



Asbestos Fibre Identification by SEM/EDS

Asbestos and other airborne fibres

One of the greatest risks to human health from airborne fibre exposure is from respirable asbestos fibres, which penetrate deep into the lungs and can accumulate throughout a person's life. Exposure to airborne asbestos fibres can cause a range of diseases, including pleural plaques, mesothelioma, lung cancer and asbestosis.

Other types of fibres may also be present in air, including natural and synthetic organic fibres or synthetic mineral fibres. Some of these types of fibres may also be harmful, whilst other types are not thought to represent any significant risk to human health.

Australian guidelines for monitoring and assessment of exposure to airborne asbestos fibres require the use of the NOHSC Membrane Filter Method (MFM). This sampling and analysis method is based on a count of the fibres on the filter, from which the airborne concentration can be calculated using the volume of air sampled. The MFM uses Phase Contrast Microscopy (PCM), which does not distinguish between different types of fibres. PCM does however, provide a conservative upper limit for exposure in asbestos risk assessments.

Since the MFM is not specific to asbestos, assessment of the health risks associated with airborne fibres exposure should therefore include definitive identification of the type and proportion of each type of fibre found, in addition to the size and concentration of fibres in the air.

Identification of asbestos fibres

When fibres are found, but are suspected to not be asbestos, or when identification of the type of fibre is necessary, samples may be subjected to Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS). This SEM/EDS analysis allows the confirmation of fibre types and morphology, including identification of different asbestos mineral types.

Fibre identification by SEM/EDS

Scanning electron microscopy (SEM) coupled with EDS or Energy Dispersive Spectroscopy analysis allows examination of fibre morphology to identify asbestiform fibres and x-ray analysis to characterise the asbestos type. The characterisation of asbestos type is achieved by comparison of the elemental composition of the fibres with the known composition of different types of asbestos. Each asbestos mineral has a characteristic EDS spectrum, with the ratios of elements such as magnesium, silicon, iron and oxygen used for identification. The presence or absence and relative proportions of other elements, such as aluminium and potassium can be used to distinguish asbestos fibres from other minerals similar in composition, such as mica (biotites) or pyroxenes. SEM/EDS also allows asbestos to be easily distinguished from glass or organic fibres.

SEM/EDS allows individual fibre bundles as narrow as 20nm to be examined by x-ray analysis and elements as low in atomic weight as boron can be identified and their relative proportions determined.

Asbestos identification

The Australian Standard method for the Qualitative Identification of Asbestos AS4964 uses polarised light microscopy (PLM) with dispersion staining to unequivocally identify chrysotile, crocidolite and amosite. Other forms of asbestos can be found using PLM, however these fibres cannot be definitively identified by this method and are therefore designated as Unidentified Mineral Fibres, or UMF. Heat or chemically damaged fibres also commonly fall into this classification.

SEM/EDS can be used to distinguish between these "UMF" forms of asbestos, as well as allowing confirmation of the asbestos type determined by PLM, when optical properties vary from expectation.

METHOD INFORMATION

EA206: Asbestos Presence/Absence by SEM/EDS

EA208: Identification and Elemental Analysis of Fibres and Particulates by SEM/EDS – Detailed report and photo-micrographs

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Chemical composition of different fibre types

All types of asbestos are hydrated inorganic silicate minerals from the serpentine and amphibole families, which naturally have a fibrous texture. They have complex crystal structures and distinctive elemental compositions. The most common form of asbestos is chrysotile, or white asbestos. This serpentine mineral is a hydrated magnesium silicate with the composition $Mg_3(Si_2O_5)(OH)_4$. The amphiboles include amosite, anthophyllite, crocidolite, actinolite and tremolite. The chemical composition of these amphiboles is a little more complex, with additional elements present in the crystal structure;

- » amosite (brown asbestos) $(FeMg)_7(Si_8O_{22})(OH)_2$
- » anthophyllite $(Mg,Fe)_7Si_8O_{22}(OH)_2$
- » crocidolite (blue asbestos) $Na_2Fe_5(Si_8O_{22})(OH)_2$
- » actinolite $Ca_2(Mg,Fe)_5(Si_8O_{22})(OH)_2$
- » tremolite $Ca_2Mg_5(Si_8O_{22})(OH)_2$

The above crystal structures and elemental ratios are based on 'pure' or 'theoretical' crystal structures, however in natural mineral deposits and products manufactured from them, these compositions and ratios can vary. Mixture with other minerals, binders and chemical and physical processes can lead to differences of up to 10% from expected values (per Libby, 2008).

Synthetic (or Man-made) Mineral Fibres (SMF or MMVF) such as glass wool and refractory ceramic fibres are generally distinguishable from asbestiform fibres by their morphology, with the chemical composition depending on the source. SEM/EDS analysis can be used to characterise SMF or match fibres with known products. One of the more hazardous types of SMF, Refractory Ceramic Fibres (RCF) can be distinguished from other SMF using EDS by the alkaline oxide and alkali earth oxide content.

Natural fibres such as spider webs and synthetic organic fibres including rayon and nylon can be easily distinguished from asbestos and other mineral fibres by their high carbon and low metal content.

Health risks and exposure standards

The National Occupational Health and Safety Council (NOHSC) has a single exposure standard for airborne asbestos fibres of 0.1 fibres/ml of air, with the same limit applying to all types of asbestos. Asbestos is designated as a Class 1A, or known, carcinogen by the International Agency for Research on Cancer (IARC). Exposure standards have also been established for different types of SMF, with RCF designated by IARC as Class 1B, or potentially carcinogenic. IARC has classified mineral wools (glass wool, rock wool (stone wool), slag wool and continuous glass filament) as not carcinogenic to humans, however NOHSC exposure standards still apply. Exposure standards equivalent to those for nuisance dust apply for fibre types such as cellulose fibres, which are not considered as harmful to human health.

SEM/EDS analysis provides a powerful tool that should be considered in epidemiological or occupational hygiene assessments whenever the composition of dusts or airborne fibres is not known or human exposure exceeds the lowest NOHSC exposure standards. This technique allows detailed classification and assessment of the hazards present and the potential risks to human health.

REFERENCES

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Saudi Arabia : 7th Street, Al-Ammamrah Area, Dammam | First Industrial City, Phase 4, 62 Street, Jeddah



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