1. Asbestos Exposure Assessment, Risk Identification, and Substitutes

1-A. Asbestos Hazard Identification

Objectives

This compendium describes the types of asbestos and their physical and chemical properties, together with their available hazard information. It is appended by a practical checklist for hazard identification used commonly in Japan.

Asian Context

Asbestos is still widely used in Asian countries, however, the basic information about asbestos hazards is lacking in the region. This compendium along with the reference documents should provide useful information on asbestos to promote better understanding of its hazard in the region and means for their identification.

References

IPCS Environmental Health Criteria 203 - Chrysotile Asbestos
Available from http://www.inchem.org/documents/ehc/ehc/ehc203.htm
(Accessed 11 August 2011)

IPCS Environmental Health Criteria 53 – Asbestos and Other Natural Mineral Fibres
Available from http://www.inchem.org/documents/ehc/ehc/ehc53.htm
(Accessed 11 September 2011)

Health Canada – Chrysotile Asbestos Consensus Statement and Summary – Chrysotile Asbestos Expert Panel
Available from http://bwcase.tripod.com/panel.pdf
(Accessed 31 August 2011)

European Commission – Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) – Risk to Human Health from Chrysotile Asbestos and Organic Substitutes
Available from http://ec.europa.eu/food/fs/sc/sct/out169_en.pdf
(Accessed 31 August 2011)

International Chemical Safety Data Card for Chrysotile, World Health Organization (WHO), ICSC 0014
Available from http://www.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=0014 (Accessed 28 June 2012)

International Chemical Safety Data Card for Chrysotile, World Health Organization (WHO), ICSC 1314

Available from http://www.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=1314 (Accessed 28 June 2012)

Cancer Control; Knowledge into Action, World Health Organization (WHO) Guide for Effective Programmes, Prevention

Available from http://www.who.int/cancer/modules/Prevention%20Module.pdf (Accessed 28 June 2012)

1. Asbestos - General information

Summary of IPCS Environmental Health Criteria 53 and IPCS Environmental Health Criteria 203

In general, the commercial term asbestos refers to a group of fibrous serpentine and amphibole minerals. The principal varieties of asbestos historically used in commerce are chrysotile, a serpentine mineral, and crocidolite and amosite, both of which are amphiboles. Anthophyllite, tremolite, and actinolite asbestos are also amphiboles, but they are rare, and the commercial exploitation of anthophyllite asbestos was discontinued. Since the turn of the century, amphiboles have not been used commercially.

Asbestos is a collective name given to minerals that occur naturally as fiber bundles and possess unusually high tensile strength, flexibility, and chemical and physical durability. Fiber bundles may be several centimeters long. Bundle diameters may vary significantly, but tend to be in the millimeter range. This has given rise to a technical grading based on fiber bundles, lengths, and diameters. However, when these fiber bundles are manipulated, they may break down into smaller units, a portion of which have dimensions in the submicron range. The asbestos minerals are not classified on a mineralogical basis, but rather on a commercial on a commercial basis because of their unique properties. The asbestos variety commercially known as crocidolite is referred to in the mineralogical literature as riebeckite. The asbestos variety called amosite is known mineralogically as grunerite. All other asbestos types are referred to by their proper mineral names.

The World Health Organization (WHO) declared that the principal varieties of asbestos (chryotile, crocidolite, amosite, anthophylite, tromolite and actinolite) **are all carcinogenic to humans**.

1.1 Asbestos hazard information

Inhalation is the main route of exposure to asbestos fibers. The most common asbestos-related diseases are pleural plaques, diffuse pleural thickening, asbestosis, lung cancer and mesothelioma. A well known characteristic of asbestos-related diseases, in general, and asbestos-related cancer, in particular is the long latency required for the development of the disease after initial exposure to asbestos.

1.1.1 Pleural plaques

Pleural plaques are discrete fibrous or partially calcified thickened areas arising from the surface of the parietal pleura and sometimes visualized on chest radiographs. Pleural plaques are an indicator of past asbestos exposure and can develop following low level of exposures. Pleural plaques generally do not in themselves cause respiratory symptoms but can complicate other asbestos-related diseases such as asbestosis, mesothelioma or lung cancer.

1.1.2 Diffuse pleural thickening

Diffuse pleural thickening can be considered as fibrosis of the pleura involving a wide surface area. It can involve both layers of the pleura, but particularly the inner lining. It is less common than pleural plaques but produces more symptoms due to the larger area affected. It is usually asymptomatic, but if extensive, it may cause shortness of breath and chest pain which usually develops 10-15 years after exposure.

Diffuse pleural thickening may occur with or without prior effusion. It may or may not be associated with asbestosis.

1.1.3 Asbestosis

Asbestosis is the pulmonary scarring or fibrosis of the lung tissue itself., People with extensive asbestosis experience severe shortness of breath and even die from this disease. The development of asbestosis normally follows high level of asbestos exposures with a latency of 15-30 years. The diagnosis of asbestosis is essentially made by radiological examination (chest X-ray and/or computed tomograhy)

1.1.4 Lung cancer

Asbestos exposure may also cause lung cancer with a latency period of 20 or more years. The risk of lung cancer increases if the individual has smoked cigarettes. Lung cancer is widely accepted as due to asbestos exposure if there is concomitant asbestosis, but the attribution is less clear with lower levels of asbestos exposure. Symptoms include chronic cough, breathlessness and chest pain as well as haemoptysis (coughing up blood), hoarseness of the voice and wheezing. Lung cancer induced by asbestos exposure is indistinguishable from that caused by other agents.

1.1.5 Mesothelioma

Malignant mesothelioma is an aggressive and fatal cancer of the parietal pleural that is primarily caused by asbestos exposure. There is scientific consensus that approximately 85% of mesothelioma cases are due to asbestos exposure., In general, the riskof mesothelioma is greater for crocidolite than other asbestos varieties. Malignant mesothelioma has also been documented to develop after domestic forms of exposure, e.g., laundry of contaminated clothing. Another important scientific consensus is that smoking does not influence the risk of mesothelioma. The latency period between first exposure to asbestos and the development of mesothelioma ranges from 15 to40 or more years. Weight loss, fever and night sweating are examples of early symptoms but may be subtle. Chest pain, breathlessness on exertion and/or pleural effusion are frequently present at the time of diagnosis. Individuals with malignant mesothelioma have a very short survival time of less than 18 months after diagnosis. Currently, there is no proven cure for malignant mesothelioma, although some treatments may prolong survival.

2. Chrysotile

Summary of IPCS Environmental Health Criteria 53 and IPCS Environmental Health Criteria 203, and Health Canada – Chrysotile Asbestos Consensus Statement and Summary – Chrysotile Asbestos Expert Panel

2.1 Background

The IPCS (International Programme on Chemical Safety) Environmental Health Criteria (203) was produced to describe chrysotile asbestos. **Chrysotile**, commonly referred to as **white asbestos**, is a naturally occurring fibrous hydrated magnesium silicate belonging to the serpentine group of minerals.

2.2 Chemical composition

The composition of chrysotile is close to the ideal unit cell formula ($Mg_3Si_2O_5(OH)_4$). Substitution by other elements in the crystal structure is possible.

2.3 Structure

Chrysotile is a sheet silicate with a basic building block of $(Si_2O_5)_n$ in which three of the oxygen atoms in each tetradedron base are shared with adjacent tetrahedral in the same layer.

2.4 Fiber properties

In terms of the relative flexibility, fibers may be "harsh" or "soft". Chrysotile fibers generally occur with properties between these end-types. Harsh chrysotile fibers tend to be straighter and less flexible than the soft fibers. Inhalation of respirable straight fibers is known to be associated with increased penetration to the terminal bronchioles than in the case of "curly" fibers. The fibers can be classified into crude chrysotile (hand-selected fibers in essentially native or unfiberized form) and milled fibers (after mechanical treatment of the ore).

2.5 Associated minerals in chrysotile ore

The mineral dusts to which miners or millers may be exposed are determined by the minerals associated with each of the chrysotile ore deposits. These depend on the composition of the original rock types and on the materials added or removed during geological events, e.g., surface weathering processes, etc. The spatial relationships among these components within ore bodies vary significantly from deposit to deposit.

Iron is ubiquitous in chrysotile deposits derived from ultramafic rocks. In some of these, magnetite occurs in intimate association with the fibers. In other deposits types, e.g., in carbonate rocks, the iron content is low. Brucite, or nemalite (the fibrous from of brucite) is found in some deposits. Micas, feldspars, altered feldspars, talc and carbonate minerals may be present. Trace metals have been described in association with fibers, particularly chromium, cobalt, nickel, iron and manganese.

Naturally occurring chrysotile has been shown to contain trace quantities of organic compounds, which are predominantly straight-chain alkanes. Processed fibers may also contain organic compounds including polycyclic aromatic hydrocarbons.

2.6 Physical properties

Heating of chrysotile fiber at 700°C for an hour converts it to an amorphous, anhydrous magnesium silicate material. Intensive dry grinding also destroys the structure of chrysotile. Analysis of wear debris from brake linings made with asbestos has shown that virtually all of the chrysotile fiber is converted to amorphous material, in association with the mineral forsterite (a recrystallization product).

Size and shape are the most important characteristics for defining the respirability of fibers. Chrysotile fibrils are long, flexible, and curved, and they tend to form bundles that are often curvilinear with splayed ends. Such bundles are held together by hydrogen bonding and/or extrafibril solid matter. Chrysotile fibers naturally occur in lengths varying from 1 to 20 mm, with occasional specimens as long as 100 mm.

Chrysotile bundles may be split longitudinally to form thinner fibers. The fibers of significance in health risk evaluation are those that can be inhaled. Chrysotile fibers less than about 3.5 μm in diameter can enter the conducting airways of the lung. The radius of the curvature of chrysotile fiber may play a role in the ability of a fiber to penetrate to distant sites along the conducting airways. The vast majority of airborne chrysotile fibers are short. The percentage of fibers more than 5 μm long in mining and milling is about 1.3 and 4.1%, respectively. Up to 24% of fibers may be longer than 5 μm in certain textile spinning operations. Virtually all airborne fibers have a diameter of less than 3 μm which are respirable. The cross-section of a chrysotile fibril is approximately circular. This is important in calculating the mass of individual fibers. Generally, the surface area depends on the degree of fiber openness. It has been suggested that surface area plays a role in imparting biological potential. Industrial processing of fibers from different sources may affect total airborne dust concentrations.

2.7 Chemical properties

Chrysotile exhibits significant solubility in aqueous neutral or acidic environment. Chrysotile fibers are almost completely destroyed within 1 hour when placed in hydrochloride acid at 95ºC. Chrysotile is highly susceptible to acid attack, but it is more resistant to attack by sodium hydroxide than any of the amphibole fibers.

Exposure to acid results in the liberation of magnesium ions and the formation of a siliceous residue. In contact with diluted acids or aqueous medium at pH less than 10, magnesium leaches from the outer brucite layer. The surface area of leached chrysotile is greatly increased. The solubility of the outer brucite layer of chrysotile in body fluids greatly affects bioaccumulation in lung tissue. The role of chemical properties in the biological behavior of chrysotile is important in that the adsorption of polar organic agents on the surface of chrysotile is higher than that of less polar or non-polar agents. Adsorption of components of cigarette smoke onto the surface of chrysotile fiber has been suggested to play a role in the etiology of lung cancer in fiber-exposed cigarette smokers.

2.8 Hazard information

The interaction of chrysotile fibers with the DNA in mammalian cells may result in chromosomal or mutational events that can initiate carcinogenesis or genetic damage. The ability of chrysotile to induce inflammation, oxidative stress and genotoxicity in several cell and animal experimental systems has been confirmed. It has been confirmed that animals incurred chrysotile-induced fibrosis.

Human studies have detected increased levels of DNA damage (8-hydroxyguanine adducts and strand fragmentation) in the blood cells of workers occupationally exposed to asbestos (primarily chrysotile, but also to other forms of asbestos, including crocidolite). Although levels of 8-hydroxyguanine were higher in asbestos-exposed workers than in the control group, no correlation with the duration, level or latency of exposure was found. The assessment of dose- and time-response relationships is thus difficult.

Occupational exposure to chrysotile in a working population has caused a high incidence of lung cancer as well as of pleural and peritoneal mesotheliomas. Although to a much lesser extent, cancers of the gastrointestinal tract and larynx have been demonstrated to increase in groups exposed occupationally to chrysotile.

3. Amphibole fibers

Summary of IPCS Environmental Health Criteria 53

3.1 Background

The International Programme on Chemical Safety (IPCS), Environmental Health Criteria (53) gives description on the amphibole type of asbestos. Amphibole type asbestos consists of crocidolite (commonly referred to as blue asbestos), amosite (brown asbestos), anthophyllite, tremolite and actinolite. They are naturally occurring fibers which consist of double chains of silica tetrahedral cross-linked with bridging cations.

3.2 Chemical composition and structure

Magnesium, iron, calcium, and sodium are the principal cations in the amphibole structure.

The compositions of crocidolite, amosite, anthophyllite, tremolite and actinolite are as follows:

Crocidolite: $Na_2FeII_3FeIII_2 (Si_8O_{22}) (OH)_2$
Amosite: $(Fe, Mg)_7 (Si_8O_{22}) (OH)_2$
Anthophyllite: $(Mg, Fe)_7 (Si_8O_{22}) (OH)_2$
Tremolite: $Ca_2Mg_5 (Si_8O_{22}) (OH)_2$
Actinolite: $Ca_2(Mg, Fe)_5 (Si_8O_{22}) (OH)_2$.

The amphibole structure allows great latitude in cation replacement, and the chemical composition and physical properties of various amphibole asbestos fibers cover a wide range. Only rarely does the composition of a field sample coincide with the assigned theoretical or idealized formula. However, theoretical compositions are used for identifying the various fibers as a matter of convenience.

3.3 Fiber properties

The breakage (both parting and cleavage) of amphiboles occurs along defined crystallographic planes. Parting along some of these surfaces may result in fibrils of amphibole, which are typically 4.0 nm in diameter. The mechanism of amphibole breakage is important with reference to: i) resultant particle number, ii) surface area, iii) general respirability (all of which control penetration to target cells and delivered dose), and iv) expressed chemical information contained on the fiber surface.

3.3.1 Crocidolite

Crocidolite is represented by the "idealized" empirical formula where iron can be partially substituted by Mg^{2+} within the structure. Typical crocidolite fiber bundles easily disperse into fibers that are shorter and thinner than other amphibole asbestos fibers, similarly dispersed. However, these ultimate fibrils are generally not as small in diameter as fibrils of chrysotile. In comparison with other amphiboles or chrysotile, crocidolite has a relatively poor resistance to heat, but its fibers have been used extensively in applications requiring good resistance to acids. Crocidolite fibers have fair to good flexibility, fair spinnability, and a texture ranging from soft to harsh. Unlike chrysotile, crocidolite is usually associated with organic impurities, including low levels of polycyclic aromatic hydrocarbons.

Physical and chemical properties of crocidolite are summarized as follows:
Decomposition temperature: 400-600 ºC
Fusion temperature of residual material: 1,200 ºC
Density: 3.3 – 3.4 g/cm^3
Resistance to acids: good
Resistance to alkalis: good

3.3.2 Amosite
The Fe^{2+} to Mg^{2+} ratio varies within the structure, but is usually about 5.5 : 1.5. Amosite fibrils are generally larger in diameter than those of crocidolite, but smaller than particles of anthophyllite asbestos similarly comminuted (breaking into very small parts). Most amosite fibrils have straight edges and characteristic right-angle fiber axis terminations.

Physical and chemical properties of amosite are summarized as follows:
Decomposition temperature: 600-800 ºC
Fusion temperature of residual material: 1,400 ºC
Density: 3.4 – 3.5 g/cm^3
Resistance to acids: attacked slowly
Resistance to alkalis: good

3.3.3 Anthophyllite
Anthophyllite is a relatively rare, fibrous, orthorhombic (a structure characterized by three unequal axes at right angles to each other), magnesium-iron amphibole, which occasionally occurs as a contaminant in talc deposits. Typically, anthophyllite fibrils are more massive than other common forms of asbestos.

Physical and chemical properties of anthophyllite are summarized as follows:
Decomposition temperature: 600-850 ºC
Fusion temperature of residual material: 1,450 ºC
Density: 2.85 – 3.1 g/cm^3
Resistance to acids: very good
Resistance to alkalis: very good

3.3.4 Tremolite and actinolite
Tremolite is a monoclinic (structure characterized by 3 unequal axes with 2 perpendicular and 1 oblique intersection) calcium-magnesium amphibole, and its iron-substituted derivative is actinolite asbestos. Both rarely occur in the asbestos habit, but are common as contaminants of other asbestos deposits. Actinolite occurs as a contaminant of both chrysotile and talc deposits. Tremolite fibrils range in size but may approach the dimensions of fibrils of crocidolite and amosite.

Physical and chemical properties of tremolite are summarized as follows:
Decomposition temperature: 950-1,040 ºC
Fusion temperature of residual material: 1,315 ºC
Density: 2.9 – 3.1 g/cm^3
Resistance to acids: very good
Resistance to alkalis: good

Physical and chemical properties of actinolite are summarized as follows:
Decomposition temperature: 620-960 ºC
Fusion temperature of residual material: 1,400 ºC
Density: 3.0 – 3.2 g/cm^3
Resistance to acids: attacked slowly
Resistance to alkalis: good

3.4 Hazard information

Occupational exposure to amosite, anthophyllite and mixed fibers in a working population has caused a high incidence of lung cancer. A predominantly tremolitic material mixed with anthophyllite has also caused an increased incidence of lung cancer. Many pleural and peritoneal mesothelioma cases have been observed after occupational exposure to crocidolite and amosite. An excess risk of gastrointestinal tract and laryngeal cancers has been demonstrated in groups exposed to amosite or mixed fibers containing crocidolite in occupational settings. Mesothelioma also occurs among individuals living in the vicinity of the crocidolite mines and by household contacts of workers.

3.5 Hazard identification via checklist

"Checklist for Asbestos Exposure"

Study No.: Informant's name:
Address:
Phone:
Relationship:

I. Have you ever worked in the following industries?

- ☐ Mining (of what?____________________)
- ☐ Shipbuilding
- ☐ Cement
- ☐ Smelting
- ☐ Metal grinding / polishing
- ☐ Plastic materials
- ☐ Shoes manufacture / repair
- ☐ Furniture / wooden product manufacture
- ☐ Gas industry
- ☐ Construction
- ☐ Chemicals production
- ☐ Insulation
- ☐ Refinery

- ☐ Casting / minting
- ☐ Chromic acid production
- ☐ Rubber products
- ☐ Printing
- ☐ Steel industry
- ☐ Paper / pulp production

II. Occupation from graduation of school to present
(include part-time job during student time; work during the war; short-term work and any other work)

Company name	Company location / address	Content of work of the company	Content of your work in the company	Materials and equipment at work	Working duration (YY/MM-YY/MM)

III. Have you ever worked at the following places?

1. ☐ Factory handling asbestos ☐ Warehouse for asbestos products
2. ☐ Construction
   ☐ Building demolition
   - ☐ Painting / spraying work ☐ Soundproofing work
   - ☐ Insulation / fireproof / thermal work ☐ Prefabricated (asbestos mill board) factory
   - ☐ Cutting of ceiling / flooring materials ☐ Corrugated concrete sheet factory
   - ☐ Electricity / gas / steam pipe laying work
3. ☐ Shipbuilding industry
   ☐ Ship repairing / breaking industry
   - ☐ Pipe wrapping / insulation work
   - ☐ Electric wiring works
   - ☐ Welding
   - ☐ Sheet metal processing
   - ☐ Crane / car operating
   - ☐ Clerical worker
   - ☐ Boiler manufacture / equipment
   - ☐ Maintenance (pipe; boiler)
   - ☐ Painting

☐ Carpenter
☐ Worker
☐ Other ______________________________

4. ☐ Insulation work ☐ Thermal work
5. ☐ Boiler manufacture / install / repair ☐ Burner manufacture / install / repair
   ☐ Blast furnace manufacture / install / repair ☐ Steam / pipe manufacture / install / repair
6. ☐ Boiler operating
   ☐ Welding work
   ☐ Sheet metal processing
   ☐ Work which require wearing heat-resistant clothes or fireproof gloves
7. ☐ Car repair work
   ☐ Gasoline station
   ☐ Manufacture of brake / lining / clutches
8. ☐ Production of electric appliances (condenser / electric battery / car battery / insulating tape)
9. ☐ Painting factory ☐ Soap factory
   ☐ Oil / chemical refinery factory
10. ☐ Laundry / cleaning shop ☐ Handling of working clothes contaminated with dust
11. ☐ Transportation of things contaminated with dust
    ☐ Merchantship sailor ☐ Truck-driver ☐ Railway worker
    ☐ Lighterman ☐ Harbor worker ☐ Crane operating worker
12. ☐ Sewage / waste collection / waste disposal / waste transportation
13. ☐ Repair / disassemble of steam locomotives
14. ☐ Gasmask production
15. ☐ Handiwork of jewelry / precious metals
16. ☐ Fire fighter
17. ☐ Dental hygienist

IV. Have you ever been engaged in work handling the following asbestos products?

☐ Asbestos fiber
☐ Asbestos pipe
☐ Asbestos tube
☐ Asbestos cement sheet / tube
☐ Asbestos rolled paper
☐ Asbestos gasket
☐ Asbestos tape
☐ Asbestos insulation felt
☐ Cardboard / insulation sheet
☐ Asbestos textile / cloth

- □ Asbestos rope
- □ Asbestos packing
- □ Asbestos curtain
- □ Asbestos paper
- □ Asbestos pipe line felt
- □ Insulation pad (for packing)
- □ Others ____

V. Have you (interviewee) ever worked near by the following works which were done by someone?

1. □ Installation / removal of insulation pad (for packing)
2. □ Installation / removal of asbestos pipes
3. □ Welding
4. □ Installation / removal of pipes wrapped with thermal materials
5. □ Attaching / removal of precut asbestos blocks
6. □ Attaching / removal of asbestos wall boards / asbestos cardboards
7. □ Attaching / removal of fireproof coating for props / partitions (bulkhead) / girders
8. □ Installation / removal of valves and packing
9. □ Roll / peel boilers and boiler pumps with thermal materials
10. □ Roll / peel steam tubes with insulation materials
11. □ Cut asbestos tube / pipe / board / cardboard / insulation materials or install them

VI.

1. □ At home, have you ever had fixing / repairing work (insulating things, heating furnace cement / insulator / water-based painting of ceiling and wall / asbestos product)
2. □ Have you ever used talc powder (body-talc, talc for face care)?
3. □ At home, have you ever used asbestos products (ironing board cover / heat-resistant gloves)?
4. □ Have you ever lived near an asbestos factory?
   □ Have you ever lived near a shipbuilding factory?
   □ Have you ever lived near places storing construction materials?
   □ Have you ever lived near a brake repairing factory?

Interviewer's Remarks:

Date:

Interviewer:____

This checklist is originally Japanese and was developed by the Osaka Mesothelioma Research Group. Although unauthorized and unofficial, English translation has been done by the Department of Environmental Epidemiology, UOEH, Japan, for the sake of reference by concerned parties in other countries. Note that the applicability of this checklist to conditions in different countries is variable and only some components may be used. Every country should identify their own source of asbestos exposure reflecting their industrial profile (historical and present) to ultimately develop their own country-specific checklist.

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

Contents

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**

1. World Health Organization. Determination of airborne fibre number concentration: A recommended method by phase contrast optical microscopy (membrane filter method). Geneva. 1997. Available from: http://www.who.int/occupational_health/publications/airfibre/en/index.html

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

3. Occupational Safety and Health Administration (OSHA), US. Asbestos in air. ID-160. 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. In: Asbestos: Health and Safety Executive. The analysts' guide for sampling, analysis and clearance procedures. Health and Safety Executive. 2005. p. 45-63. Available from: http://www.hse.gov.uk/pubns/books/hsg248.htm

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 ㎛ 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 ㎛, width <3 ㎛ 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 ㎛, width >0.002 ㎛ and aspect ratio (length: width ratio) >5:1. PCM equivalent fibers with length >5 ㎛, width >0.25 ㎛ 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 ㎛, width >0.002 ㎛ 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 ㎛, width 0. 2-3 ㎛ 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%.

b) Work practices for preventing asbestos exposure

Work practices are ways of structuring things that must be done, or ways in which something is done. Several agencies have issued work practices for preventing asbestos exposure but only a few documents dealing with safe work practice for asbestos in general industries are available.

In 1984, the International Labor Office (ILO) issued an ILO code of practice, which provides recommendations and safe work practices for asbestos. The practices detailed in this document are appropriate actions to be taken by Asian developing countries for preventing asbestos exposure. In addition, the regulations and guidelines of the US, the UK and Canada on asbestos are reviewed in this document. The detailed recommendations and requirements of the regulations and guidelines reviewed in this document should be read in the context of local conditions, the scale of operation involved and the technical possibilities of Asian countries.

References

- **Safe work practice of ILO**

1. International Labour Office. Safety in the use of asbestos: An ILO code of practice. International Labour Office. Geneva. 1984. Available from: http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/normativeinstrument/wcms_107843.pdf

- **Regulations and guidelines of OSHA and EPA, US.**

2. Occupational Safety and Health Administration. 29 CFR 1910.1001 Asbestos. Available from: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9995

3. Occupational Safety and Health Administration. 29 CFR 1926.1101 Asbestos. Available from: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10862

4. Occupational Safety and Health Administration. 29 CFR 1915.1001 Asbestos. Available from: http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1915

5. Environmental Protection Agency. Guidance for controlling asbestos-containing materials in buildings. EPA 560/5-85-024. 1985.

6. Environmental Protection Agency. How to manage asbestos in school buildings: The AHERA designated person's self-study guide. EPA 910-B-96-001. 1996. Available from: http://www.epa.gov/region2/ahera/e23.pdf

- **Guidelines of HSE, UK.**

7. Health and Safety Executive. Asbestos essentials. Available from: http://www.hse.gov.uk/asbestos/essentials

8. Health and Safety Executive. A comprehensive guide to managing asbestos in premises. Health and Safety Executive. 2002. Available from: http://www.hse.gov.uk/pubns/books/hsg227.htm

- **Guidelines of WorkSafe BC, Canada**

9. WorkSafe BC. Safe work practices for handling asbestos. 1996. Available from: http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/asbestos.pdf

10. WorkSafe BC. Safe work practices for asbestos laboratories. 2008. Available from: http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/asbestos_labs.pdf

1. International Labor Office (ILO). Safety in the use of asbestos: An ILO code of practice. ILO. Geneva. 1984.

Background: The practical recommendations of this code of practice are intended for the use of all those, in both the public and private sectors, who have responsibility for safety in the use of asbestos. The code has been drawn up with the objective of providing guidance to those who may be engaged in the framing of provisions of this kind and, in particular, governmental or other public authorities, committees or management in related enterprises.

Objective: The ILO code of practice on safety in the use of asbestos incorporates recommendations regarding the following topics: the general duties, exposure limits, workplace monitoring, general preventive methods, personal protection, cleaning of premises, transport and storage, disposal of asbestos waste, supervision of the health of workers, information, labeling, education and training, control of asbestos exposure and specific activities.
Asian Context: Local circumstances and technical possibilities determine how practicable it is to follow its provisions. Furthermore, these provisions should be read in the context of local conditions, the scale of operation involved and technical possibilities. The detailed practices of this document are valuable for Asian developing countries.

Critical Appraisal: This document presents specified recommendations and work practices for asbestos through all industries. This document also includes the principles of the membrane filter method for determining airborne asbestos fiber concentrations by light microscopy, the principles of gravimetric methods for measuring airborne dust containing asbestos at the workplace, and recommendations concerning medical examinations.

Available from:
http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/normativeinstrument/wcms_107843.pdf

2. Occupational Safety and Health Administration (OSHA), US. 29 CFR 1910.1001 Asbestos.

Background: This mandatory regulation of the US, OSHA specifies the regulatory requirements and work practices that must be implemented by the employer in general industries.

Objective: Regulatory requirements such as permissible exposure limit, exposure monitoring, respiratory protection, hygiene facilities and practices, communication of hazards to employees, medical surveillance, and recordkeeping are detailed to reduce employees' asbestos exposure below the PEL in general industries.

Asian Context: This regulation provides not only OSHA's regulatory requirements but also detailed work practices which can be a common factor for safe work practices in general industries. However, the provisions in this regulation should be read in the context of local conditions, the scale of operation involved and technical possibilities.

Critical Appraisal: OSHA's reference sampling and analytical methods, medical questionnaires, interpretation and classification of chest roentgenograms, work practices and engineering controls for automotive brake and clutch inspection, disassembly, repair and assembly, substance technical information for asbestos, medical surveillance guidelines for asbestos smoking cessation program, and information for asbestos are also provided in the appendix.

Available from:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9995

3. Occupational Safety and Health Administration (OSHA), US. 29 CFR 1926.1101 Asbestos.

Background: This mandatory regulation of the US, OSHA specifies the regulatory requirements and work practices that must be implemented by the employer in construction industries.

Objective: Regulatory requirements and work procedures of asbestos abatement sites such as permissible exposure limit, exposure monitoring, personal protective equipments, and decontamination facilities are detailed to reduce employees' asbestos exposure below the PEL in construction industries.

Asian Context: This regulation provides not only OSHA's regulatory requirements but also detailed work practices which can be a common factor for safe work practices in construction industries. However, the provisions in this regulation should be read in the context of local conditions, the scale of operation involved and technical possibilities.

Critical Appraisal: OSHA classifies asbestos-containing materials into 4 categories according to their friability and regulates friable materials more strictly. OSHA's mandatory and non-mandatory technical information such as reference sampling and analytical methods, medical questionnaires, interpretation and classification of chest roentgenograms, work practices and engineering controls for Class I asbestos operations are also provided in the appendix.

Available from:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10862

4. Occupational Safety and Health Administration (OSHA), US. 29 CFR 1926.1101 Asbestos.

Background: This mandatory regulation of the US, OSHA specifies the regulatory requirements and work practices that must be implemented by the employer in shipyard industries.

Objective: Regulatory requirements and work procedures of asbestos abatement sites such as permissible exposure limit, exposure monitoring, and personal protective equipments are detailed to reduce employees' asbestos exposure below the PEL in shipyard industries.

Asian Context: This regulation provides not only OSHA's regulatory requirements but also detailed work practices which can be a common factor for safe work practices in shipyard industries. However, the provisions in this regulation should be read in the context of local conditions, the scale of operation involved and technical possibilities.

Critical Appraisal: OSHA's mandatory and non-mandatory technical information such as reference sampling and analytical methods, medical questionnaires, interpretation and classification of chest roentgenograms, work practices and engineering controls for Class I asbestos operations are also provided in the appendix.

Available from:
http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1915

5. Environmental Protection Agency (EPA), US. Guidance for controlling asbestos-containing materials in buildings. EPA 560/5-85-024. 1985.

Background: This manual, issued by the US, EPA is a building owners' guidance to understand the technical issues, determine if asbestos is present in a building, plan a control program, and choose the course of further action if necessary.

Objective: This manual covers the steps that a building owner should take to control asbestos. This manual details determining if asbestos-containing material is present in buildings, establishing a special operations and maintenance program, asbestos control beyond special operations and maintenance, abatement methods and conducting abatement projects.

Asian Context: Controlling asbestos in buildings is important because most asbestos has been used in building materials. This manual provides detailed information about the maintenance of asbestos in buildings.

Critical Appraisal: This document is one of the most well organized manuals for the management of asbestos in buildings.

6. Environmental Protection Agency (EPA), US. How to manage asbestos in school buildings: The AHERA designated person's self-study guide. EPA 910-B-96-001. 1996.

Background: This document is for persons recently appointed to the position of AHERA-designated person, as well as persons who have held the position for some time. EPA requires schools to appoint an asbestos manager, called the "Asbestos Hazard Emergency Response Act (AHERA)-Designated Person".

Objective: This manual covers an introduction to asbestos, asbestos health risks, requirements of local education agencies, AHERA inspection, management plan, re-inspections and periodic surveillance, operation and management program, training and accreditation, recordkeeping and related regulations in the US.

Asian Context: Although this manual is for the management of asbestos in schools in the US, its general management process and requirement can be expanded and applied to the management of public buildings.

Critical Appraisal: This document is one of the most well organized manuals for the management of asbestos in schools. Sometimes more strict regulations are required for children who are more vulnerable to asbestos.

Available from:
http://www.epa.gov/region2/ahera/e23.pdf

7. Health and Safety Executive (HSE), UK. Asbestos essentials.

Background: This document is a task manual for buildings, maintenance and allied trades on non-licensed asbestos work by the Control of Asbestos Regulations 2006 in the UK.

Objective: A manual with guidance and an extensive list of task sheets are provided for all workers (employers, employees and self-employed) who may come into contact with asbestos, such as electricians, builders, plumbers, carpenters and other trades. The 38-specific task sheets cover most aspects of potentially hazardous work on, or near, asbestos materials including drilling, removing, repairing, painting, enclosing and cleaning. Broader issues relating to uncovering or damaging asbestos, the required training, vacuuming, damp wetting, decontamination, personal protective equipments and disposal are covered by general advice given in stage-by-stage method sheets.

Asian Context: This document provides safe work practices for the operation and management of asbestos-containing buildings and facilities.

Critical Appraisal: This document is one of the most well organized safe work practices for asbestos work but does not cover work activities involving work in general industries and work with friable asbestos-containing materials, which are classified as the licensed works and are more strictly regulated in the UK.

Available from:
http://www.hse.gov.uk/asbestos/essentials/index.htm

8. Health and Safety Executive (HSE), UK. A comprehensive guide to managing asbestos in premises. 2002.

Background: This guidance issued by the UK, HSE is for those who have a duty to manage the risks from asbestos-containing materials in premises. HSE mentions that following this guidance is not compulsory but will normally be sufficient to comply with the law in the UK.

Objective: This guidance covers how to prevent, or, where this is not reasonably practicable, minimize, exposure to this group of workers and other employees by managing the asbestos-containing materials. This guidance also includes appendices on surveying to find asbestos in buildings, how to assess the risks from the asbestos, the options available for the management of the asbestos-containing materials present, deciding which management option is appropriate and assessing information of selecting surveyors, consultants and licensed asbestos removal contractors. Real examples of approaches to the management of asbestos-containing program are also provided.

Asian Context: This document provides safe work practices for the operation and management of asbestos-containing buildings and facilities for Asian countries.

Critical Appraisal: This document does not cover work activities involving work in general industries.

Available from:
http://www.hse.gov.uk/pubns/books/hsg227.htm

9. WorkSafe BC. Safe work practices for handling asbestos. 1996.

Background: This document provides safe work practices for handing asbestos and is issued by WorkSafeBC, which is dedicated to promoting workplace health and safety for the workers and employers of British Columbia.

Objective: This manual provides general information that employers can use to develop their own site-specific procedures. The manual covers safe employer's responsibilities, safe work procedures, personal protective equipment and emergencies and incidents for handling of asbestos in buildings and facilities.

Asian Context: This document provides safe work practices for the operation and management of asbestos-containing buildings and facilities for Asian countries.

Critical Appraisal: This document is one of the most well organized safe work practices for asbestos work but does not cover work activities in general industries.

Available from:
http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/asbestos.pdf

10. WorkSafe BC. Safe work practices for asbestos laboratories. 2008.

Background: This manual is intended for asbestos laboratories and laboratory analysts, including field analysts, who examine building products, other materials (brake pads, clutch pads, furniture, etc.), and air samples for the presence of asbestos and is issued by WorkSafeBC, which is dedicated to promoting workplace health and safety for the workers and employers of British Columbia.

Objective: This manual provides general health and safety requirements and detailed procedures for safe laboratories, including identifying and assessing hazards, exposure control plans, personal protective equipment, emergency preparedness and waste disposal. An occupational health and safety regulation checklist for asbestos laboratories is also provided.

Asian Context: The increasing demand for asbestos analysis can produce many asbestos analysts and surveyors who are also asbestos workers and who need to be taken care of. For Asian countries facing an increase in laboratory asbestos testing due to the strengthening of regulations on asbestos, this document shows good examples of safe work practices on asbestos laboratories.

Critical Appraisal: This document provides well organized safe work practices for asbestos laboratories that should be applied by occupational health and safety regulation of British Columbia.

Available from:
http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/asbestos_labs.pdf

c) Asbestos exposure levels of various situations and conditions

Asbestos has been used widely in various industries because of its useful physical and chemical properties such as high flexibility, durability of abrasion and heat resistance. The published literature contains numerous data sets on airborne asbestos concentrations in various occupational settings. In 2007, Williams et al reviewed the published and selected unpublished literature on historical asbestos exposure among skilled craftsmen in various non-shipyard and shipyard settings. In this document, 24 published studies, including recent ones not covered by Williams et al, on asbestos exposure concentration are reviewed and exposure levels commonly encountered in variable situations and conditions in occupational settings are presented according to the industries and worker tasks in the format of tables. In spite of limited detailed information associated with the data sets, data mining through this document and Williams's work shall provide information about asbestos exposure levels of various situations and conditions in occupational settings.

Table 1. Measured airborne asbestos exposure levels of workers in asbestos-containing product manufacturing industries.

Job task		Analysis method	Sample type	No. of sample	Airborne fiber concentration (fibers/cc)			Reference
					Arithmetic mean	Standard deviation	Range	
Asbestos mill, India	Asbestos mill in Rajaschan, India	PCM[1)]	Personal/Area	30			2.00-5.09	Ansari et al. 2007
	Asbestos mill in Deogarh, India			25			4.07-15.60	
Thermal insulating board manufacturing, India	Feeding of materials	PCM	Personal	4	0.1087	0.0631	0.0341-0.1681	Bhagia et al. 2010
	Weighing/Slurry making			6	0.0571	0.0255	0.0571-0.0812	
	Pressing			6	0.0656	0.0378	0.0383-0.1220	
	Machine grinding			6	0.0817	0.0437	0.0289-0.1384	
	Hand finishing			6	0.0451	0.0257	0.0189-0.0783	
Cement sheet and pipe manufacturing, Iran	Storage(raw materials and productions)	PCM	Personal	7	0.056	0.01	0.04-0.07	Marioryad et al. 2011
	Feeding of raw materials (milling and mixing)			8	0.131	0.027	0.09-0.17	
	Sheet molding(hacheck, perdorit)			11	0.085	0.025	0.04-0.12	
	Pipe molding			12	0.125	0.021	0.1-0.17	
	Sheet finishing			12	0.168	0.069	0.08-0.3	
	Pipe finishing			13	0.223	0.065	0.14-0.34	
	Recycling (residual mill)			7	0.453	0.06	0.39-0.55	
	Laboratory (physics lab, chemistry lab)			8	0.041	0.014	0.02-0.06	
	Administration (health care clinic, office)			12	0.043	0.015	0.02-0.06	
	Others (kitchen, dining, laundry)			8	0.040	0.011	0.03-0.06	
Slate manufacturing, Korea	Mixing	PCM	Personal	6	0.05(GM)	2.37(GSD)		Oh et al.1993
	Cutting			2	0.04(GM)	1.23(GSD)		
	Pressing			2	0.12(GM)	11.68(GSD)		
Textile manufacturing, Korea, (1987)	Fiberizing and Mixing	PCM	Personal	4	4.5(GM)	3.07(GSD)		Park and Paik. 1988
	Carding			8	3.9(GM)	3.56(GSD)		
	Spinning			11	5.6(GM)	2.16(GSD)		
	Twisting			10	4.8(GM)	2.29(GSD)		
	Winding			7	3.0(GM)	2.37(GSD)		
	Weaving			4	5.3(GM)	1.83(GSD)		
Textile manufacturing, Korea, (1992)	Mixing	PCM	Personal	1	6.10(GM)			Oh et al.1993
	Carding			8	0.91(GM)			
	Spinning			12	0.85(GM)			
	Twisting			14	0.94(GM)			
	Weaving			5	1.33(GM)			

[1)] : Phase contrast microscopy (PCM)-based method

Table 1. (continued)

Job task		Analysis method	Sample type	No. of sample	Airborne fiber concentration (fibers/cc)			Reference
					Arithmetic mean	Standard deviation	Range	
Mobile brake lining manufacturing , Iran	Drilling machine	PCM[1)]	Personal	5	0.39	0.06	0.48-0.36	Kakooei et al. 2007
	Reassembling lining from drilling form			5	0.61	0.07	0.65-0.58	
	Both and bottom grinding			5	0.38	0.02	0.43-0.32	
	Cutting			10	0.37	0.08	0.44-0.33	
	Polish machine			10	0.63	0.07	0.68-0.59	
	Bevel			5	0.88	0.06	0.92-0.80	
Automobile brake and clutch manufacturing industry, Iran	Drilling	PCM	Personal	13	0.31(GM)	0.08(GSD)		Kakooei and Marioryad. 2010
	Process baking			6	0.42(GM)	0.08(GSD)		
	Process form			7	0.60(GM)	0.17(GSD)		
	Clutches baking			7	0.43(GM)	0.20(GSD)		
	Bevels			5	0.88(GM)	0.06(GSD)		
	Cutting			10	0.63(GM)	0.07(GSD)		
	Grinding(finishing)			7	0.32(GM)	0.05(GSD)		
Automobile brake lining manufacturing industry, Korea	Weighing/Mixing	PCM	Personal	21	0.15(GM)			Oh et al.1993
	Molding			10	0.14(GM)			
	Drilling			14	0.15(GM)			
	Grinding			28	0.20(GM)			
	Assembling/Packing			19	0.07(GM)			

[1)] : Phase contrast microscopy (PCM) -based method

Table 2. Measured airborne asbestos exposure levels of workers in automobile service industries.

Job task		Analysis method	Sample type	No. of sample	Airborne fiber concentration (fibers/cc)			Reference
					Arithmetic mean	Standard deviation	Range	
Automobile brake change	Filing	PCM[1)]	Personal		0.0376			Blake et al. 2003
	Sanding				0.0776			
	Arc grinding1				0.4368			
	Cleaning				0.0146			
	Arc grinding2				0.2005			
	Filing	TEM[2)]	Personal		0.0356			
	Sanding				0.0684			
	Arc grinding1				0.4358			
	Cleaning				0.0048			
	Arc grinding2				0.1734			
Aircraft brake replacement	Brake change	PCM	Personal				<0.011-0.024	Blake et al. 2009
	Brake change using blowout cleaning						<0.001-0.037	
Motor vehicle brake service	Brake replacement(without compressed air)	PCM		16			0.005-0.02	Weir et al. 2001
	Brake replacement(with compressed air)			15			0.05-0.9	
	Arc grinding				0.43			
Motor Brake service	Brake service of 11 vehicles	PCM	Personal	6	0.68			Hickish and Knight. 1970
Heavy equipment brake removal	Brake and bench work(Stockton)	PCM/TEM	Personal	10	0.024	0.016	0.001-0.09	Madl et al. 2009
	Brake and bench work(Big Rock)			1	0.01			
	Clothes handling			2	0.036		0.032-0.039	
Clutch service	Clutch service of 11 vehicles	PCM/TEM	Personal	46	0.047		0.015-0.13	Cohen et al. 2008
Automobile sealants and clutch replacement	Hand scraping of seam sealant	TEM	Personal	7	0.0061			Blake et al. 2008
	Pneumatic chipping of seam sealant			7	0.0059			
	Clutch removal(right shoulder location)			1	Not detected			
	Clutch removal(left shoulder location)			1	Not detected			
	Clutch installation(left shoulder location)			1	0.0027			

[1)] : Phase contrast microscopy-based method
[2)] : Transmission electron microscopy-based method

Table 2. (continued)

Job task		Analysis method	Sample type	No. of sample	Airborne fiber concentration (fibers/cc)			Reference
					Arithmetic mean	Standard deviation	Range	
Brake repair of passenger car, Korea	Opening of brake	PCM[1)]	Personal	3	0.06(GM)		0.05-0.08	Shin and Paik. 1989
	Opening and brushing of brake			3	0.07(GM)		0.06-0.18	
	Dry brushing of brake			5	0.27(GM)		0.08-0.62	
	Grinding of brake lining with sand paper			5	0.28(GM)		0.06-0.71	
	Compressed air blowing of dust (no exhaust available)			3	4.26(GM)		0.11-7.28	
	Repair of clutch lining others			5	0.13(GM)		0.04-0.30	
	Others			17	0.05(GM)		0.02-0.11	
Brake repair of truck and bus, Korea	Opening of brake			3	0.03(GM)		0.01-0.06	
	Opening and brushing of brake			7	0.16(GM)		0.01-0.69	
	Dry brushing of brake			7	0.25(GM)		0.10-0.61	
	Grinding of brake lining with sand paper			8	0.46(GM)		0.04-2.51	
	Compressed air blowing of dust (no exhaust available)			2	4.26(GM)		2.58-7.04	
	Opening and assembling of brake			6	0.06(GM)		0.02-0.24	
	Sweeping floor of garage			5	0.03(GM)		<0.01-0.07	
	Others			10	0.06(GM)		0.01-0.17	

[1)] : Phase contrast microscopy-based method

Table 3. Measured airborne asbestos exposure levels of workers gaskets and packaging service industries.

Job task		Analysis method	Sample type	No. of sample	Airborne fiber concentration (fibers/cc)			Reference
					Arithmetic mean	Standard deviation	Range	
Installation and removal of gasket	Disassembly and assembly of flanges	PCM[1)]	Personal	9		0.001	0.003-0.006	Mangold et al. 2006
	Gasket activity(hand punching)			5	0.06	0.01		
	Gasket activity(hand operated mechanical punch)			5	0.02	0.02		
	Gasket activity(machine punch)			5	0.11	0.04		
	Gasket activity(hand shaping table with knives, scissors, scribes)			5	0.04	0.02		
	Gasket activity(machine shearing)			5	0.09	0.04		
	Gasket activity(nibbler machine)			5	0.14	0.05		
	Gasket activity(flange opened, no scraping gasket installation)			3	0.03	0.02		
	Gasket activity(flange opened, scraping gasket installing)			3	0.03	0.01		
	Ship flange and gasket removal(onboard ship)			20	0.03	0.021	0.01-0.08	
	Ship flange and gasket removal(on land)			10	0.023	0.013	0.01-0.05	
	Gasket formation, removal and flange face(ball peen hammer)			8	0.005			
	Gasket formation, removal and flange face(hand wire brush)			8	0.07			
	Gasket formation, removal and flange face(power wire brush)			8	0.009			
	Gasket formation, removal and flange face(hand wire brush)	TEM[2)]		8	0.024	0.012	0.012-0.042	
	Gasket formation, removal and flange face(power wire brush)				0.028	0.007	0.021-0.042	
	Removal and replacement of valve packing			8	0.008	0.003	0.002-0.012	

[1)] : Phase contrast microscopy-based method
[2)] : Transmission electron microscopy-based method

Table 3. (continued)

Job task		Analysis method	Sample type	No. of sample	Airborne fiber concentration (fibers/cc)			Reference
					Arithmetic mean	Standard deviation	Range	
Gasket removal in chemical industry	Gasket removal with a wetting agent and putty knife	PCM[1)]	Personal	11			0.042-0.242	Spence and Rocchi. 1996
		TEM[2)]		4			0.0007-0.0014	
	Gasket removal(with gaskets difficult to remove)	PCM		10			Not detected - 0.025	
		TEM					Not detected - 0.0037	
Gasket service of automobile		PCM/TEM	Personal	3	0.0026	0.0018	0.0008-0.0044	Blake et al. 2006
Gasket service of a medium duty diesel engine		PCM	Personal/Area	29			<0.011-0.032	Liukonen and Weir. 2005

1) : Phase contrast microscopy-based method
2) : Transmission electron microscopy-based method

Table 4. Measured airborne asbestos exposure levels of workers in construction industries.

Job task		Analysis method	Sample type	No. of sample	Airborne fiber concentration (fibers/cc)			Reference
					Arithmetic mean	Standard deviation	Range	
Asbestos abatement	Abatement of pipe/boiler in a Crawl space	PCM	Personal	42	0.187		0.005-0.957	Lange et al. 1996
	Abatement of ceiling tile removal in a mini-containment			9	0.022		0.005-0.154	
	Abatement of transite			41	0.077		0.005-0.279	
	Abatement of 10-15% asbestos-containing floor tiles	PCM	Personal	11	0.032	0.020	0.009-0.076	Lange. 2002
	Abatement of 3-5% asbestos-containing floor tiles			14	0.015	0.014	0.006-0.055	
	Abatement of sprayed fireproofing material(dry method)	PCM	Personal	79	16.4(GM)	3.16(GSD)		Paik. 1983
	Abatement of sprayed fireproofing material(wet method)			15	0.5(GM)	2.0(GSD)		
	Abatement of floor tile and mastic(chemical stripping)	PCM	Personal	20	0.0087	0.0072	0.004-0.015	Racine. 2010
	Abatement of floor tile and mastic(wet grinding)			28	0.0124	0.0099	0.007-0.024	
Building maintenance	Asbestos-containing material cleanup	PCM	Personal	9	0.074	0.13	0.012-0.36	Mlynarek et al. 1996
	Bulk sample collection			31	0.034	0.037	0.003-0.17	
	Cable pull			37	0.048	0.041	0.11-0.2	
	Ceiling tile replacement			67	0.35	0.53	0.03-3.5	
	Electrical installation			14	0.037	0.026	0.01-0.11	
	Electrical repair			24	0.02	0.014	0.0034-0.052	
	Fluorescent lamp replacement			78	0.025	0.013	0.0054-0.065	
	HEPA vacuum/wet wiping dust/debris			17	0.098	0.069	0.029-0.3	
	Wet wipe cleaning			25	0.031	0.009	0.0018-0.048	

References

1) Williams PRD, Phelka AD, Paustenbach DJ. A review of historical exposures to asbestos among skilled craftsmen (1940-2006). J Toxicol Environ Health B Crit Rev. 2007 Sep-Oct;10(5):319-77.

2) Ansari FA, Ahmad I, Ashquin M, Yunus M, Rahman Q. Monitoring and identification of air-borne asbestos in unorganized sectors, India. Chemosphere. 2007;68:716-23.

3) Bhagia LJ, Vyas JB, Shaikh MI, Dodia SL. Chrydotile asbestos exposure in the manufacturing of thermal insulating boards. Environ Monit Assess. 2010;167:559-64.

4) Marioryad H, Kakooei Hossein, Shahtaheri SJ, Yunesian M, Azam K. Assessment of airborne asbestos exposure at an asbestos cement sheet and pipe factory in Iran. Regul Toxicol Pharmacol. 2001 March. PubMed PMID: 21420461. [Epub ahead of print]

5) Oh SM, Shin YC, Park DY, Park DU, Chung KC. A study on worker exposure level and variation to asbestos in some asbestos industries. Korean Ind Hyg Assoc J. 1993;3:100-9. [In Korean]

6) Park DY, Paik NW. Worker exposure to asbestos fibers in asbestos slate manufacturing and asbestos textile industries. Korean Ind Hyg Assoc J. 1988;14(2):13-27. [In Korean]

7) Kakooei H, Sameti M, Kakooei AA. Asbestos exposure during routine brake lining manufacture. Industrial Health. 2007;45:787-92.

8) Kakooei H, Marioryad H. Evaluation of exposure to the airborne asbestos in an automobile brake and clutch manufacturing industry in Iran. Regul Toxicol Pharmacol. 2010;56:143-7.

9) Blake CL, Orden DRV, Banasik M, Harbison RD. Airborne asbestos concentration from brake changing does not exceed permissible exposure limit. Regul Toxicol Phamacol. 2003;38:58-70.

10) Blake CL, Dotson GS, Harbison RD. Evaluation of asbestos exposure within the automotive repair industry: A study involving removal of asbestos-containing body sealants and drive clutch replacement. Regul Toxicol Pharmacol. 2008;52:324-31.

11) Weir FW, Tolar G, Meraz LB. Characterization of vehicular brake service personnel exposure to airborne asbestos and particulate. Appl Occup Environ Hyg. 2001;16:1139-46.

12) Hickish DE, Knight KL. Exposure to asbestos during brake maintenance. Ann Occup Hyg

1970;13:17-21.

13) Madl AK, Gaffney SH, Blazer JL, Paustenbach DJ. Airborne asbestos concentrations associated with heavy equipment brake removal. Ann Occup Hyg. 2009;53(8):839-57.

14) Chen HJ, Orden DRV. Asbestos exposures of mechanics performing clutch service on motor vehicles. J Occup and Environ Hyg. 2008 Mar;5(3):148-56.

15) Blake CL, Johnson GT, Harbison RD. Airborne asbestos exposure during light aircraft brake replacement. Regul Toxicol Pharmacol. 2009;54:242-6.

16) Shin YC, Paik NW. A study on worker exposure to asbestos fibers during automobile maintenance. Korean J Environ Health Soc. 1989;15(1):19-32 [In Korean]

17) Mangold C, Clark K, Madl A, Paustenbach D. An exposure study of bystanders and workers during the installation and removal of asbestos gaskets and packing. J Occup Environ Hyg. 2006 Feb;3:87-98.

18) Spence SK, Rocchi PSJ. Exposure to asbestos fibres during gasket removal. Ann Occup Hyg. 1996;40(5):583-8.

19) Blake CL, Dotson GS, Harbison RD. Assessment of airborne asbestos exposure during the servicing and handling of automobile asbestos-containing gaskets. Regul Toxicol Pharmacol. 2006;45:214-22.

20) Liukonen LR, Weir FW. Asbestos exposure from gaskets during disassembly of a medium duty diesel engine. Regul Toxicol and Pharmacol. 2005;41:113-21.

21) Lange JH, Lange PR, Reinhard TK, Thomulka KW. A study of personal and area airborne asbestos concentrations during asbestos abatement: A statistical evaluation of fibre concentration data. Ann Occup Hyg 1996;40(4):449-66.

22) Lange JH. Impact of asbestos concentrations in floor tiles on exposure during removal. Int J Environ Health Res. 2002 Dec;12(4):293-300.

23) Paik NW, Walcott RJ, Brogan PA. Worker exposure to asbestos during removal of sprayed material and renovation activity in buildings containing sprayed material. Am Ind Hyg Assoc J. 1983 Jun;44(6):428-32.

24) Racine WP. Emissions concerns during renovation in the healthcare setting: Asbestos abatement of floor tile and mastic in medical facilities. J Environ Manage. 2010 Jul;91(7):1429-36.

25) Mlynarek S, Corn M, Blake C. Asbestos exposure of building maintenance personnel. Regul Toxicol Pharmacol. 1996;23:213-24.

1-D. High Risk Occupation and Industries in Regards to Asbestos Related Diseases

Compile information on methods to identify high risk occupations and industrial sectors in relation to asbestos related diseases (ARDs) from information sources including the database system of European Union for carcinogenic exposure in workers (CAREX), surveillance system of developed countries, and job exposure matrix for asbestos exposure of published peer reviewed articles.

Introduction

Following matters can be included in the introduction part.

High risk industry and occupation exposed to asbestos can be classified to primary and secondary asbestos production or manufacturing industry, and others. CAREX is comprehensive evaluation of asbestos industries developed by European Union, which lists 41 kinds of industries. It also estimated the magnitude and the proportion of exposed workers by industries. Industries with high exposure prevalence were mining, fishing, petroleum refineries, construction, and others (*from EU CAREX report*). Construction industry and the related occupation was the most common referred sector for asbestos exposure in many countries.

USA, Germany, Netherlands and Korea developed Industry/occupation with the exposure level of asbestos based on historical records from their own countries, which can be used for the basic frame of Job exposure matrix of asbestos in workplace. The highest level of asbestos exposure reported from mining industry in USA, textile industries in Germany and Korea. In Netherlands, asbestos insulation, cement and friction materials were the highest exposure level from historical review.

Surveillance system of ARDs have been operating in many developed countries (USA, UK, New Zealand, and Australia) by compulsory or voluntarily reporting system, which provides informative lists of high risk occupations.

Combined these information especially CAREX, USA and British databases, informative JEM can be accomplished.

The reviewed articles include below contents

- Job exposure matrix based on exposure assessment
  - EU CAREX (Carcinogen Exposure) database
  - USA
  - Finnish lists

- German
- Job exposure matrix of Netherlands
- Korea

- Job exposure matrix based on health outcome
  - US NCHS (National Center for Health Statistics)
  - HSE, UK
  - German registry : central registration agency for employees exposed to asbestos dust (ZAs)
  - Other countries
    - Australian registry of mesothelioma
    - China
    - South Africa
    - New Zealand

References

- **Job exposure matrix based on exposure assessment**

1. Finnish Institute of Occupational Health (FIOH). OCCUPATIONAL EXPOSURE TO CARCINOGENS IN THE EUROPEAN UNION IN 1990-93. FIOH; 1998 [updated 21.06.2010 cited 2011 18th Feb]; Available from: http://www.ttl.fi/en/chemical_safety/carex/countries/pages/
   CAREX

2. Kauppinen T, Toikkanen J, Pedersen D, Young R, Ahrens W, Boffetta P, Hansen J, Kromhout H, Maqueda Blasco J, Mirabelli D, de la Orden-Rivera V, Pannett B, Plato N, Savela A, Vincent R, Kogevinas M. Occupational exposure to carcinogens in the European Union. Occup Environ Med 2000;57(1):10-8.
   CAREX

3. Rice C, Heineman EF. An asbestos job exposure matrix to characterize fiber type, length, and relative exposure intensity. Applied occupational and environmental hygiene 2003;18(7):506-12.
   Job exposure matrix of USA

4. Rantanen J. Incidence and use of asbestos, technical prevention. European Conference 2003. 2003 [cited 2011 18th Feb]
   List of asbestos industry of Finland

5. Hagemeyer O, Otten H, Kraus T. Asbestos consumption, asbestos exposure and asbestos-related occupational diseases in Germany. International archives of occupational and environmental health 2006;79(8):613-20.
   Job exposure matrix of German

6. Swuste P, Dahhan M, Burdorf A. Linking expert judgement and trends in occupational exposure into a job-exposure matrix for historical exposure to asbestos in the Netherlands. Ann Occup Hyg 2008;52(5):397-403.
   Job exposure matrix of Netherlands

7. Burdorf A, Swuste P. An expert system for the evaluation of historical asbestos exposure as diagnostic criterion in asbestos-related diseases. Ann Occup Hyg 1999;43(1):57-66.
   Job exposure matrix of Netherlands

8. Park D, Choi S, Ryu K, Park J, Paik N. Trends in occupational asbestos exposure and asbestos consumption over recent decades in Korea. Int J Occup Environ Health 2008;14(1):18-24.
Asbestos Exposure level of Korea

- **Job exposure matrix based on health outcome**

9. NIOSH. The Work-Related Lung Disease Surveillance Report, 2007, DHHS (NIOSH) Publication No. 2008-143a NIOSH; 2008 [updated Sep 2008; cited 2011 May]; Available from: http://www.cdc.gov/niosh/docs/2008-143/
US NCHS

10. McElvenny DM, Darnton AJ, Price MJ, Hodgson JT. Mesothelioma mortality in Great Britain from 1968 to 2001. Occup Med (Lond) 2005;55(2):79-87.
Health and Safety Executive, United Kingdom

11. HSE. Occupational, domestic and environmental mesothelioma risks in Britain; A case-control study. HSE; 2009 [cited 2011 May]; Available from: http://www.hse.gov.uk/research/rrpdf/rr696.pdf
Health and Safety Executive, United Kingdom

12. Neumann V, Gunthe S, Mulle KM, Fischer M. Malignant mesothelioma-German mesothelioma register 1987-1999. International archives of occupational and environmental health 2001;74(6):383-95.
Germanny: Central Registration Agency for Employees Exposed to Asbestos Dust (ZAs)

13. Yeung P, Rogers A. An occupation-industry matrix analysis of mesothelioma cases in Australia 1980-1985. Applied occupational and environmental hygiene 2001;16(1):40-4.
Australian registry of mesothelioma

14. Yeung P, Rogers A, Johnson A. Distribution of mesothelioma cases in different occupational groups and industries in Australia, 1979-1995. Applied occupational and environmental hygiene 1999;14(11):759-67.
Australian registry of mesothelioma

15. Cai SX, Zhang CH, Zhang X, Morinaga K. Epidemiology of occupational asbestos-related diseases in China. Industrial health 2001;39(2):75-83.
China

16. Kgalamono SM, Rees D, Kielkowski D, Solomon A. Asbestos in the non-mining industry on the Witwatersrand, South Africa. S Afr Med J 2005;95(1):47-51.
South Africa

17. Department of Labour. Asbestos and other occupational Lung diseases in New Zealand. Department of Labour, New Zealand; 2010 [cited 2011 May].
Available from:
http://www.osh.dol.govt.nz/publications/booklets/asbestos-report-2010/report-2010.pdf.
New Zealand

Brief review of the articles

1. Finnish Institute of Occupational Health (FIOH). Carex: Industry Specific Estimates-Summary in: Occupational exposure to carcinogens in the European Union in 1990-93. FIOH; 1998 [updated 21.06.2010 cited 2011 18th Feb]

2. Kauppinen T, Toikkanen J, Pedersen D, Young R, Ahrens W, Boffetta P, Hansen J, Kromhout H, Maqueda Blasco J, Mirabelli D, de la Orden-Rivera V, Pannett B, Plato N, Savela A, Vincent R, Kogevinas M. Occupational exposure to carcinogens in the European Union. Occup Environ Med 2000;57(1):10-8.

Background: CAREX is an international information system on occupational exposure to known and suspected carcinogens which provides selected exposure data and documented estimates of the number of exposed workers by country, carcinogen, and industry. This project is substudy of a project on the estimation of the burden of occupational cancer in Europe.

Objective: This document estimates the proportion of the workers exposed to carcinogens including asbestos across industrial classes of industries in European countries.

Asian Context: Among 55 industries, the highest proportion of asbestos exposure was from construction industry followed by personal service, mining, and agriculture. This trend can be applied to most Asian countries.

Critical Appraisal: The information for asbestos exposed industries in CAREX system is comprehensive with high validity which is reviewed by experts of European countries. However, most information of exposure to carcinogen was from surveillance data of Finnish and USA. The disposal and demolition industry which was developed after ban of asbestos, might have been underestimated.

Available from:
http://www.ttl.fi/en/chemical_safety/carex/Documents/5_exposures_by_agent_and_industry.pdf

3. Rice C, Heineman EF. An asbestos job exposure matrix to characterize fiber type, length, and relative exposure intensity. Appl Occup Environ Hyg 2003;18(7):506-12.

Background: The relationship between asbestos exposure and disease has been well documented, although questions persist as to variation in risk by the type and length of fiber. Job exposure matrix by fiber type and length is useful in epidemiological studies where asbestos is an exposure of interest.

Objective: This document construct the JEM based on literature review regarding exposure level of asbestos.

Asian Context: By level of exposure, 4 categories were developed in JEM. Primary and secondary industries using asbestos by job and exposure level were listed in the result. The information might be useful for Asian countries.

Critical Appraisal: To adapt the JEM, the kinds of asbestos products should be identified. Therefore, this information might be limited to use in some countries.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12791547

4. Rantanen J. Incidence and use of asbestos, technical prevention. European Conference 2003. 2003 [cited 2011 18th Feb]

Background: It took 85 years before the International Labour Organisation was able to agree on the International Convention on Safety in the Use of Asbestos. At European conference of Asbestos, the author presented the trend of usage of asbestos and incidence in Finnish society.

Objective: This document addresses the change of the production and consumption of asbestos and the asbestos related industries and occupations in Finland.

Asian Context: In most industrialized counties, the heavily exposing thermal insulation, spraying of surfaces and textile production has been stopped. The uses in developing countries are primarily in asbestos cement products, pipes, sheets, and in roofing but also asbestos textile production may still occur.

Critical Appraisal: This paper compare the usage of asbestos in 1970s and 1990s. It also presented asbestos industry and occupations in Finnish workers in 2003 and earlier time. Asbestos related industries and occupations mixed up in the lists.

Available from:
http://www.hvbg.de/e/asbest/konfrep/konfrep/repbeitr/rantanen_en.pdf

5. Hagemeyer O, Otten H, Kraus T. Asbestos consumption, asbestos exposure and asbestos-related occupational diseases in Germany. Int Arch Occup Environ Health 2006;79(8):613-20.

Background: Asbestos is a leading cause of occupational diseases, especially malignant diseases, in Germany. Following the increased consumption of asbestos after World War I, the recognition of asbestos related diseases developed.

Objective: This document reviewed the historical consumption of asbestos and the trend of related disease in Germany.

Asian Context: It listed the high exposure industry and the exposure level in earlier industrial era. The exposure level of asbestos in Germany during 1950s to 1990s could be informative for Asian countries.

Critical Appraisal: The exposure level of German industries came from high risk industries for asbestos exposure. The industries limited to only 5 kinds of asbestos sector.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16523318

6. Swuste P, Dahhan M, Burdorf A. Linking expert judgement and trends in occupational exposure into a job-exposure matrix for historical exposure to asbestos in the Netherlands. Ann Occup Hyg 2008;52(5):397-403.

Background: Netherlands is a country with late start of asbestos legislation, with high incidence rate of mesothelioma. Because paucity of information on asbestos exposure before 1970, a job-exposure matrix (JEM) on historical asbestos exposure must rely heavily on qualitative descriptions of working conditions and subsequent translation into expected exposure levels by experts in Netherlands.

Objective: This article describes the structure and content of a JEM for historical asbestos exposure in the Netherlands during 1945-1994, using databases from three British sources and one Netherlands source.

Asian Context: JEM resulted in seven categories of exposure levels to asbestos by 4 categories of period (70~74, 75~79, 80~84, and 85-89). The exposure level of seven categories (handling raw asbestos > manufacturing> handling products, waste management> transportation > supervision and inspection) will be useful for estimation of exposure level of asbestos in Asian countries.

Critical Appraisal: This article provides some information for exposure level by occupation, especially the information for supervision and inspection or waste management is valuable. Because it does not list the industries, the information will be limited to evaluation the asbestos risk in occupation, not industries.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18524755

7. Burdorf A, Swuste P. An expert system for the evaluation of historical asbestos exposure as diagnostic criterion in asbestos-related diseases. Ann Occup Hyg 1999;43(1):57-66.

Background: In the absence of quantitative exposure information that allows a valid estimate of an individual's historical exposure, general guidelines are required to retrospectively evaluate asbestos exposure.

Objective: A risk matrix has been developed that contains qualitative information on the proportion of workers exposed and the level of exposure in particular industries over time.

Asian Context: Asbestos related industries in compensation system in Netherlands JEM listed three categories of industries such as primary industries (manufacturing of insulation, textile, cements, friction materials, interior, and floors), secondary industries (construction, ship building, installation of insulation, car maintenance), and others (loader/sacker, engineer, furnace, foundry, demolition of ship building, etc). These lists have quite informative for Asian countries.

Critical Appraisal: Because the compensation scheme always requests confirmative causal relationship, the list might be limited to high level of exposure. The list of industries is too simple and short to make JEM for asbestos.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10028894

8. Park D, Choi S, Ryu K, Park J, Paik N. Trends in occupational asbestos exposure and asbestos consumption over recent decades in Korea. Int J Occup Environ Health 2008;14(1):18-24.

Background: In Korea, asbestos was first recorded as having been mined in the mid-1930s and in the mid-1980s, asbestos mining again ceased. The trend of asbestos exposure is related with industrial structure and social policy.

Objective: This article analyzed a total of 2,089 asbestos exposure data sets compiled from 1995 through 2006 as well as all occupational asbestos exposure levels reported in occupational health related journals in Korea.

Asian Context: Asbestos exposure level of Korea was categorized according to the time period and the industries such as primary and secondary industries. This information will be helpful for Asian countries, especially late-developed or developing countries where the asbestos usage started late 1980s.

Critical Appraisal: Because the peak of asbestos using was 1980s in Korea, and the lack of information earlier than 1980s, the expected high exposure level of asbestos mining in Korea in 1940s is ignored in this article.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18320728

9. NIOSH. The work-related lung disease surveillance report, 2007, DHHS (NIOSH) Publication No. 2008-143a NIOSH; 2008 [updated Sep 2008; cited 2011 May].

Background: Work-Related Lung Disease (WoRLD) Surveillance Report presents national and state summary statistics such as counts, crude and age-adjusted mortality rates by industry and occupation.

Objective: This report includes national rates of asbestos related disease (ARD) such as asbestosis and mesothelioma. It represents the high risk industries and occupation for ARD.

Asian Context: The construction industry accounted for nearly one-fourth of decedents with asbestosis and mesothelioma in USA, Insulation workers or boilermakers had proportionate asbestosis mortality 20 times higher than that in all occupations combined. The lists of industries and occupation of this report can be used for Asian countries' high risk lists.

Critical Appraisal: The risk rate and ratio was based on US population, which might not appropriate for other countries.

Available from:
http://www.cdc.gov/niosh/docs/2008-143/.

10. McElvenny DM, Darnton AJ, Price MJ, Hodgson JT. Mesothelioma mortality in Great Britain from 1968 to 2001. Occup Med (Lond) 2005;55(2):79-87.

Background: The British mesothelioma register contains all deaths from 1968 to 2001 where mesothelioma was mentioned on the death certificate. The information analyzed to assess the proportional mortality ratio (PMR) of mesothelioma by occupations.

Objective: This report estimates summary statistics of the British mesothelioma epidemic including summaries by occupation and geographical area.

Asian Context: The highest SMRs over the period 1981-2000. The occupations with the highest PMRs are metal plate workers, vehicle body builders, plumbers and gas fitters and carpenters. The trends over time suggest a change in the balance of risk away from traditional asbestos exposure industries to industries where one could describe the exposure as secondary, such as plumbers and gas fitters, carpenters, and electricians.

Critical Appraisal: The risk rate and ratio was based on UK population, which might not appropriate for other developing countries.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15757980

11. HSE, UK. Occupational, domestic and environmental mesothelioma risks in Britain; A case-control study. HSE; 2009 [cited 2011 May].

Background: UK mesothelioma mortality is the highest worldwide, but no large case-control study with personal interviews has been conducted. This article obtained lifetime occupational and residential histories from 622 mesothelioma patients.

Objective: This report estimates the high risk industry and occupation for mesothelioma due to the asbestos exposure in UK.

Asian Context: The risk ration was estimated according to three categories of occupations, such as high, medium and low risk group. This study developed construction and non-construction lists of risk group for risk of mesothelioma. Asian countries will adapt this list.

Critical Appraisal: The risk rate and ratio was based on UK population, which might not appropriate for other developing countries.

Available from:
http://www.hse.gov.uk/research/rrpdf/rr696.pdf

12. Neumann V, Gunthe S, Mulle KM, Fischer M. Malignant mesothelioma-German mesothelioma register 1987-1999. Int Arch Occup Environ Health 2001;74(6):383-95.

Background: The study group comprised a collective of 1,605 patients with malignant mesotheliomas from German central registries. This registry have been collection the useful information from asbestos exposed patients

Objective: This report evaluates the asbestos bodies of lung tissue from mesothelioma patients due to explore high risk occupation.

Asian Context: The high risk occupations were asbestos using manufacturers, insulation sectors, car manufacturing, ship building, and etc. This information can be adapted Asian countries.

Critical Appraisal: The risk rate and ratio was based on German population, which might not appropriate for other developing countries. Among 1,605 patients, 364 cases did not have record of occupation, which means that reliability of this data could be questionable.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11563601

13. Yeung P, Rogers A. An occupation-industry matrix analysis of mesothelioma cases in Australia 1980-1985. Appl Occup Environ Hyg 2001;16(1):40-4.

Background: Australia has one of the highest national incidences of mesothelioma in the world and the rate is still rising. Australia has been operating Mesothelioma Surveillance Program and registration system, which could provide reliable information for JEM.

Objective: An industry-occupation matrix analysis was conducted for the 858 mesothelioma cases that were reported to the Australian Mesothelioma Surveillance Program between 1980 and 1985.

Asian Context: Definite, probable, or possible occupational exposure had occurred in 57 percent of the subjects. The primary asbestos production or manufacturing industry constituted the largest number of cases, followed by shipbuilding, repair and demolition, the building industry, and the railway locomotive construction and maintenance industry. The information seems to be comparable with many Asian countries.

Critical Appraisal: In case of the Laborers of which 14% of them had a history of exposure to asbestos, the classification of the occupation was to broad to understand the working situation.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11202027

14. Yeung P, Rogers A, Johnson A. Distribution of mesothelioma cases in different occupational groups and industries in Australia, 1979-1995. Appl Occup Environ Hyg 1999;14(11):759-67.

Background: Occupational histories of a total of 3758 mesothelioma cases collected by two sequential national schemes--the Australian Mesothelioma Surveillance Program (1979-1985) and Australian Mesothelioma Register (1986-1995)--were reviewed and coded by the authors.

Objective: Review of the occupational and industrial distribution of mesothelioma cases.

Asian Context: The high risk occupations were categorized to primary, secondary and other industries. More than 40 % of asbestos related mesothelioma came from other industries. Therefore, not only primary and secondary asbestos industries, but also other industries are important regarding asbestos exposure.

Critical Appraisal: The insufficient information for industries were 16-28% in the data, which means the possibility of misclassification of the occupation in this surveillance data.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10590549

15. Cai SX, Zhang CH, Zhang X, Morinaga K. Epidemiology of occupational asbestos-related diseases in China. Ind Health 2001;39(2):75-83.

Background: Various industries were produce or using asbestos, mainly chrysotile in China. Therefore systematic review of the asbestos related disease in China is necessary to summarize the asbestos and the health effects in China.

Objective: Review of epidemiological studies on asbestosis, lung cancer, malignant mesothelioma, and pleural plaques in China.

Asian Context: In 1950s and 60s, asbestosis had been a major health hazard for asbestos exposed workers. In the late 1970s, lung cancers with or without asbestosis were found among asbestos workers. There have been not so many cases of malignant mesothelioma reported. Experience of China is relevant to most of Asian counties especially where the mining and textile is prevalent.

Critical Appraisal: More specific industrial profile is not presented in this article. The usage for JEM is very limited.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11341561

16. Kgalamono SM, Rees D, Kielkowski D, Solomon A. Asbestos in the non-mining industry on the Witwatersrand, South Africa. S Afr Med J 2005; 95(1):47-51.

Background: Asbestos was commonly found in most sectors of South African industry. Consequently there is a large but indeterminate pool of formerly exposed workers, will present possible asbestosis, the pneumoconiosis.

Objective: Review the specific situation of asbestos exposure in 141 cases of asbestosis identified for the years 1980-2000 in South Africa. Patients were included in if they had no asbestos exposure in mining, and had been certified with asbestosis by a compensation panel.

Asian Context: Majority (54%) of the cases arose from exposure in primary asbestos industries, i.e. companies selling, distributing, refining, milling or using raw asbestos to manufacture products. This information will be practical for the Asian countries where the major portion of asbestos related industry is non-mining sector.

Critical Appraisal: The cases were collected from compensation system; therefore the information from exposure might be limited to high exposure industries.

Available from:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15762249

17-1. Department of Labour. Asbestos and other occupational Lung diseases in New Zealand. Department of Labour, New Zealand; 2010 [cited 2011 May].

17-2. Asbestos Exposure and Disease: Notes for Medical Practitioners. (Information Bulletin) 1992.

Background: The Department of Labour's two Asbestos Registers - the Disease Register and the Exposure Register - have been in existence since 1992.

Objective: This report reviews 1198 cases that were notified to the National Asbestos Medical Panel between March 1992 and July 2010. They include: 224 cases of mesothelioma, 116 cases of lung cancer, 269 cases of asbestosis, and 589 cases of pleural abnormalities.

Asian Context: Carpenters, plumbers and electricians are together responsible for 67 percent of all cases. Department of Labor listed the high risk occupation related to asbestos and their level of the exposure. The information is identical from Australian system, might be helpful for Asian workers.

Critical Appraisal: Surveillance of New Zealand present only percentage of the cases, not estimate the risk rate or ratio. The cases were collected from compensation system; therefore the information from exposure might be limited to high exposure industries.

Available from:
a. http://www.osh.dol.govt.nz/publications/booklets/asbestos-report-2010/report-2010.pdf
b. http://www.osh.dol.govt.nz/order/catalogue/237.shtml

1-E. Asbestos Substitutes

Introduction

It is true that substitute products, particularly fibres, are often more expensive than asbestos. However, this additional cost must be considered in the light of the enormous cost of asbestos-related diseases to society. The carcinogenicity of certain substitute fibres remains under close surveillance and the development of substitute products continues. Doubts remain as regards the health effects of certain fibres which up to now have not been fully examined, because seldom used (*from ISSA technical report*).

Considerable effort has been devoted to finding alternative fibers or minerals to replace asbestos fibers in their applications. Such efforts have been motivated by various reasons, typically, availability and cost, and more recently, health and liability concerns. The substitution of asbestos fibers by other types of fibers or minerals must, in principle, comply with three types of criteria: the technical feasibility of the substitution; the gain in the safety of the asbestos-free product relative to the asbestos-containing product; and the availability of the substitute and its comparative cost (*from USGS Asbestos 2002*).

Safer substitutes for asbestos products of all kinds are increasingly available. These include fiber-cement products using combinations of local vegetable fibers and synthetic fibers, as well as other products that serve the same purposes. The WHO is actively involved in evaluating alternatives (f*rom WBG good practice note*).

Contents

The reviewed articles include following contents

- Types and uses of asbestos substitutes
  - Materials known as asbestos substitutes
  - Classification of fibers
  - Status of technology and development for asbestos substitutes
  - Costs of asbestos substitutes
- Health hazards of asbestos substitutes
  - Toxicities of asbestos substitutes
  - Comparative hazards of chrysotile asbestos and its substitutes
  - Backgrounds for occupational exposure limits of asbestos substitutes
- Consideration for safer substitution of asbestos: *Characteristics of fibers, etc*
- Health and safety in using asbestos substitutes: *ILO code of practice, etc*.
- Direction of asbestos substitution research: *NIOSH roadmap, etc.*

References

- **Types and uses of asbestos substitutes**

1. Annie Leprince (National Research and Safety Institute, Responsible for International Cooperation, France), et al. Asbestos: Protecting the future and coping with the past. International Social Security Association (ISSA); 2007. Technical Report No.: 08.

Types of use, substitute methods, substitute materials

2. Robert L. Virta. US Geological Survey: Asbestos (Geology, Mineralogy, Mining, and Uses). US Department of the Interior: Open-File 02-149; 2002. p. 13-23.
Types, uses and costs of asbestos substitutes

3. World Bank Group. Good practice note: Asbestos: Occupational and community health issues. Washington, D.C: The Group; 2009 May.
Types, uses and cost issues

4. ILSI (International Life Sciences Institute) risk science institute working group. Testing of fibrous particles: Short-term assays. Inhalation Toxicology. 2005;17: 497-537.
Classification of fibers, health hazards and testing methods of fibers

5. National Institute of Advanced Industrial Science and Technology (AIST). The development of a substitute for asbestos gasket material. Sealing Technology. 2007; 6:9-10.
Technology and development for asbestos substitutes

6. Baker R, Smith ET, Dickinson VT, Mckenzie NC, Hargreaves B, inventors; Ferodo Ltd., T&N Research Ltd., assignees. Manufacture of asbestos-free friction facing material. United States Patent US 4631209. 1986 Dec 23.

Technology and development for asbestos substitutes

7. Shiraishi H, Morita T, inventors; Akebono Brake Industry Co., Ltd., assignees. Method for manufacturing a reinforcing element for asbestos free friction material. United States Patent US 4924566. 1990 May 15.

Technology and development for asbestos substitutes

8. Patil AS, Boyd GP, inventors; Avco Corporation, Monsanto Company, assignee. Fiber blend for low cost, asbestos free friction material. United States Patent US 5508109. 1996 Apr 16.
Technology and development for asbestos substitutes

9. Kaminski SS, Evan RE, inventors; Cytec Technology Corp., assignee. Asbestos-free gaskets and the like containing blends of organic fibrous and particulate components. United States Patent US 5472995. 1995 Dec 5.
Technology and development for asbestos substitutes

10. Bauer G, Wolfshofer FE inventor; Frenzelit-Werke GmbH & Co. KG, assignee. Soft asbestos-free sealing material. United States Patent US 5437920. 1995 Aug 1.
Technology and development for asbestos substitutes

11. Largent WJ, Kaloczi C, inventors; Akzo Nobel nv, assignee. Asbestos-free roof coatings. United States Patent US 5693133. 1997 Dec 2.
Technology and development for asbestos substitutes

12. Velayutha R, inventor; Westinghouse Air Brake Co., assignee. Polymer based backing plates for railway brake shoes and disc pads. United States Patent US 6474452. 2002 Nov 5.
Technology and development for asbestos substitutes

- **Health hazards of asbestos substitutes**

13. United Nations (UN). Report of the World Health Organization workshop on mechanisms of fibre carcinogenesis and assessment of chrysotile asbestos substitutes (8–12 November 2005, Lyon, France). UN UNEP/FAO/RC/COP.4/INF/16; 2008 Oct 9.
Health hazards of asbestos substitutes

14. International Agency for Research on Cancer (IARC). IARC Monographs on the evaluation of carcinogenic risk to humans: Silica, some silicates, coal dust and para-aramid fibrils. vol. 68. Lyon: The Agency; 1997.
Health hazards of asbestos substitutes
(Attapulgite, Sepiolite, Wollastonite, Zeolites, para-Aramid)

15. International Agency for Research on Cancer (IARC). IARC Monographs on the evaluation of carcinogenic risk to humans: Man-made vitreous fibres. vol. 81. Lyon: The Agency; 2002.
Health hazards of asbestos substitutes (Man-made vitreous fibres)

16. Paul T.C. Harrison, Leonard S. Levy, Graham Patrick, Geoffrey H. Pigott, and Lewis L. Smith. Comparative hazards of chrysotile asbestos and its substitutes: A European perspective. Environmental Health Perspectives. 1999;107(8):607-611.
Health hazards of asbestos substitutes and
consideration for safer substitution of asbestos

17. Agency for Toxic Substances and Disease Registry (ATSDR), Report on the Expert Panel on Health Effects of Asbestos and Synthetic Vitreous Fibers: The Influence of Fiber Length. Atlanta GA: The Agency; 2003 Mar 17.
Health hazards of asbestos substitutes

18. National Institute for Occupational Safety and Health [Internet]. Atlanta: The institute; [cited 2011 Mar 3]. NIOSH Respiratory Disease Research Program; Evidence Package for the National Academies' Review 2006-2007: Fiber-induced disease; [about 6 screens]. Available from: http://www.cdc.gov/niosh/nas/RDRP/ch3.3.htm
Health hazards of fibers (asbestos substitutes)

19. American Conference of Governmental Industrial Hygienists (ACGIH). Documentations of the Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs): Synthetic vitreous fibers. 7th ed. Cincinnati: The Conference; 2010.
Backgrounds for occupational exposure limits of asbestos substitutes

- **Consideration for safer substitution of asbestos**

16. Paul T.C. Harrison, Leonard S. Levy, Graham Patrick, Geoffrey H. Pigott, and Lewis L. Smith. Comparative hazards of chrysotile asbestos and its substitutes: A European perspective. Environmental Health Perspectives. 1999;107(8):607-611.
Health hazards of asbestos substitutes and consideration for safer substitution of asbestos

20. Morton Lippmann. Effects of Fiber Characteristics on Lung Deposition, Retention, and Disease. Environmental Health Perspectives. 1990;88: 311-317.
Fiber Characteristics on Lung Deposition, Retention, and Disease

- **Health and safety in using asbestos substitutes**

21. International Labour Office (ILO). Code of practice: Safety in the use of synthetic vitreous fibre insulation wools (glass wool, rock wool, slag wool). ISBN 92-2-111629-8. ILO, Geneva, 2001.
Health and safety in using asbestos substitutes

- **Direction of asbestos substitution research**

22. National Institute for Occupational Safety and Health (NIOSH). NIOSH Mineral Fibers Work Group: Asbestos and Other Mineral Fibers: A Roadmap for Scientific Research. Atlanta: The Institute; 2007 Feb.
Direction of asbestos substitution research

** Each reference includes many useful references.*

1. Leprince A. et al (National Research and Safety Institute, Responsible for International Cooperation, France). Asbestos: Protecting the future and coping with the past. International Social Security Association (ISSA); 2007. Technical Report No.: 08.

Background: All types of asbestos cause cancer in humans. It is thus estimated that hundreds of thousands of people around the world fall ill each year as a result of asbestos exposure in the workplace. This article laid emphasis on a ban of asbestos and following measures such as asbestos removal and substitution.

Objective: A ban of asbestos is inevitable. Additional cost for asbestos substitution must be considered in the light of the enormous cost of asbestos-related diseases to society. The authors looked into the practical implication of the different stages that will follow an asbestos ban, namely a) the removal of asbestos-containing material and b) the availability of alternative, substitute products.

Asian Context: The report provides information about asbestos substitutes and encourages Asian countries to take into account a ban of asbestos.

Critical Appraisal: The main alternatives to the traditional uses of asbestos are summarized in the report. Especially the report includes information about substitute methods and materials by asbestos category and types of use.

Available from:
http://www.issa.int/Resources/Technical-Reports/Asbestos

2. Virta RL. US Geological Survey: Asbestos (Geology, Mineralogy, Mining, and Uses). US Department of the Interior: Open-File 02-149; 2002. p. 13-23.

Background: This paper is the results of the US. geological survey in 2002 about geology, mineralogy, mining, and uses of asbestos. The paper includes some information about alternative industrial fibers and materials, and costs of asbestos substitutes.

Objective: This paper introduced criteria and strategies for asbestos substitution, examples of asbestos substitution, and estimated cost range of asbestos fibers and several types of substitution materials.

Asian Context: The survey results provide important information for Asian countries preparing a ban of asbestos. Especially the survey results include basic principle of substitution and estimated cost of substitution materials.

Critical Appraisal: This paper provides some information about basic principle of substitution and estimated cost of substitution materials. Asbestos consumption can be expected to decline as substitutes and alternative products gain favor in the remaining world markets.

Available from:
http://pubs.usgs.gov/of/2002/of02-149/

3. World Bank Group. Good practice note: Asbestos: Occupational and community health issues. Washington, D.C: The Group; 2009 May.

Background: Good practice is to minimize the health risks associated with asbestos-containing materials (ACMs) by avoiding their use in new construction and renovation, and, if installed ACMs are encountered, by using internationally recognized standards and best practices to mitigate their impact. In all cases, the Bank expects borrowers and other clients of World Bank funding to use alternative materials wherever feasible.

Objective: The purpose of this good practice note is to increase the awareness of the health risks related to occupational asbestos exposure, provide a list of resources on international good practices available to minimize these risks, and present an overview of some of the available product alternatives on the market.

Asian Context: The good practice note presents an overview of some of the available product alternatives on the market. Information about asbestos substitution is very useful to Asian countries taking into account a ban of asbestos and substitution of asbestos-containing materials.

Critical Appraisal: The good practice note deals with growing marketplace, substitutes for asbestos products and cost-performance issues. Safer substitutes for asbestos products of all kinds are increasingly available. These include fiber-cement products using combinations of local vegetable fibers and synthetic fibers, as well as other products that serve the same purposes.

Available from:

http://siteresources.worldbank.org/EXTPOPS/Resources/AsbestosGuidanceNoteFinal.pdf

4. International Life Sciences Institute (ILSI) risk science institute working group. Testing of fibrous particles: Short-term assays. Inhal Toxicol. 2005;17: 497-537.

Background: In contrast to asbestos or synthetic vitreous fibers, other types of fibers have not been systematically assessed for carcinogenicity using lifetime rodent inhalation assays because these are technically demanding, expensive, and require large numbers of animals. ILSI risk science institute (RSI) convened an expert working group to review and evaluate the available short-term assay systems for assessing fiber toxicity and carcinogenic potential.

Objective: The objectives of the working group were 1) to summarize the current state of the science on short-term assay systems for assessing potential fiber toxicity and carcinogenicity, 2) to offer insights and perspectives on the strengths and limitations of the various methods and approaches, and 3) to consider how the available methods might be combined in a testing strategy to assess the likelihood that particular fibers may present a hazard and therefore may be candidates for further testing.

Asian Context: This article will help Asian counties to understand and select asbestos substitutes. It will be also used as reference to conduct research on health hazard of fibers.

Critical Appraisal: This article includes very useful information, such as classification and health effects of asbestos substitutes, as well as review results of short-term assay systems for assessing fiber toxicity and carcinogenic potential.

Available from:
www.cdc.gov/niosh/nas/RDRP/appendices/chapter3/a3-83.pdf

5. National Institute of Advanced Industrial Science and Technology (AIST). The development of a substitute for asbestos gasket material. Sealing Technology. 2007; 6:9-10.

Background: In the field of gaskets and packing, asbestos production is scheduled to be banned completely in Japan by 2008. The Research Center for Compact Chemical Process of the National Institute of Advanced Industrial Science and Technology (AIST) and Japan Matex Co. Ltd. have combined a heat-resistant clay membrane and exfoliated graphite, a conventional material, to develop a non-asbestos gasket.

Objective: This article describes the development of a non-asbestos gasket that is easy to handle and extensively applicable. It is composed of exfoliated graphite and a clay membrane that make it suitable for applications across a wide temperature range in a variety of chemical processing and power plants.

Asian Context: In many industrial chemical fields, gaskets are used to prevent liquids and gases from leaking from the pipe connections in the production processes at high temperatures. The article introduces a good example of substitute for asbestos-containing gasket. Efforts for development of asbestos substitutes will encourage Asian countries to take into account a ban of asbestos.

Critical Appraisal: Performance tests of the gasket were carried out to evaluate ease in handling, powder-off properties, and adhesion to flanges. The test proved that this gasket material maintains good seal performance even after exposure to temperatures up to 420°C. But a verification test is currently being conducted in the high temperature piping division of actual petrochemical plants.

Available from:

http://www.aist.go.jp/aist_e/latest_research/2007/20070206/20070206.html

6-12. United State Patents related to technology and development of asbestos-free materials.

Background: Recently the demand for asbestos free materials has increased. Asbestos-containing materials such as gaskets, brake linings, pneumatic tires, conveyor belts, timing belts, power transmission coupling, shock absorbers, sealants, and paints are well known and have achieved significant commercial success. However, health hazard problems of asbestos fibers have made related industries search for replacement composition.

Objective: The patents describe several asbestos substitutes such as manufacture of asbestos-free friction facing material (Patent No. 4631209), method for manufacturing a reinforcing element for asbestos free friction material (Patent No. 4924566, Date of Patent: May 15, 1990), fiber blend for low cost, asbestos free friction material (Patent No. 5508109), asbestos-free gaskets and the like containing blends of organic fibrous and particulate components (Patent No. 5472995), soft asbestos-free sealing material (Patent No. 5437920), asbestos-free roof coatings (Patent No. 5693133) and polymer based backing plates for railway brake shoes and disc pads (Patent No. 6474452)

Asian Context: The patents provide good examples for asbestos substitutes including technologies applied and development method. These efforts for development of asbestos substitutes will encourage Asian countries to take into account a ban of asbestos.

Critical Appraisal: Development of available asbestos substitutes will facilitate efforts of international society to eliminate asbestos-related disease.

Available from:
http://www.google.com/patents

13. United Nations (UN). Report of the World Health Organization workshop on mechanisms of fibre carcinogenesis and assessment of chrysotile asbestos substitutes (8–12 November 2005, Lyon, France). UN UNEP/FAO/RC/COP.4/INF/16; 2008 Oct 9.

Background: The WHO workshop on mechanisms of fibre carcinogenesis and assessment of chrysotile asbestos substitutes was convened at IARC in Lyon, in response to a request from the Intergovernmental Negotiating Committee (INC) for the Rotterdam Convention on the prior informed consent procedure for certain hazardous chemicals and pesticides in international trade.

Objective: The workshop established a framework for hazard assessment based on: epidemiologic data (whether data are sufficient to determine carcinogenicity); in vivo animal data (whether there is a indication of carcinogenicity or lung fibrosis); mechanistic information (whether critical indictors of carcinogenicity exist, e.g. positive results for genotoxicity in *in vitro* tests); and physico-chemical and biopersistence data as determinants of dose at the target site and possible indicators of carcinogenic potential. The workshop conducted the hazard assessment of the 15 chrysotile substitutes focusing on lung cancer, mesothelioma and lung fibrosis.

Asian Context: The survey results provide important information for Asian countries preparing a ban of asbestos. Especially the results of hazard assessment for the 15 substitutes will provide Asian countries with guidance for selecting asbestos substitutes.

Critical Appraisal: The WHO is actively involved in evaluating alternatives. The report is providing useful information about evaluation principles and examples for asbestos substitutes. The workshop developed general principles for the evaluation of chrysotile asbestos substitutes. The workshop decided to group substitutes roughly into hazard groupings of high, medium and low. However for some substitutes there was insufficient information to draw any conclusion on hazard and in this case the workshop categorized the hazard as indeterminate. The hazard groups high, medium and low should be considered in relation to each other, and did not have reference to formal criteria or definitions, as such.

Available from:
http://www.pic.int/home.php?type=b&id=138

14. International Agency for Research on Cancer (IARC). IARC Monographs on the evaluation of carcinogenic risk to humans: Silica, some silicates, coal dust and para-aramid fibrils. vol. 68. Lyon: The Agency; 1997.

15. International Agency for Research on Cancer (IARC). IARC Monographs on the evaluation of carcinogenic risk to humans: Man-made vitreous fibres. vol. 81. Lyon: The Agency; 2002.

Background: ln 1969, the International Agency for Research on Cancer (IARC) initiated a programme to evaluate the carcinogenic risk of chemicals to humans and to produce monographs on individual chemicals. The *Monographs* programme has since been expanded to include consideration of exposures to complex mixtures of chemicals and of exposures to asbestos substitutes, such as some silicates, para-aramid fibrils and man-made vitreous fibres.

Objective: The objective of the programme is to elaborate and publish in the form of monographs critical reviews of data on carcinogenicity for agents to which humans are known to be exposed and on specific exposure situations; to evaluate these data in terms of human risk with the help of international working groups of experts in chemical carcinogenesis and related fields; and to indicate where additional research efforts are needed.

Asian Context: The *Monographs* provide useful information about various types of asbestos substitutes, such as attapulgite, sepiolite, wollastonite, zeolites, para-Aramid and man-made vitreous fibres. The information includes “chemical and physical properties”, “production and use”, “occurrence and exposure”, “regulation and guidelines”, “studies of cancer in humans”, “studies of cancer in experimental animals”, “other data relevant to an evaluation of carcinogenicity and its mechanisms” with reference information.

Critical Appraisal: The IARC *Monographs* will be a basic reference on research or project concerning asbestos substitutes.

Available from:
http://monographs.iarc.fr/ENG/Monographs/PDFs/index.php

16. Paul T.C. Harrison, Leonard S. Levy, Graham Patrick, Geoffrey H. Pigott, and Lewis L. Smith. Comparative hazards of chrysotile asbestos and its substitutes: A European perspective. Environ Health Perspect 1999;107(8):607-611.

Background: Chrysotile asbestos remains in use in a number of widely used products, notably asbestos cement and friction linings in vehicle brakes and clutches. A ban on chrysotile throughout the European Union for these remaining applications is currently under consideration, but this requires confidence in the safety of substitute materials.
Objective: This paper evaluated comparative hazards of chrysotile asbestos and its substitutes. The paper specifically addresses p-aramid, polyvinyl alcohol (PVA), and cellulose, which are currently being exploited in the United Kingdom as substitutes for remaining uses of chrysotile asbestos. The paper does not cover substitute materials already widely used for thermal and sound insulation, such as glass and other man-made mineral fibers.
Asian Context: These efforts for development of asbestos substitutes will encourage Asian countries to take into account a ban of asbestos. Especially this article explains basic principles to select asbestos substitutes. Diameter is a key determinant of the intrinsic hazard of a fiber, the propensity of a material to release fibers into the air is also important.
Critical Appraisal: The authors conclude that chrysotile asbestos is intrinsically more hazardous than p-aramid, PVA, or cellulose fibers and that its continued use in asbestos-cement products and friction materials is not justifiable in the face of available technically adequate substitutes. This paper focuses only on health impacts and does not attempt a cost-benefit analysis.

Available from:
http://ehp03.niehs.nih.gov/article/fetchArticle.action?articleURI=info:doi/10.1289/ehp.99107607

"Diameter is a key determinant of the intrinsic hazard of a fiber, the propensity of a material to release fibers into the air is also important. It is generally accepted that be pathogenic to the lung or pleura, fibers must be long, thin, and durable; fiber chemistry may also be significant. These basic principles are used a pragmatic way to form a judgment on the relative safety of the substitute materials, taking into account is known about their hazardous and also the potential for uncontrolled exposures during a lifetime of use"

17. Agency for Toxic Substances and Disease Registry (ATSDR), Report on the Expert Panel on Health Effects of Asbestos and Synthetic Vitreous Fibers: The Influence of Fiber Length. Atlanta GA: The Agency; 2003 Mar 17.

Background: The Agency for Toxic Substances and Disease Registry (ATSDR) hold a panel discussion to review and discuss health effects associated with asbestos and synthetic (man-made) vitreous fibers (SVFs), especially those of less than 5 microns in length. ATSDR has invited a cross-section of scientific experts in the fields of toxicology, epidemiology, pulmonology/pathology, and medicine.

Objective: Significant toxicology and occupational health research has focused on asbestos fibers and SVF greater than five microns in length, however, it seems that much less is known about the potential health effects of smaller fibers. ATSDR has identified a need to understand the potential for fibers less than 5 microns in length to contribute to adverse health effects.

Asian Context: Smaller fibers and non-fibrous particles may be generated as fibrous materials such as SVFs are processed, disposed of, or damaged. Therefore, this report will provide Asian countries with important information for health protection of workers exposed to SVFs.

Critical Appraisal: The report includes reviews for various articles about physiological deposition pattern, clearance/biopersistence and health effects of synthetic vitreous fibers (SVFs).

Available from:
http://www.atsdr.cdc.gov/HAC/asbestospanel/index.html#full_report

18. NIOSH Respiratory Disease Research Program; Evidence Package for the National Academies' Review 2006-2007: Fiber-induced disease. National Institute for Occupational Safety and Health [Internet]. Atlanta: The institute; [cited 2011 Mar 3].

Background: The Respiratory Diseases Research Program (RDRP) is the broad range of individuals and groups supported by NIOSH to do work that is relevant to occupational respiratory disease. The National Academies was asked to evaluate what NIOSH research programs are producing and to determine the extent to which NIOSH research is responsible for changes in the workplace that reduce the risk of occupational injuries, illnesses, and deaths.

Objective: The evidence package introduces approach, outputs, intermediated outcomes, and progress towards end outcomes of RDRP about some issues concerning fiber-induced diseases (1. occupational hazard associated with asbestiform fibers contaminating vermiculite from a mine in Montana, 2. identification and control of a newly recognized occupational lung disease affecting flock workers, 3. occupational exposure to refractory ceramic fibers, and 4. determinants of fiber toxicity).

Asian Context: Information about health hazards of flock and refractory ceramic fibers, and determinants of fiber toxicity will be helpful to select asbestos substitutes or conduct related research.

Critical Appraisal: This evidence package includes very useful information. Fiber-induced diseases are presented with detailed cases and many valuable references.

Available from:
http://www.cdc.gov/niosh/nas/RDRP/ch3.3.htm

19. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the threshold limit values (TLVs) for chemical substances and physical agents and biological exposure indices (BEIs): Synthetic vitreous fibers. 7th ed. Cincinnati: The Conference; 2010.

Background: The documentation of the Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) presents the basic rationale for the establishment of occupational exposure values for cited chemical substances and physical agents and data on BEIs, all of which are summarized in the TLV and BEIs Book.

Objective: The documentations for synthetic vitreous fibers provides comprehensive information about chemical and physical properties, classification and types, composition, characteristics, nominal diameters, sources of occupational exposure, health effects (animal studies, human studies, cell culture studies, and epidemiological studies), and carcinogenicity for each synthetic vitreous fibers, as well as TLV recommendations.

Asian Context: This article provides important information for health protection of workers using synthetic vitreous fibers.

Critical Appraisal: A hundred of references were reviewed to establish TLVs for synthetic vitreous fibers. This is very informative documentation about characteristics and health effects for synthetic vitreous fibers with plenty of references.

20. Lippmann M. Effects of fiber characteristics on lung deposition, retention, and disease. Environ Health Perspect 1990;88: 311-317.

Background: The author's earlier review demonstrated the critical role of fiber dimensions on the pathogenesis of the chronic diseases associated with inhalation exposures to asbestos and other natural mineral fibers. This paper has examined the underlying roles that the physicochemical properties of mineral fibers play in modifying the pathogenic responses associated with inhaled fibers.

Objective: This article reviewed effects of fiber characteristics on lung deposition, retention, dissolution, translocation. The reasons for the lesser durability of MMMF were summarized in this review, along with the principal factors affecting fiber deposition patterns and efficiencies, i.e., the aerodynamic properties of the fibers and the nature of convective flow within lung airways.

Asian Context: This article will provide information on characteristics of fiber in selecting asbestos substitutes. It will be also used as reference to conduct research on health hazard of fibers or select asbestos substitutes.

Critical Appraisal: This article explains effects of fiber characteristics in the aspect of size of fiber, penetration into lung, durability.

Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1568011/

"The critical role of fiber dimensions is confirmed by the evidence that those MMMFs in the right size range and having sufficient durability within the body can also cause lung cancer in exposed workers. Fibers, such as conventional fibrous glass, with lesser fractions having the critical dimensions for pathogenic response and lesser durability within the body, have not been associated with excess cancer in workers. Artificial in vivo tests in animals that enhance the yields of fibrosis and mesotheliomas provide further evidence of the critical roles of fiber dimensions and durability on fiber toxicity. Virtually all fibrous minerals containing long fibers (i.e., > 10 ,um in length) produce lung fibrosis following intratracheal instillation, with the potency ranging from very high for asbestos to very low for conventional fibrous glass. Similar potency rankings apply to mesothelioma yields following intrapleural injections of fiber suspensions or implantations of fiber mats. These potency rankings indicate that the elemental compositions of the fibers play little, if any, role in fiber toxicity, except insofar as they affect the fiber durability in cells and lung fluids"

21. International Labour Office (ILO). Code of practice: Safety in the use of synthetic vitreous fibre insulation wools (glass wool, rock wool, slag wool). ISBN 92-2-111629-8. ILO, Geneva, 2001.

Background: The use of synthetic fibre insulation wools in construction has become increasingly widespread. This ILO code of practice is intended to be applied worldwide, and particularly in countries that do not have, or are in the process of developing, safe work practices in the use of insulation wools. The code takes an integrated approach since insulation wools do not appear in their pure forms but rather as products with mixed components. It addresses all the hazards arising from the product (insulation fibres, binders and other materials), with regard to real-life situations, and contains useful appendices on classification systems, exposure data and risk assessment.

Objective: This code of practice addresses occupational hazards due to insulation wools. Its purpose is to protect workers' health by ensuring safety in the use of insulation wools. The provisions of this code are aimed at: (i) minimizing exposure to fibres and dust from insulation wools at work; (ii) preventing the mechanical irritation and discomfort known to be associated with these materials, and averting the potential for long-term health effects; and (iii) providing practical control measures for minimizing occupational exposure to fibres and dust from insulation wools during manufacture, transport and storage, use, maintenance, removal, recycling and disposal of insulation wools.

Asian Context: The code of practice includes comprehensive information about health protection for workers using insulation wools.

Critical Appraisal: Although the code was written for insulation wools (glass wool, rock wool and slag wool), many of its provisions could be applied to other synthetic vitreous fibre materials. The code sets out the general duties for manufacturers, suppliers, specifiers, employers, workers and competent authorities, all of whom have an important role to play in maintaining the safety of the entire process, from production to waste management and disposal.
Available from:
http://www.ilo.org/safework/normative/codes/lang--en/docName--WCMS_107790/index.htm

22. National Institute for Occupational Safety and Health (NIOSH). NIOSH Mineral Fibers Work Group: Asbestos and Other Mineral Fibers: A roadmap for scientific Research. Atlanta: The Institute; 2007 Feb.

Background: For over a decade, the NIOSH Recommended Exposure Limit (REL) has defined airborne asbestos fibers as those particles that, when examined using phase contrast microscopy, have: (1) an aspect ratio of 3:1 or greater and a length greater than 5 μm; and (2) the mineralogic characteristics of the asbestos minerals or their nonasbestiform analogs. Several issues have been raised about the minerals covered by this definition. The first issue is whether other fibrous minerals, amphiboles and zeolites, should also be included; the second is whether the inclusion of fiber-like cleavage fragments of nonasbestiform amphiboles is appropriate; and the third issue is whether the specified dimensional criteria for fibers are appropriate.

Objective: To reduce the uncertainty and controversy concerning exposure assessment and health effects of asbestos and other mineral fibers, strategic research endeavors are needed in toxicology, epidemiology, exposure assessment, and analytical methods. To bridge the uncertainty gaps, this *Roadmap* proposes to address the following three strategic goals: (1) to develop improved sampling and analytical methods for fibers; (2) to develop information on occupational exposures to fibers and health outcomes; and (3) to develop a broader understanding of the important determinants of toxicity for fibers and fiber-like cleavage fragments.

Asian Context: The roadmap will provide guidance for hazard evaluations of asbestos substitutes.

Critical Appraisal: Despite draft stage, the roadmap includes a comprehensive approach to evaluate asbestos and mineral fibers such as sampling and analytical methods, development on information on occupational exposures to fibers, and toxicity for fibers and fiber-like cleavage fragments.

Available from:
http://www.cdc.gov/niosh/review/public/099/