Relationship between the growth habit of asbestos and the dimensions of asbestos fibers

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Abstract — *The dimensions and shape of both airborne and bulk amphibole-asbestos fibers are different from those of both airborne and bulk of cleavage fragments of the amphiboles. These differences are related to the mineralogical properties unique to the habit of asbestos, including the fibrillar structure, small fibril widths and distinctive crystallographic faces of fibrils. Criteria for distinguishing amphibole cleavage fragments from amphibole-asbestos include mineralogical properties observable in bulk samples and the dimensions of particles collected on air filters. It would be very helpful to the mining and mineral industry if these properties were recognized in the regulation of asbestos.*

Introduction

Asbestos is a term applied to a group of highly fibrous silicate minerals that readily separate into long, thin, strong fibers of sufficient flexibility to be woven, are heat resistant and chemically inert, and possess a high electrical insulation and, therefore, are suitable for uses where incombustible, nonconducting or chemically resistant material is required (Gary et al., 1974).

Heat resistance, chemical inertia and high electrical insulation are properties of almost all silicates. Therefore, they are not unique to asbestos. However, long, thin, strong flexible fibers are limited almost exclusively to asbestos and are the properties that made the use of asbestos in building materials so widespread.

Nonetheless, in the regulation of asbestos, the federal government, and many state and local governments following the federal government's lead, define asbestos as anyone of six minerals: chrysotile, crocidolite (riebeckite), amosite (grunerite or cummingtonite), tremolite, actinolite, and anthophyllite. Further, asbestos is regulated on the exposure to or content of particles that are longer than 5 μm and have aspect ratios (length:width) of 3:1 or greater. This has the effect of making cleavage fragments of any of these minerals into asbestos fibers.

This paper will describe the mineralogical characteristics of asbestos and the shape of both airborne and bulk asbestos particles. The properties and dimensions relate to the habit of asbestos, distinguish asbestos from the more common varieties of the same silicate minerals, and could provide a basis for the regulation of asbestos without the inclusion of cleavage fragments for which no carcinogenic potential has been established.

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Mineralogical properties of asbestos

Chemical composition and atomic structure

In modern times, only four minerals have been mined as asbestos on a large scale: anthophyllite-asbestos ($Mg_7Si_8O_{22}(OH)_2$); grunerite-asbestos (amosite) ($(Fe,Mg)_7Si_8O_{22}(OH)_2$)); riebeckite-asbestos (crocidolite) ($Na_2Fe_5Si_8O_{22}(OH)_2$; and chrysotile ($Mg_3Si_2O_5(OH)_4$). In earlier times, actinolite-asbestos ($Ca_2(Fe,Mg)_5Si_8O_{22}(OH)_2$) and tremolite-asbestos ($Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$) have been used locally. Other minerals, including arfvedsonite (Deer et al., 1962), potassian winchite (Wylie and Huggins, 1980) and richterite (Malyshonok et al., 1986), talc, and erionite, may occasionally occur in an asbestiform habit.

All of the major types of asbestos, except chrysotile, have essentially the same atomic structure and, because of it, are known as amphiboles. Amphiboles have a double chain of SiO_4-4 tetrahedra as their basic building block. Amphibole asbestos fibers are elongated parallel to the double chain. Chrysotile is a sheet silicate, so-called because its basic structural unit is a sheet of connected SiO_4-4 tetrahedra. Rolling up of the sheet forms its fibers.

Fibrillar structure

Asbestos of all types is composed of bundles of individual fibrils. These fibrils vary in size among the different asbestos types and occurrences. South African and Australian crocidolite have fibrils that range in width from about 500 to 2000 A. Grunerite-asbestos (amosite) from South Africa ranges from about 2000-6000 A and chrysotile fibrils from most localities range from about 200 to 500 A in width.

These fibrils share a common axis of elongation but are randomly oriented with respect to the other crystallographic directions. There have been reports of other minerals forming between these fibrils (talc, brucite), but generally asbestos fibers are monomineralic. The fibrils are held together by weak bonds and are easily separated by gentle pressure of the hand. Separation of the fibrils in this manner is not cleavage; no structural bonds are broken.

The fibrillar structure of asbestos hinders the use of single crystal X-ray techniques to study it. Instead of producing a pattern of spots, which can be interpreted to determine symmetry and structure, an asbestos fiber with a diameter of about 0.1 mm (0.004 in.) will produce a pattern consisting of lines derived from spot patterns of thousands of individual fibrils that share only one crystallographic axis in common. For many years, the inability to study asbestos by classical X-ray techniques left the determination of symmetry to the optical properties (which also are affected by the fibrillar structure)