1-B. Asbestos Exposure Assessment and Control in Occupational Settings

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a) Methodologies related to environmental monitoring of asbestos

More than 30 different standard methods have been issued by various governmental agencies and standard organizations to standardize laboratory analysis results by using the same analytical procedures. Because positive identification of asbestos requires analysis of the morphology, chemical composition and crystal structure of fibers due to the attributes of asbestos minerals, various analytical techniques are used in these standard methods. Among these analytical techniques, microscopy is the most important tool used for the detection of fibrous morphology. For the counting analysis of airborne fibers, microscopic techniques such as phase contrast microscopy (PCM), transmission electron microscopy (TEM) and scanning electron microscopy (SEM) are widely used. For the analysis of bulk asbestos such as asbestos in commercial products and building materials, polarized light microscopy (PLM), TEM and SEM are generally used. As non-microscopic techniques, X-ray diffraction (XRD) and differential thermal analysis (DTA) have also been adopted in several standard methods. Different techniques have their own strong and weak points and different methods have their own applications. Therefore care should be taken to select and apply a standard method. The following present a review of existing standard testing methods related to asbestos in air or bulk materials for the monitoring of asbestos in occupational settings.

References

- **Asbestos in Air**

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2. National Institute for Occupational Safety and Health. Asbestos and other fibers by PCM. NMAM 7400. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 2003-154. 2003. Available from: http://www.cdc.gov/niosh/docs/2003-154/pdfs/7400.pdf

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5. National Occupational Health and Safety Commission. Guidance note on the membrane filter method for estimating airborne asbestos fibres. 2nd ed. National Occupational Health and Safety Commission. 2005. Available from: http://www.safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Documents/236/GuidanceNote_MembraneFilterMethodForEstimatingAirborneAsbestosFibres_2ndEdition_NOHSC3003-2005_PDF.pdf

6. Japanese Industrial Standard Organization. Determination of airborne fibrous particles - Part 1: Optical microscopy method and scanning electron microscopy method. JIS K 3850-1. 2006.

7. National Institute for Occupational Safety and Health. Asbestos by TEM: NMAM 7402. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 2003-154. 2003. Available from: http://www.cdc.gov/niosh/docs/2003-154/pdfs/7402.pdf

8. Environmental Protection Agency (EPA), US. 40CFR Part 763 Appendix A to Subpart E – Interim transmission electron microscopy analytical methods. Fed. Reg. 52(210), 41857-41894. 1987. Available from: http://www.epa.gov/asbestos/pubs/2003pt763.pdf

9. International Organization for Standardization. Ambient air - Determination of asbestos fibres - direct-transfer transmission electron microscopy method. ISO 10312. International Organization for Standardization. Geneva. 1995.

10. International Organization for Standardization. Ambient air – Determination of asbestos fibres - indirect-transfer transmission electron microscopy method. ISO 13794. International Organization for Standardization. Geneva. 1999.

11. American Society for Testing and Materials. Standard practice for sampling and counting airborne fibers, including asbestos fibers, in the workplace, by phase contrast microscopy (with and option of transmission electron microscopy). ASTM D7201-06. American Society for Testing and Materials. 2006.

12. American Society for Testing and Materials. Standard test method for airborne asbestos concentration in ambient and indoor atmospheres as determined by transmission electron microscopy direct transfer (TEM). ASTM D6281-09. American Society for Testing and Materials. 2009.

13. International Standards Organization. Ambient air: Determination of numerical concentration of inorganic fibrous particles - scanning electron microscopy method. ISO 19466. International Organization for Standardization. Geneva. 2002.

- **Asbestos in bulk materials**

14. National Institute for Occupational Safety and Health. Asbestos (bulk) by PLM . NMAM 9002. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 2003-154. 2003. Available from: http://www.cdc.gov/niosh/docs/2003-154/pdfs/9002.pdf

15. Occupational Safety and Health Administration(OSHA), US. OSHA ID-191, Polarized light microscopy of asbestos – Non-mandatory 1915.1001 App K, Occupational Safety and Health Standards for Shipyard Employment, Subpart Z: Toxic and Hazardous Substances. Fed. Reg., 59(113), 40964, 1994. Available from: http://www.osha.gov/dts/sltc/methods/inorganic/id191/id191.html

16. Environmental Protection Agency (EPA), US. Method for the determination of asbestos in bulk building materials. EPA 600-R-93-116. 1993. Available from: http://www.epa.gov/ne/info/testmethods/

17. Health and Safety Executive (HSE), UK. Appendix 2: Asbestos in bulk materials: Sampling and identification by polarized light microscopy (PLM). In: Asbestos: The analysts' guide for sampling, analysis and clearance procedures. Health and Safety Executive. 2005. p. 65-84. Available from: http://www.hse.gov.uk/pubns/books/hsg248.htm

18. Standards Australia International. Method for the qualitative identification of asbestos in bulk samples. AS4964-2004. Standards Australia International Ltd. Sydney. 2004.

19. National Institute for Occupational Safety and Health. Asbestos, chrysotile by XRD. NMAM 9000. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 2003-154. National Institute for Occupational Safety and Health. 2003. Available from: http://www.cdc.gov/niosh/docs/2003-154/pdfs/9000.pdf

20. Japan Standard Association. Determination of asbestos in building material products. JIS A 1481. Japan Standard Association. Akasaka. 2008.

1. World Health Organization (WHO). Determination of airborne fibre number concentration: A recommended method by PCM (membrane filter method). Geneva. 1997.

Background: This sampling and analytical method for asbestos in air, generally called the WHO method, was established and recommended by the WHO to unify various methodologies for the evaluation of airborne fibers, including asbestos in the work environment.

Objective: This method measures the airborne concentration of countable fibers using. Countable fibers are defined as particles with length >5 ㎛, width <3 ㎛ and aspect ratio (length: width ratio) >3:1. The collection of airborne asbestos fibers using calibrated sampling pumps with mixed-cellulose ester (MCE) filters and the analysis by PCM are described.

Asian Context: WHO method is one of the representative PCM-based methods which can be taken into account as a national standard testing method of airborne asbestos in a work environment for Asian countries. This PCM-based method is inexpensive, time-efficient and suitable for the monitoring of airborne asbestos in work environment and its control.

Critical Appraisal: This method does not provide positive confirmation of asbestos fibers. Alternative differential counting techniques should be used if discrimination is desirable. Supplementary methods for the differentiation of fiber types are discussed in Annex 2.

Available from:
http://www.who.int/occupational_health/publications/airfibre/en/index.html

2. National Institute for Occupational Safety and Health (NIOSH). Asbestos and other fibers by PCM: NMAM 7400. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 94-113. 1994 Aug.

Background: This document, generally called the NIOSH 7400, is a method for sampling and analyzing contaminants in workplace air. This method has been developed by NIOSH and evaluated according to established experimental protocols and performance criteria.

Objective: This method measures the airborne concentration of countable fibers using PCM. Countable fibers are defined as particles with length >5 ㎛ and aspect ratio (length: width ratio) >3:1. The collection of airborne asbestos fibers using calibrated sampling pumps with mixed-cellulose ester (MCE) filters and the analysis by PCM are described.

Asian Context: The NIOSH 7400 method is one of the representative PCM-based methods which can be taken into account as a national standard testing method of airborne asbestos in a work environment by Asian countries. This PCM-based method is inexpensive, time-efficient and suitable for the monitoring of airborne asbestos in work environment and its control.

Critical Appraisal: This method specifies the airborne fiber counting process and the result does not provide positive confirmation of asbestos fibers. Alternate differential counting techniques should be used if discrimination is desirable. As a supplementary method, Method 7402, which uses TEM, is provided in the NIOSH Manual of Analytical Methods.

Available from:
http://www.cdc.gov/niosh/docs/2003-154/pdfs/7400.pdf

3. Occupational Safety and Health Administration (OSHA), US. Asbestos in air. ID-160.

Background: This document is a method for sampling and analyzing contaminants in workplace air. This method was designed and tested for internal use by OSHA personnel to determine compliance to OSHA permissible exposure level (PEL).

Objective: This method measures the airborne concentration of countable fibers using PCM. Countable fibers are defined as particles with length >5 μm and aspect ratio (length: width ratio) >3:1. The collection of airborne asbestos fibers using calibrated sampling pumps with mixed-cellulose ester (MCE) filters and the analysis by PCM are described.

Asian Context: This PCM-based method is inexpensive, time-efficient and suitable for the monitoring of airborne asbestos in work environment and its control. This method shows an example for Asian countries that PCM-based method can be used for the determination of compliance to national control limit on asbestos work.

Critical Appraisal: OSHA adopted this method for the determination of compliance, although it does not provide positive confirmation of asbestos fibers. Practical maximum air sample volumes for specific environments are also suggested in this method.

Available from:
http://www.osha.gov/dts/sltc/methods/inorganic/id160/id160.html

4. Health and Safety Executive (HSE), UK. Appendix 1: Fibres in air: Sampling and evaluation of by phase contrast microscopy (PCM). Asbestos: The analysts' guide for sampling, analysis and clearance procedures. HSE. 2005. p. 45-63.

Background: This sampling and analytical method was described for the measurement of airborne fiber concentrations and recommended by the HSE in the UK. This method replaced the previously recommended guidance in MDHS39/4.

Objective: This method measures the airborne concentration of countable fibers using PCM. Countable fibers are defined as particles with length >5 ㎛, width <3 ㎛ and aspect ratio (length: width ratio) >3:1. The collection of airborne asbestos fibers using calibrated sampling pumps with mixed-cellulose ester (MCE) filters and the analysis by PCM are described.

Asian Context: This method can be used not only for measuring airborne asbestos concentration in the workplace but also for clearance testing of asbestos abatement sites in the UK. This method shows an example for Asian countries that the PCM-based method can be used for the site assessment for reoccupation of asbestos abatement sites, although the US, EPA adopts the TEM-based method for same purpose in AHERA.

Critical Appraisal: Detailed uncertainty budget of the method is exemplified in this method. Other fibers which are not asbestos may be included in the count unless differential counting is performed. HSE recommends that discrimination against non-asbestos fibers should be applied after the initial total count. Several differential counting techniques of airborne asbestos fibers are well discussed in MDHS 100 by HSE.

Available from:
http://www.hse.gov.uk/pubns/books/hsg248.htm

5. National Occupational Health and Safety Commission (NOHSC). Guidance note on the membrane filter method for estimating airborne asbestos fibres. 2nd ed. NOHSC. 2005.

Background: This sampling and analytical method was issued to provide laboratories and analysts with a consistent methodology for the sampling and analysis of airborne asbestos fibers in workplaces by the NOHSC in Australia.

Objective: This method measures the airborne concentration of countable fibers using PCM. Countable fibers are defined as particles with length >5 ㎛, width <3 ㎛ and aspect ratio (length: width ratio) >3:1. The collection of airborne asbestos fibers using calibrated sampling pumps with mixed-cellulose ester (MCE) filters and the analysis by PCM are described.

Asian Context: This method can be used not only for measuring airborne asbestos concentration in the workplace but also for clearance testing of asbestos abatement sites in Australia. This method shows an example for Asian countries that the PCM-based method can be used for the site assessment for reoccupation of asbestos abatement sites, although the US. EPA adopts the TEM-based method for same purpose in AHERA.

Critical Appraisal: Detailed sampling strategies according to the purpose are well discussed in this method. Several technical processes such as microscope adjustment procedure and calibration are well described in this method. This method does not provide positive confirmation of asbestos fibers. Alternate differential counting techniques should be used if discrimination is desirable.

Available from:
http://www.safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Documents/236/GuidanceNote_MembraneFilterMethodForEstimatingAirborneAsbestosFibres_2ndEdition_NOHSC3003-2005_PDF.pdf

6. Japanese Industrial Standard Organization. Determination of airborne fibrous particles - Part 1: Optical microscopy method and scanning electron microscopy (SEM) method. JIS K 3850-1. 2006.

Background: This sampling and analytical method for asbestos in air provides detailed procedure for sampling and analysis of fibrous particles in air using PCM, dispersion staining PCM (DS-PCM) and SEM.

Objective: This method measures the airborne concentration of countable fibers using PCM and differential counting techniques are applied using DS-PCM or SEM. Countable fibers are defined as particles with length >5 μm, width <3 μm and aspect ratio (length: width ratio) >3:1.

Asian Context: Asian countries adopting the area sampling technique as a national sampling strategy need to refer to the sampling process of this method. In addition, the DS-PCM-based technique is a rapid and inexpensive differential counting method compared to analytical electron microscopy (AEM)-based techniques.

Critical Appraisal: This method is valuable because both area sampling and DS-PCM-based technique were detailed.

7. National Institute for Occupational Safety and Health (NIOSH). Asbestos by TEM: NMAM 7402. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 94-113. 1994 Aug.

Background: This method, generally called NIOSH 7402, provides detailed procedure for sampling and analyzing fibrous particles in air using TEM. This method has been developed by NIOSH and evaluated according to established experimental protocols and performance criteria and generally applicable to monitoring of workplace exposure to asbestos.

Objective: This method is a supplementary differential counting method of asbestos and measures the ratio of asbestos to total PCM-countable fibers using TEM. The collection of airborne asbestos fibers using calibrated sampling pumps with MCE filters and analysis by TEM are described. Countable fibers are defined as particles with length >5 ㎛ and aspect ratio (length: width ratio) >3:1.

Asian Context: The NIOSH 7402 method is one of the representative differential counting methods of airborne asbestos using TEM. However, this TEM-based method is expensive and its long turna-round restricts availability for monitoring of work control.

Critical Appraisal: This method provides positive confirmation of asbestos fibers in PCM-countable fibers but should be applied with the PCM method. The accuracy of this method is not covered in this method.

Available from:
http://www.cdc.gov/niosh/docs/2003-154/pdfs/7402.pdf

8. Environmental Protection Agency (EPA), US. 40CFR Part 763 Appendix A to Subpart E – Interim TEM analytical methods. Fed. Reg. 52(210), 41857-41894. 1987.

Background: This method, generally called the AHERA TEM, provides detailed procedure for sampling and analyzing asbestos in air using TEM. This method has been issued by the US. EPA to determine completion of response actions such as asbestos abatement in school buildings under the Asbestos Hazard Emergency Response Act (AHERA) in the US.

Objective: For abatement clearance, five or more area air samples inside the containment are compared with five or more area air samples collected outside the containment. Countable fibers are defined as particles with length >0.5 ㎛, width >0.002 ㎛ and aspect ratio (length: width ratio) >5:1. Detailed sampling and pretreatment and analysis procedures are specified.

Asian Context: As a standard testing method for clearance testing of asbestos abatement sites, the US. EPA applies this TEM-based method. When introducing the TEM-based method as a national standard testing method, its cost and effectiveness should be taken into account. Although there are some controversies on using the PCM-based method for clearance testing, many developed countries did not adopt the TEM-based method like the US.

Critical Appraisal: This method specifies a detailed direct TEM analysis method which is generally applied in other TEM methods in the US. The analysis results cannot be directly compared with current occupational exposure limits on asbestos.

Available from:
http://www.epa.gov/asbestos/pubs/2003pt763.pdf

9. International Organization for Standardization. Ambient air - Determination of asbestos fibres - direct-transfer TEM method. ISO 10312. 1995.

Background: This method provides a detailed procedure for sampling and analyzing asbestos in ambient atmospheres using TEM.

Objective: The method is defined for polycarbonate capillary-pore filters or cellulose ester (either mixed esters of cellulose or cellulose nitrate) filters through which a known volume of air has been drawn. The method is suitable for determining asbestos in both exterior and building atmospheres. Countable asbestos fibers are defined as asbestos structures with length >0.5 μm, width >0.002 μm and aspect ratio (length: width ratio) >5:1. PCM equivalent fibers with length >5 μm, width >0.25 μm and aspect ratio (length: width ratio) >3:1 are also counted.

Asian Context: This method is one of the representative direct TEM methods frequently used and its appendices include specific technical details that are very useful for the introduction of TEM microscopy for Asian countries. Valuable discussions on the calibration procedure and determination process of asbestos are well provided in this method.

Critical Appraisal: This method provides a specified and refined technique using TEM that permits characterization of both fiber size and type. In order to compare the analysis results of this method directly with current occupational exposure limits on asbestos, analysis results of PCME fibers should be used.

10. International Organization for Standardization. Ambient air – determination of asbestos fibres - indirect-transfer TEM method. ISO 13794. 1999.

Background: This method provides a detailed procedure for sampling and analyzing asbestos in ambient atmospheres using TEM.

Objective: The method is defined for polycarbonate capillary-pore filters or cellulose ester (either mixed esters of cellulose or cellulose nitrate) filters through which a known volume of air has been drawn. The method is suitable for determining asbestos in both exterior and building atmospheres. Countable asbestos fibers are defined as asbestos structures with length >0.5 μm, width >0.002 μm and aspect ratio (length: width ratio) >5:1.

Asian Context: This method is one of the representative indirect TEM methods frequently used and its appendices include specific technical details that are very useful for the introduction of TEM microscopy for Asian countries. Valuable discussions on the calibration procedure and determination process of asbestos are well provided in this method.

Critical Appraisal: This method provides a specified and refined indirect analysis method using TEM. Because asbestos bundles can be separated into thinner fibers or bundles, care should be taken to compare analysis results of this method directly with current occupational exposure limits on asbestos.

11. American Society for Testing and Materials (ASTM). Standard practice for sampling and counting airborne fibers, including asbestos fibers, in the workplace, by phase contrast microscopy (PCM; with the option of transmission electron microscopy; TEM). ASTM D7201-06. 2006.

Background: This method, issued by the ASTM, provides a detailed procedure for determining the concentration of fibers using PCM and optionally TEM to evaluate particulate material collected on a membrane filter in the breathing zone of an individual or by area sampling in a specific location.

Objective: The method is defined for cellulose ester (either mixed esters of cellulose or cellulose nitrate) filters, housed in a conductive polypropylene cassette, through which a known volume of air has been drawn. Countable asbestos fibers are defined as asbestos structures with length >5 ㎛, width >0.2 ㎛ and aspect ratio (length: width ratio) >3:1.

Asian Context: Introducing the PCM-based method followed by the TEM-based method for the counting of PCME fibers is the most widely used technique to determine the concentration of airborne asbestos in occupational settings. This method gives a good example of the combination of these two methods.

Critical Appraisal: This method provides specified and detailed procedures for the analysis of airborne fibers with PCM and TEM that is similar to the NIOSH 7400 and 7402 methods.

12. American Society for Testing and Materials (ASTM). Standard test method for airborne asbestos concentration in ambient and indoor atmospheres as determined by transmission electron microscopy direct transfer (TEM). ASTM D6281-09. 2009.

Background: This method, issued by ASTM, provides a detailed procedure for determining the concentration of airborne asbestos in a wide range of ambient air situations and for detailed evaluation of any atmosphere in which asbestos structures are likely to be present.

Objective: The method is defined for cellulose ester (either mixed esters of cellulose or cellulose nitrate) filters, housed in a conductive polypropylene cassette, through which a known volume of air has been drawn.

Asian Context: This method provides specified technical details on a direct TEM method that will be valuable for Asian countries.

Critical Appraisal: As most fibers in ambient atmospheres are not asbestos, such fibers need to be identified. Most of the airborne asbestos fibers in ambient atmospheres have diameters below the resolution limit of optical microscopy. This test method is based on TEM, which has an adequate resolution to allow detection of small thin fibers and is capable of unequivocal identification of the majority of individual fibers of asbestos.

13. International Standards Organization. Ambient air: Determination of numerical concentration of inorganic fibrous particles - SEM method. ISO 19466. Geneva. 2002.

Background: This method provides detailed procedure for sampling and analyzing inorganic particles in ambient atmospheres using SEM.

Objective: The method specifies the use of gold-coated, capillary-pore, track-etched membrane filters, through which a known volume of air has been drawn. Using energy-dispersive X-ray analysis, the method can discriminate between fibers with compositions consistent with those of the asbestos varieties (e.g., serpentine and amphibole), gypsum and other inorganic fibers. Annex C in this method provides a summary of fiber types which can be measured. Countable fibers are defined as particles with length >5 μm, width 0. 2-3 μm and aspect ratio (length: width ratio) >3:1.

Asian Context: SEM is less positive than TEM in its ability to differentiate between asbestos and non-asbestos fibers. However the SEM-based method is applicable to the discriminatory counting of airborne fibers at a lower cost than the TEM-based method.

Critical Appraisal: This method provides a specified and refined technique using SEM that permits characterization of both fiber size and type.

14. National Institute for Occupational Safety and Health (NIOSH). Asbestos (bulk) by PLM. NMAM 9002. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 2003-154. 2003.

Background: This method describes the collection and analysis of asbestos bulk materials by PLM techniques including central-stop dispersion microscopy. This method has been developed by NIOSH and evaluated according to established experimental protocols and performance criteria.

Objective: This method measures the presence of asbestos and its type and contents in a positive sample using PLM. Asbestos is identified on the basis of optical properties and its amount is estimated in relation to the rest of the bulk sample. The method estimates the asbestos percentage visually as perceived by the analyst in comparison to standard area projections, photos, and drawings, or trained experience.

Asian Context: This PLM procedure provides an economical technique for screening large numbers of samples. Despite some disadvantages, it is worth considering the PLM-based method for analyzing asbestos in bulk for Asian countries.

Critical Appraisal: This method is designed for use with NIOSH Methods 7400 (PCM) and 7402 (electron microscopy/EDS). This method provides a detailed procedure of bulk asbestos analysis using PLM. Any material which is long, thin, and small enough to be viewed under the microscope can be considered an interference for asbestos

Available from:
http://www.cdc.gov/niosh/docs/2003-154/pdfs/9002.pdf

15. Occupational Safety and Health Administration (OSHA), US. OSHA ID-191. Polarized light microscopy (PLM) of asbestos. ID-190

Background: This method describes the collection and analysis of asbestos bulk materials by PLM techniques including central-stop dispersion microscopy. This method was designed and tested for internal use by OSHA personnel to determine compliance to OSHA PEL.

Objective: This method measures the presence of asbestos and its type and contents in a positive sample using PLM. Asbestos is identified on the basis of optical properties and its amount is estimated in relation to the rest of the bulk sample. Quantitative estimates are given in terms of percentages.

Asian Context: This PLM procedure provides an economical technique for screening large numbers of samples. Despite some disadvantages, it is worth considering the PLM-based method for analyzing asbestos in bulk for Asian countries.

Critical Appraisal: This method provides a detailed procedure of bulk asbestos analysis using PLM. Any material which is long, thin, and small enough to be viewed under the microscope can be considered an interference for asbestos.

Available from:
http://www.osha.gov/dts/sltc/methods/inorganic/id191/id191.html

16. Environmental Protection Agency (EPA), US. Method for the determination of asbestos in bulk building materials. EPA 600-R-93-116. 1993.

Background: This method describes the analysis of asbestos bulk materials by PLM. Additional techniques and detailed procedures for sample preparation are also provided.

Objective: In this method, bulk asbestos is analyzed by stereomicroscopic examination always followed by PLM analysis. If additional techniques are needed to positively identify asbestos, accurately quantify the quantity of asbestos in the sample or perform quality assurance activities, XRD, (Ed- this acronym has already been defined above) analytical electron microscopy (AEM) or gravimetric method is applied.

Asian Context: The detailed procedures on sample preparation and quality control/quality assurance operations specified in this method are very valuable.

Critical Appraisal: This method is one the most commonly used analysis methods for asbestos in bulk samples.

Available from:
http://www.epa.gov/ne/info/testmethods/

17. Health and Safety Executive (HSE), UK. Appendix 2: Asbestos in bulk materials: Sampling and identification by polarized light microscopy (PLM). Asbestos: The analysts' guide for sampling, analysis and clearance procedures. HSE. 2005. p. 65-84.

Background: This method describes the collection and analysis of asbestos bulk materials by PLM techniques including central-stop dispersion microscopy.

Objective: This method identifies asbestos in a bulk sample using PLM. Asbestos is identified on the basis of optical properties. This method does not provide quantitative estimation of asbestos in samples.

Asian Context: This PLM procedure provides an economical technique for screening large numbers of samples. Despite some disadvantages, it is worth considering the PLM-based method for analyzing asbestos in bulk for Asian countries. The colored micrographs of the HSE reference samples in this method are also useful.

Critical Appraisal: This method is designed for use with the sampling procedures described in Chapters 3 and 4 of the HSE guidance book on asbestos analysts. This method provides a detailed procedure of bulk asbestos analysis using PLM. Any material which is long, thin, and small enough to be viewed under the microscope can be considered an interference for asbestos

Available from:
http://www.hse.gov.uk/pubns/books/hsg248.htm

18. Standards Australia International. Method for the qualitative identification of asbestos in bulk samples. AS4964-2004. Standards Australia International. 2004.

Background: This method describes the collection and analysis of asbestos bulk materials by PLM techniques including central-stop dispersion microscopy.

Objective: This method identifies asbestos in a bulk sample using PLM. Asbestos is identified on the basis of optical properties. This method does not provide quantitative estimation of asbestos in samples.

Asian Context: This PLM procedure provides an economical technique for screening large numbers of samples. Despite some disadvantages, it is worth considering the PLM-based method for analyzing asbestos in bulk for Asian countries. The guidelines and strategies for sampling and the flowchart for bulk asbestos identification in the appendix are also very informative.

Critical Appraisal: This method provides a detailed procedure of bulk asbestos analysis using PLM. This method also provides detailed preparation procedures for soil samples. The introduction of trace analysis for the negative samples is distinctive.

19. National Institute for Occupational Safety and Health (NIOSH). Asbestos, chrysotile by XRD. NMAM 9000. NIOSH Manual of Analytical Methods (NMAM) 4th ed. DHHS (NIOSH) Publication 2003-154. 2003.

Background: This method describes the analysis of chrysotile in bulk materials by XRD techniques. This method has been developed by NIOSH and evaluated according to established experimental protocols and performance criteria.

Objective: This method measures the weight percentages of chrysotile asbestos in a positive sample using XRD. The response of an unknown sample is compared to a calibration curve of standard chrysotile and the weight percentages are calculated. The working range of this method is from 1% to 100%.

Asian Context: This method is useful because the analysis results are close to the weight percentages. However, the high cost and complicated sample preparation and analysis process of this method should be taken into account for its availability.

Critical Appraisal: The XRD-based method should be applied in conjunction with another microscopic technique such as PLM and TEM because asbestiform and non-asbestiform minerals are not differentiated using the XRD technique.

Available from:
http://www.cdc.gov/niosh/docs/2003-154/pdfs/9000.pdf

20. Japan Standard Association. Determination of asbestos in building material products. JIS A 1481. Akasaka. 2008.

Background: This method describes the analysis of asbestos in bulk materials by XRD techniques coupled with dispersion staining PCM (DS-PCM).

Objective: The building material products to be measured with this method are fire proofing protecting coverings, interior finishing materials, floor tiles, exterior materials, roofing materials, chimney materials, heat insulating materials, textile goods, sealing compounds and expansion joints. This standard is mainly applied to materials with an asbestos content less than 5% in mass.

Asian Context: This method is useful because the analysis results are close to the weight percentages. However, the high cost and complicated sample preparation and analysis process of this method should be taken into account for its availability.

Critical Appraisal: The advantage of this XRD-based method is that its quantitative analysis results are close to the weight percentages of asbestos. However there is controversy on the availability of this method associated with low content samples nearby 0.1%.