data concerning the size distribution of LA. Amandus et al. (1987a) summarized lengths and widths separately based on light microscopy inspection of 599 LA structures collected in air samples. Amandus reported results only for structures longer than 5 μm and thicker than 0.45 μm. Seventy four percent (74%) of the structures were longer than 10 μm, 11% were longer than 40 μm, and 93% had diameters between 0.45 and 0.90 μm. McDonald et al. (1986) provides preliminary results of an electron microscopy study to characterize the structure size distribution of LA conducted by the Institute of Occupational Health and Safety at McGill University. McDonald's results indicate that 62% of LA structures were longer than 5 μm. Additional results from McGill based on three air samples confirm McDonald's result (McGill University, 1983). Ten percent (10%) of the structures were longer than 20 μm and 73% were thinner than 0.50 μm. The McGill data also provides information about the two-dimensional distribution of structures. Focusing on structures no thicker than 0.50 μm, 38.9% were longer than 5 μm; 13.1% were longer than 10 μm; and 2.7% were longer than 20 μm.

ADL (1983) used electron microscopy to determine the percentage of structures typically counted by light micros-