Measurement of asbestos fibres in occupational health: the role and relevance of analytical transmission electron microscopy (ATEM)

The INRS emphasises that analytical transmission electron microscopy (ATEM) is now the only valid and appropriate method for measuring occupational exposure to asbestos. Why? This method meets several essential requirements: the need for reliable chemical and crystallographic identification, and for the comprehensive counting of all asbestos fibres, including fine and short fibres present in occupational environments.

In France, standard NF X 43-050 requires the use of analytical transmission electron microscopy (ATEM) for the regulatory measurement of occupational exposure to asbestos. Currently this method is the only technique capable of providing a reliable exposure assessment by meeting all metrological requirements.

Specifics and metrological requirements of asbestos fibre measurements in occupational risk prevention

In the absence of any proven safe threshold for exposure to asbestos fibres, the metrological requirements are particularly stringent. Assessment tools must not only identify the fibres accurately, based on reliable characterisation of their chemical composition and crystallographic structure, but also provide a sensitive and reproducible quantification of inhalable airborne fibres present in the workplace.

Asbestos is characterised by its fibrous particulate nature and by its combined mineralogical and morphological definition. The six historically used types of asbestos (one chrysotile and five amphibole types) have a silicate crystalline structure composed of SiO_4 tetrahedra, enriched with characteristic elements such as magnesium, iron or sodium, the analysis of which makes it possible to determine the mineralogical variety. This chemical and structural diversity is a key prerequisite for their analytical classification.

Asbestos fibres present in occupational environments are grouped into three categories:

- WHO fibres: length (L) > 5 µm, diameter (d) < 3 µm, L/d ratio ≥ 3
- Fine asbestos fibres (FAF): diameter < 0.2 µm
- Short asbestos fibres (SAF): length < 5 µm

Fine and short asbestos fibres—often abundant in the workplace—play a decisive role in determining the true level of airborne fibre contamination. Their significant presence, below the analytical sensitivity threshold of certain techniques, therefore requires the use of very high-resolution methods.

For the purposes of risk prevention, a reliable measurement method must therefore satisfy three fundamental criteria simultaneously:

- Sufficient resolution to visualise the entire spectrum of fibres, including the shortest and finest;
- A chemical analysis method capable of determining the chemical composition of fibres;
- Determination of crystallographic structure, which is essential for distinguishing between different chrysotile, amphibole and other asbestos varieties.

ATEM resolution and detection capability in measuring exposure

The ATEM method provides nanometric scale resolution, enabling detailed observation of extremely fine asbestos fibres, even those of less than 0.2 µm in diameter. This capability is essential to ensure the comprehensive counting of fine fibres, a large proportion of which cannot be detected using other optical or electronic techniques with lower resolution.

By comparison, conventional analytical scanning electron microscopy (SEM)—although useful for materials analysis or exploratory diagnostics—has insufficient resolution to identify fine asbestos fibres.

Elemental and crystallographic identification

ATEM analysis combines X-ray microanalysis by energy-dispersive spectrometry (EDS), to determine with precision the chemical composition of fibres, and selected-area electron diffraction (SAED), to identify their crystallographic structure by analysing diffraction patterns.

The EDS + SAED combination provides a complete mineralogical identification, even in complex matrices containing both asbestos and non-asbestos fibres. ATEM can therefore unambiguously distinguish chrysotile fibres from amphibole fibres, a vital distinction in risk assessment and exposure traceability.

By contrast, SEM cannot determine crystallographic structure, and its ability to differentiate certain non-asbestos mineral fibres from asbestos fibres is limited which compromises the reliability of fibre counting in an occupational health context.

Limitations of other techniques and justification for the exclusive use of ATEM

Although SEM offers operational advantages in materials diagnostics and surface mineralogical analysis, it presents major limitations when used to measure occupational exposure:

- Insufficient resolution to detect fine fibres;
- Inability to determine crystallographic structure;
- Increased risk of confusion with non-asbestos fibres.

These limitations undermine the accuracy, representativeness and robustness of measurements.