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Characterizing and Discriminating Airborne Amphibole Cleavage Fragments and Amosite Fibers: Implications for the NIOSH Method

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The NIOSH method for determining asbestos exposure in the mining environment involves using phase contrast microscopy to examine mineral particulates collected on air monitor filters. Particles are classified as asbestiform or non-asbestiform based on their size and length-to-width (aspect) ratio. The procedure works well when only fibers are present. In most non-asbestos mining operations, however, cleavage fragments are the most abundant airborne particulates. In this research, discriminate function analysis was applied to morphological data for airborne amphibole particulates to show that dimensional criteria could distinguish between amphibole asbestos and amphibole cleavage fragments. The particulates for this research were collected from industrial sites where amosite alone was in use and from mining sites where amphiboles are major rock-forming minerals. The results suggest that cleavage fragments can be differentiated from asbestos fibers based on dimensional criteria alone, but only if the current working definition of a fiber is modified. The data suggest that an appropriate definition of a regulatory fiber would be a particle longer than 5μm with a width less than 3μm and an aspect ratio of 20:1 or greater. Adoption of the 20:1 aspect ratio would greatly increase the precision of the NIOSH method. However, a new aspect ratio criterion must be coupled with a lower exposure index in order to prevent an increase in worker exposure to asbestos.

Introduction

The membrane filter method is specified as the method of test by the Occupational Safety and Health Administration (OSHA) Federal Standard for asbestos in industrial air (29 CFR Part 1910.1001) and in the Mine Safety and Health Administration (MSHA) regulations (30 CFR 55.5-1(b), 56.5-1(b), 57.5-1(b) and 71.202) governing mining air. The federal standards define asbestos as chrysotile, amosite, crocidolite, tremolite, anthophyllite and actinolite. The membrane filter method (NIOSH analytical method #P&CAM 239) defines an asbestos fiber as "a particulate which has a physical dimension longer than five micrometers and with a length to diameter ratio of three to one or greater."[1] Futhermore, it specifies that "in an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of three to one or greater, and a length greater than five micrometers should, in the absence of other information, be considered to be asbestos fibers."[1] The five micrometer length is the most practical minimum fiber length measurable by phase contrast microscopy for fiber counting.[2-4] The choice of an elongated aspect ratio was made to eliminate most confounding mineral particles such as dirt and rock fragments, but the lower bound of three was arbitrary.[5] As long as the asbestos fiber definition is applied to an industrial environment in which only asbestos is being used, it provides a useful basis for exposure monitoring. However, in the mining environment, where many nonfibrous particles may fit the definition of a fiber, it may not be appropriate. The problem is especially acute when amphibole minerals are abundant.

Of the six minerals regulated as asbestos in the United States, all but chrysotile belong to a group of silicate minerals known as the amphiboles. Amphiboles are extremely common in the earth's crust. Approximately 30% of the rocks found in the continental United States contain amphiboles as major constituents.[6] Amphiboles are characterized structurally by a double chain of silicon-oxygen tetrahedra and they form prismatic crystals. When crushed, they form prismatic cleavage fragments which frequently have aspect ratios in excess of 3:1. Only rarely do the amphiboles grow with the extreme elongation and narrow widths typical of asbestos. This rare habit is characterized by flexibility and high tensile strength. A more extensive discussion of the asbestiform habit is presented elsewhere.[7,8] Because of the unique physical properties of asbestos, the distinction between asbestiform and other amphibole habits is readily apparent in hand specimens, but these macroscopic properties often cannot be observed on small discrete particles such as those collected on air monitoring filters. In many mining operations amphiboles are a common constituent of the rock while amphibole asbestos is present in trace amounts or absent entirely. In these environments, elongated cleavage fragments are classified as amphibole asbestos fibers according to the existing regulatory criteria and the membrane filter method.

The Bureau of Mines undertook this study in an attempt to provide criteria for discriminating between airborne amphibole cleavage fragments and amphibole asbestos fibers. Specific questions addressed were:

1. What are the dimensional characteristics of both populations?
2. What particle dimensions are common to both populations and how abundant are these particles?
3. How can the populations be best distinguished?