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Discovering the True Morphology of Amphibole Minerals: Complementary TEM and FESEM Characterization of Particles in Mixed Mineral Dust

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This study involved the development and application of a protocol using transmission electron microscopy (TEM), energy dispersive X-ray spectroscopy (EDS), selected area electron diffraction (SAED), and field emission scanning electron microscopy (FESEM) techniques for the particle-by-particle characterization (i.e., chemistry, crystallography, and morphology) of mixed mineral dust. This protocol was developed to characterize amphibole particles that occur as accessory minerals around the former vermiculite mine located near Libby, Montana. Media and public attention has been focused on Libby since the fall of 1999 due to health concerns over potential amphibole asbestos exposure occurring in and around the community. The mineralogy in the Libby area is complex. There is ongoing research and debate on the composition and morphology of the various types of asbestos and non-asbestos amphibole particles present in the mixed mineral dust and their relative quantities and potential health risks. Therefore, the distinction among asbestos and non-asbestos amphibole particles is important from both a scientific and regulatory standpoint.

In this study, the Yamate Level III TEM method for asbestos analysis of air samples was supplemented by FESEM imaging. The FESEM procedure involved relocation of all amphibole particles analyzed by TEM/EDS/SAED and the collection of secondary electron images of the full structure, both structure ends, and the structure surface. Direct comparison of the TEM and FESEM images for a specific particle reveals morphological features that cannot be observed in a TEM image. Features key to distinguishing between asbestos and non-asbestos amphibole particles, such as overall particle shape and surface roughness, are readily apparent in the FESEM images.

Particle-by-particle examination of multiple air samples generated large volumes of TEM and FESEM images, EDS spectra, and SAED patterns. To facilitate data review, more than 67,000 TEM and FESEM images, spectra, and diffraction patterns were imported into a database. The database allows simultaneous viewing of multiple TEM and/or FESEM images, EDS spectra, and SAED patterns for a given particle. More than 3,700 structures were classified by various categories, such as particle shape, end and side geometries, and surface texture. The organization and viewing capacity of the database are useful for sharing technical results with other experts and training new analysts. This study demonstrated that FESEM imaging and digital database utilization are essential elements for accurate characterization of complex mixed mineral dusts, particularly when dealing with large numbers of samples.

Keywords amphibole; asbestos; digital database; FESEM; field emission scanning electron microscopy; mixed mineral dust; SEM; TEM; transmission electron microscopy

1. Introduction

"Asbestos" is a commercial term applied to a group of naturally occurring silicate minerals that grow in a specific fibrous form and exhibit unique characteristics such as: flexibility, high tensile strength, and resistance to heat and chemical degradation. Six minerals are specifically regulated as asbestos by the U.S. Federal government [1]: chrysotile (fibrous serpentine) and five varieties of amphibole fibers: crocidolite (riebeckite asbestos), amosite (cummingtonite-grunerite asbestos), anthophyllite asbestos, tremolite asbestos, and actinolite asbestos. In addition to the six regulated asbestos minerals, 388 minerals (including 92 silicate and aluminosilicate species) are known to occur, at least occasionally, in fibrous

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