enHEALTH

Management of asbestos in the non-occupational environment

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Department of Health and Ageing

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the booklet *Asbestos in the home - Health and safety in the home*, published by Department of Human Services, Victoria, Australia (2003) and available at http://www.dhs.vic.gov.au/phd/environmental/ and the ACT Government website http://www.asbestos.act.gov.au/

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Preface

In 2001, the National Occupational Health and Safety Commission (NOHSC) declared a prohibition on all uses of chrysotile asbestos to take effect from December 31 2003. The prohibition of uses includes manufacture, processing, sale, storage and re-use of asbestos and materials containing asbestos. The prohibition consolidated previous prohibitions on the use of other forms of asbestos. The prohibition does not extend to asbestos containing materials in place (in situ) at the time prohibition took effect. For this reason, many asbestos products that were used in the past are still present in both the occupational and non-occupational environment.

This document provides information to help promote a nationally consistent approach to investigating and managing the risk of asbestos in the non-occupational environment. It will assist environmental health agencies in effective and efficient management of asbestos issues in these environments.

For the purposes of this document the non-occupational environment comprises settings and activities that are not currently covered by occupational health and safety legislation, including:

- asbestos-containing materials in and around the home, including consumer products
- land contaminated with asbestos
- abandoned industrial sites
- removal, handling and disposal of asbestos-containing materials
- disposal of asbestos waste in non-approved disposal sites
- natural geological areas containing asbestos.

The information in this document outlines health risks associated with asbestos-containing materials and seeks to assist in asbestos detection, hazard identification, risk assessment and risk management.

This document is primarily intended for environment and health agencies and local authorities conducting risk assessments and determining risk management strategies for the control of asbestos in the non-occupational environment.

Agencies that need to manage asbestos in workplaces or as part of a work activity should seek further guidance from agencies that administer occupational health and safety legislation in their states and territories.

Further information

Human health effects from exposure to asbestos are well documented. There are many reviews available that give detailed information on the health risks of asbestos-related diseases. These include:

- Doll R & Peto J, 1985, *Asbestos: Effects on health of exposure to asbestos,* Her Majesty's Stationery Office, London
- Agency for Toxic Substances and Disease Registry (ATSDR), 1995, ATSDR Toxicological Profiles: Asbestos
- World Health Organization, 1986, *Asbestos and Other Natural Mineral Fibres*, EHC, 53
- Bignon J, Peto J & Saracci R, 1989, 'Mineral fibres in the non-occupational environment' in *Non-occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

The National Occupation Health and Safety Commission (NOHSC) has revised its *Code of Practice for the Safe Removal of Asbestos and Guidance Notes* (1988). Two new codes support the Australian-wide ban on new uses of asbestos in workplaces and ultimately aims to make workplaces asbestos-free. The new NOHSC documents are downloadable from http://www.nohsc.gov.au/OHSInformation/NOHSCPublications/ and include:

- *Code of Practice for the Safe Removal of Asbestos* 2nd ed. [NOHSC:2002(2005)]
- *Code of Practice for the Management and Control of Asbestos in Workplaces* [NOHSC: 2018 (2005)]
- *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres* 2nd ed. [NOHSC: 3003 (2005)].

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Thank you to the many people who provided comment as part of the consultation process. Their insight and contributions are appreciated.

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Glossary

approved	approved by the relevant state or territory authority
asbestos	the asbestiform varieties of mineral silicates belonging to the serpentine and amphibole groups of rock-forming minerals, including actinolite, amosite (brown asbestos), anthophyllite, crocidolite (blue asbestos), chrysotile (white), tremolite, or any mixture containing one or more of these
ATSDR	Agency for Toxic Substances and Disease Registry (United States of America)
background exposure	Two types of background levels may exist for asbestos: (a) naturally occurring levels: ambient concentrations of asbestos in the environment, without human influences; (b) anthropogenic levels: concentrations of asbestos present in the environment due to human-made sources eg mining activities.
f/mL	fibres per millilitre
f/mL-years	fibres per millilitre multiplied by the number of years of exposure, e.g. exposure to 1 f/mL for 2 years is reported as 2 f/mL-years – used to estimate the cumulative dose
fibril	the smallest discrete constituent that can be physically separated from a bundle of asbestos, representing a single microscopic or sub-microscopic crystal
friable material	material that is easily crumbled or reduced to powder. Asbestos in this form represents a particular hazardous state because of the potential to become airborne
hazard	the capacity of an agent to produce a particular type of adverse health or environmental effect (e.g. the capacity of asbestos to cause mesothelioma)
HEI–AR	Health Effects Institute–Asbestos Research
IARC	International Agency for Research on Cancer
IPCS	International Program on Chemical Safety
NATA	National Association of Testing Authorities
neighbourhood exposure	exposure of residents living in the vicinity of a natural deposit, mining or industrial source of asbestos
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NOHSC	National Occupational Health and Safety Commission
OH&S	occupational health and safety
para-occupational samples	those static samples taken as an indicator in the para-occupational setting of the effectiveness of control techniques – and they cannot be compared with occupational exposure standards
para-occupational exposure	exposure to airborne asbestos fibres in the home in which a worker lives (e.g. washing clothes of asbestos workers)

PLM	polarised light microscopy
PM10	particulate matter with an equivalent aerodynamic diameter of 10 or less micrometers
PM2.5	particulate matter with an equivalent aerodynamic diameter of 2.5 or less micrometers
property owner	includes the owner of buildings or other structures in which asbestos-containing products may exist
registered removalist	a removalist registered, licensed or otherwise authorised, under the relevant state or territory legislation to perform asbestos removal and maintenance work
regulated or respirable fibres	any object having a maximum width of less than 3 μm and a length greater than 5 μm and a length to width ratio greater than 3:1
risk	the probability that, in a certain timeframe, an adverse outcome will occur in a person, group of people, plants, animals and/or ecology of a specified area that is exposed to a particular dose or concentration of a hazardous agent
static samples	samples taken at fixed locations, usually 1–2 m above ground level
structure	includes any industrial plant, edifice, wall, chimney, fence, bridge, dam, reservoir, wharf, jetty, earth works, reclamation, ship, floating structure or tunnel
TEM	Transmission Electron Microscope
TSP	Total Suspended Particles
WAACHS	Western Australian Advisory Committee on Hazardous Substances
WHO	World Health Organization
μm	micrometre: one millionth of a metre – 10^{-6} m

Executive summary

Asbestos fibre types and asbestos products have differing physical, chemical and biological properties resulting in different potential risks to human health. Amphibole fibres, such as crocidolite, tremolite and amosite, are considered more dangerous than chrysotile and appear to be the critical fibres in the development of mesothelioma. The most prevalent asbestos type in Australia is chrysotile asbestos.

The dose–response characteristics of the various fibre types have been extensively studied, but there are limitations to many of these studies due to inadequate testing regimes. Nonetheless a number of them indicate that there may be a threshold for the effects of asbestos, casting doubt on the belief that 'one fibre can kill'. The evidence for a threshold is strongest for asbestosis and lung cancer. The data from published occupational studies generally show there is a direct relationship between exposure and risk for all industries and fibre types, although the estimates of risk vary between studies.

Epidemiological studies have demonstrated that the background incidence rate of mesothelioma in people without occupational, domestic or neighbourhood exposure to asbestos and with normal lung fibre content is about one per million person-years for either sex. The rate of mesothelioma for those living in close proximity to a crocidolite mine with extensive tailing contamination has been estimated to be 260 per million person-years. The rate of mesothelioma for people living near an asbestos cement factory is estimated to be 73 and 114 per million person-years for females and males respectively. Thus short-term exposures to low concentrations of airborne asbestos in the non-occupational environment are associated with very low health risks.

Health effects from asbestos result primarily from chronic exposure. However, relatively brief, high- and low-level neighbourhood exposures near a crocidolite mine or mill can also cause asbestos-related diseases. The incidence of mesothelioma has been found to be exposure dependent.

Asbestos may be encountered in the non-occupational setting from a variety of sources including asbestos cement products, floor finishes, insulation material, mining or industrial sources, sites contaminated with asbestos and other sources, such as decorative coatings applied to a ceiling. The general population will be exposed to asbestos fibres from a variety of sources such as common asbestos products or contaminated land. The risk from these sources of free asbestos fibres vary dramatically, as do strategies for managing them.

Asbestos management aims to employ protective control measures for when asbestos products or deposits are disturbed. Failure to control the release of fibres can result in short-term asbestos fibre levels comparable to those seen in neighbourhood exposure. Due to the lack of accurate and reliable exposure data, it has not been possible to determine an acceptable level of airborne asbestos in non-occupational environments, therefore management strategies aim to keep exposure to airborne fibres as low as reasonably possible.

Effective communication is integral to managing asbestos risk. Any affected individual or community should be involved and kept informed at each step of inspection, risk assessment and risk management. The belief in the community that one fibre can kill compounds the problem of risk communication. While this claim is not supported by scientific evidence, it underpins the fear and anxiety about asbestos exposure. Asbestos fibres are widespread in the environment, but the incidence of asbestos-related disease is extremely low, except in cases of high occupational or para-occupational exposure. This means everyone breathes in asbestos fibres during their lifetime. The small burden of fibres resulting from this background exposure appears to be tolerated.

There is still is a lot of uncertainty related to the risk of asbestos in the non-occupational environment. This document provides a summary of the current scientific data. New data are emerging in this expanding field of research.

Chapter 1: Introduction

The public is increasingly concerned about asbestos in building materials, waste and soil. Asbestos in existing materials becomes a problem during removal, renovation or disposal. There is a need for risk assessment of the non-occupational potential for exposure. Communication on the issues with the concerned public from an early stage is recommended.

The purpose of this document is to provide guidance to environmental health and public health services that contribute to managing asbestos health risks in non-occupational settings. It presents a consistent national approach for risk assessment and management, and aims to provide sufficient information to understand and communicate the health risks associated with exposure to asbestos.

This document promotes a risk management approach for protecting public health that is non-prescriptive. Regulation within each jurisdiction may provide greater control than recommended within this document. Management of asbestos in each jurisdiction will need to take into account the existing jurisdictional or national legislative arrangements.

The Environmental Health Risk Assessment Guidelines for assessing human health risks from environmental hazards (2002) provide general information on the risk assessment and risk management process, including the need for risk communication through all steps of the process. The general principles of risk management are shown in Figure 1.

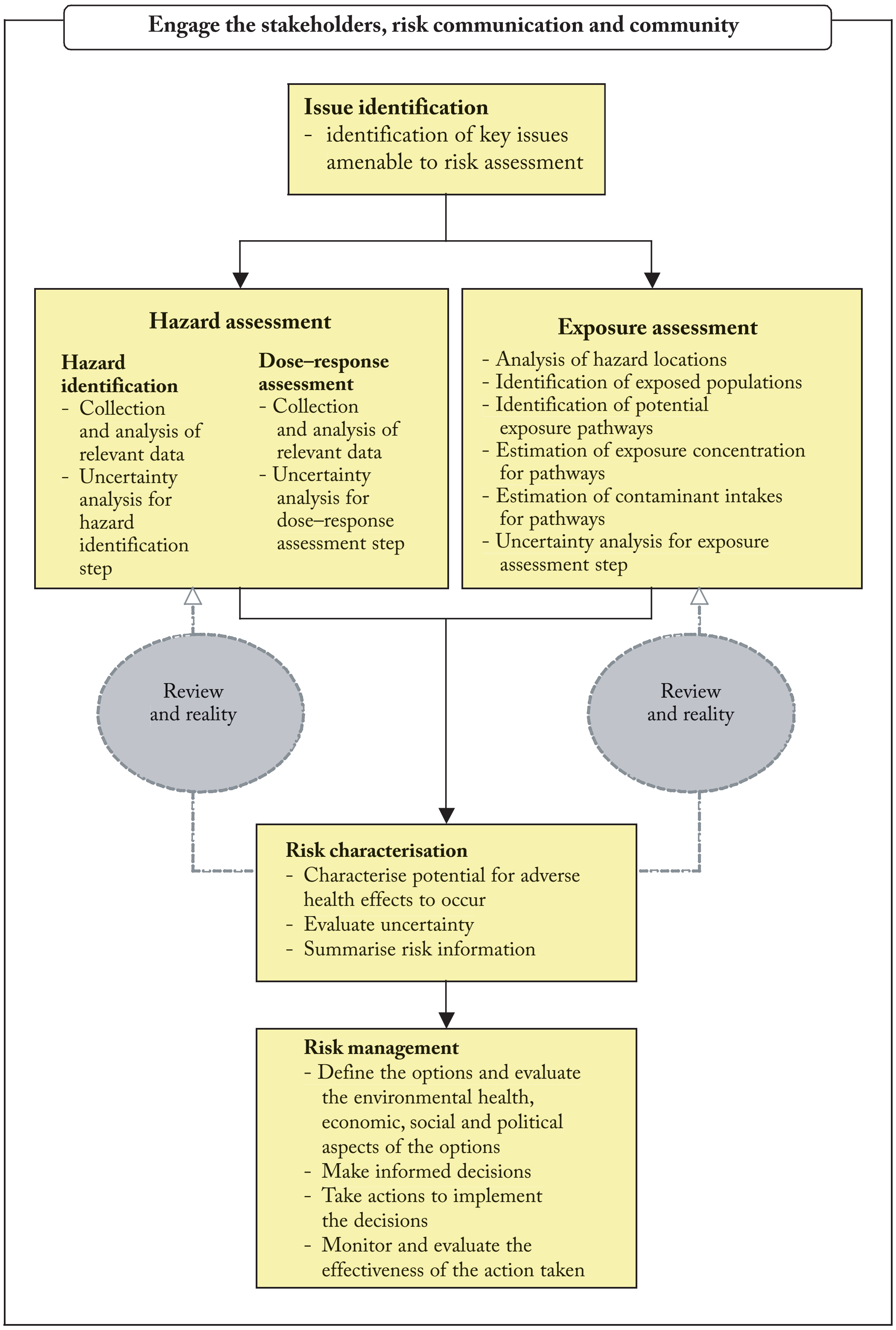
Non-occupational environments

These guidelines address the following public health risk management aspects of asbestos-containing materials:

- asbestos products in and around the home
- demolition control by local government or private building surveyors in some jurisdictions
- land contaminated with asbestos
- transport and disposal of asbestos.

Relevant legislation and guideline documents for the occupational environment are available nationally and in each jurisdiction. Occupational health and safety (OH&S) legislation and the National Occupational Health and Safety Commission (NOHSC) Codes of Practice prescribe the use, handling or removal of asbestos - containing material in public and commercial buildings or structures, and the use of asbestos in commercial and industrial settings. The application of occupational health and safety regulations (including requirements for asbestos removal) in each jurisdiction varies.

Figure 1: General principles of risk assessment and management



Chapter 2: Asbestos and health effects

Asbestos is the generic term applied to naturally occurring hydrated mineral silicate fibres belonging to the serpentine and amphibole groups of rock-forming minerals.

Asbestos is ubiquitous in the environment, with fibre release from natural sources and extensive industrial and commercial use of asbestos in the past. Asbestos and materials containing asbestos were widely produced in Australia between the 1940s and the 1980s.

The naturally occurring mineral has been mined then broken down from mineral clumps into groups of loose fibres for use in commercial applications. The majority of asbestos (95%) used throughout the world, including Australia, is chrysotile (WHO, 1986).

Asbestos minerals have been classified (see Figure 2) on a commercial rather than a mineralogical basis (WHO, 1986). This has caused problems for defining exposure and communicating health risks from asbestos fibres in the non-occupational environment, where asbestos types vary.

The common types of asbestos available commercially have been chrysotile 'white', crocidolite 'blue' and amosite 'brown' or 'grey'. Anthophyllite, tremolite and actinolite are lesser-used forms. Tremolite is mainly found as a contaminant of chrysotile asbestos. McDonald (2001:p. 2) stated that:

> Use of a single commercial term, asbestos, to cover at least five fibrous silicate minerals, each with quite different physical, chemical and biological properties, has done much to inhibit proper consideration of their individual health effects.

The different types of asbestos fibre are considered separately in the risk assessment process in this document.

These asbestos types vary in physical and chemical properties but, to a greater or lesser degree, they all show good qualities of tensile strength, flexibility and resistance to heat and chemical attack.

Respirability of asbestos fibres varies according to fibre type and degree of manipulation, i.e. the fibres become progressively finer and more hazardous with increased processing (NOHSC, 1988).

Fibre types

Serpentine

Chrysotile is a hydrated magnesium silicate, white or greenish, which occurs in serpentine rock. Serpentine rock is primarily composed of one or more of the three-magnesium silicate minerals: lizardite, chrysotile and antigorite. Chrysotile often occurs as fibrous veinlets in serpentine. The crystalline sheet silicate structure of chrysotile is distorted by curvature to form parallel bundles of long, thin, hollow cylinders (fibrils) that resemble scrolls and are flexible and 'weavable'. Chrysotile readily dissolves in acid and is hydrophilic.

Amphiboles

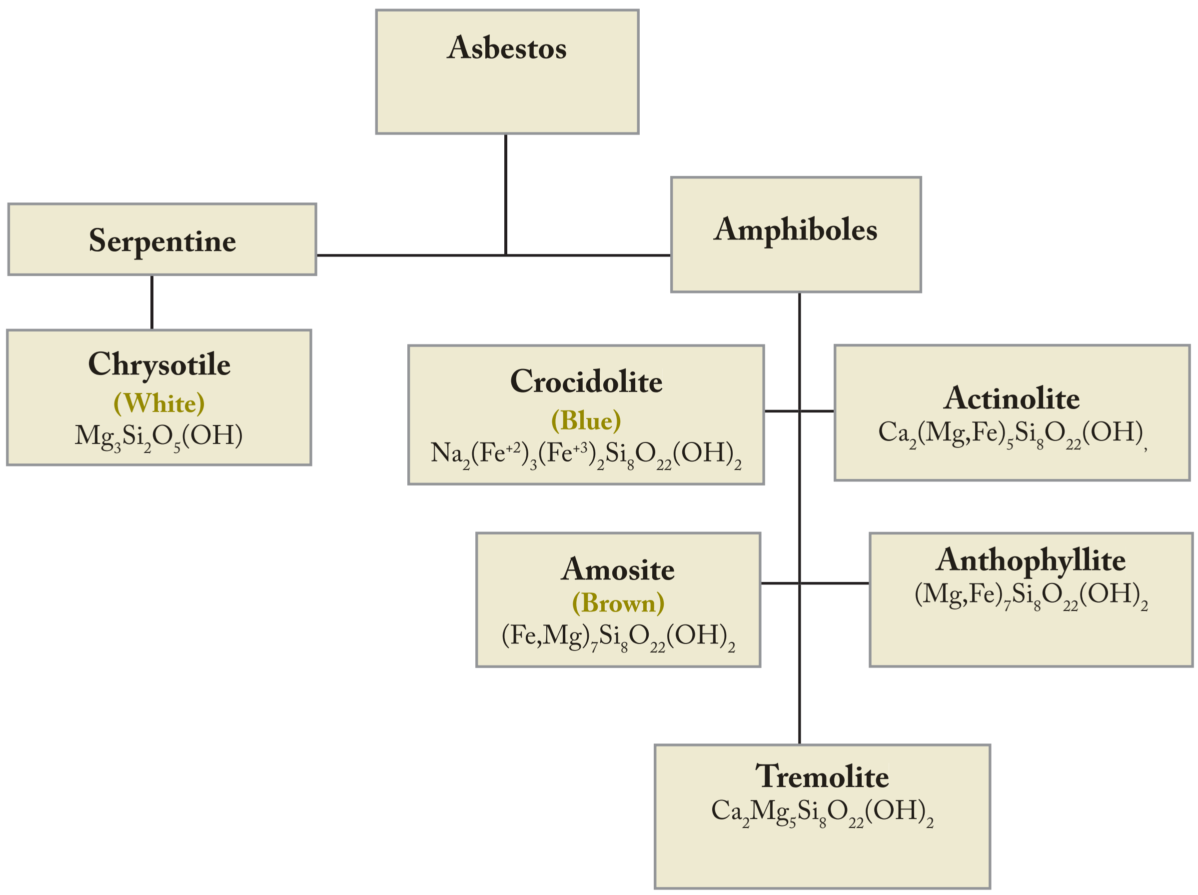
Amphiboles have a crystalline chain silicate structure. Amosite and anthophyllite are iron-magnesium silicates (brown to grey), while crocidolite is a sodium iron silicate (blue). Tremolite and actinolite (white to green) are calcium-magnesium-iron silicates. Asbestiform amphiboles grow preferentially along their crystallographic chain axis to form rigid, straight rods that are durable, even in aggressive chemical environments, and are hydrophobic. The longitudinal splitting of the amphibole fibres increases their respirability and biological activity.

Other mineral fibres

Addison (2001) describes fibres that may also be intergrowths of two or more minerals where crystal lattice orientations of the two minerals are similar. Both fibrous and non-fibrous forms of amphibole minerals are sometimes found as contaminants of chrysotile, vermiculite and other minerals (Ministry of Health, 1997).

Numerous minerals, other than asbestos, exhibit fibrous structure, such as erionite (a zeolite of

Figure 2: Commercial asbestos fibre types and their theoretical formulae



fibrous aluminosilicates) or synthetic mineral fibres (manufactured from slag, rock, or glass from blends of silica, alumina, zirconia and other materials).

Asbestiform fibres

The term asbestiform fibre relates to all fibres with the same dimensions as asbestos fibres. Regulated or respirable fibres are particles of length >5 µm, diameter <3 µm and a length to width aspect ratio of greater than 3:1 (NOHSC, 1988).

Summary of health risks

All types of asbestos fibres can cause health effects through inhalation. Some of the fibres will be deposited in air passages and on cells that make up the lungs. Most fibres are removed from the lungs by being carried away by macrophages (scavenger cells) or coughed up in a layer of mucus to the throat, where they are swallowed. Nearly all fibres that are swallowed are passed along the intestines within a few days and are excreted. A small number of fibres may penetrate cells that line the stomach or intestines and a few penetrate the blood stream and are either trapped in other tissues or removed in the urine.

Health effects commonly associated with inhalation exposure to asbestos are asbestosis, lung cancer and a rare cancer called mesothelioma that affects the pleural and peritoneal membranes lining the chest and abdominal cavity. Benign pleural abnormalities, also known as pleural plaques, can also result from asbestos exposure.

Identification of other health effects is less convincing. Evidence does not exist for non-cancer effects outside the respiratory system, other than some suggestion of immunotoxic effects (ATSDR, 2001). The International Agency for Research on Cancer (IARC, 1987) and the World Health Organization (WHO, 1986) concluded that the information for development of other health effects, such as gastrointestinal cancer from inhalation or ingestion of fibres, is inconsistent and inconclusive. More recently the United States Department of Health and Human Services (DHHS) declared 'an increased risk of gastrointestinal cancer to be an effect of concern' (ATSDR, 2001).

Asbestos has been shown to cause laryngeal cancer but to a much lesser degree than it causes lung cancer (Doll & Peto, 1985).

Asbestos-related diseases evident today are largely a result of past high occupational exposures to people employed in the asbestos mining and production industries or in the building trade. As a consequence, existing Australian asbestos-related regulations are primarily aimed at the occupational environment and prohibit use of any form of asbestos including manufacture, processing, sale, storage and re-use of asbestos and materials containing asbestos.

Asbestosis

Asbestosis is irreversible fibrosis (scarring) of the lungs caused by inhalation of asbestos fibres. Asbestos fibres can remain in the lungs for long periods and the fibrosis that results from their presence continues to develop for many years after exposure stops. Asbestosis may become evident 5–15 years after continued exposure to high respirable asbestos fibre concentrations.

Lung cancer

Asbestos, by itself or acting synergistically with tobacco smoke, causes lung cancer. Lung cancer can occur many years after initial exposure (10–40 years). Lung cancer has been identified in people exposed to respirable asbestos in occupational environments and has been associated with exposure to both amphibole and chrysotile asbestos (ATSDR, 2001).

Mesothelioma

Mesothelioma is a cancer of the lining of the chest cavity (the pleura) or, less commonly, the lining of the abdominal cavity (the peritoneum). It is generally, but not always, associated with continued occupational or other high exposure to respirable asbestos. Fairly consistent and strong epidemiological evidence indicates that approximately 70% to 90% of mesothelioma cases can be related to asbestos exposure (Youakim 2005), and hence it is commonly accepted that asbestos exposure is the cause.

The ability to link asbestos exposure to the development of mesothelioma is subject to sufficient time elapsing since the exposure occurred, to permit the disease to have initiated and developed. Mesothelioma generally does not occur until 20–50 years after exposure. Mesothelioma has been associated with all types of asbestos. However, the evidence for causality is strongest for amphiboles. Mesothelioma occurrence does not appear to be affected by smoking history (Doll & Peto, 1985).

Benign conditions of the pleura

Thickening of the pleural membrane (and creation of pleural plaques or fibroses) may develop from exposure to any asbestos fibre type, or from other causes. There are usually no symptoms, but in severe cases it may cause constriction of the lungs and impaired lung function. Short-term but high fibre concentration exposures or long-term lower concentration exposures are required for the pleural plaques to form (Berman et al, 1995; ATSDR, 1995).

Pleural abnormalities are common in family members of asbestos workers (presumably from washing asbestos covered work clothes) and in people who live in regions with naturally high asbestos levels in the soil (ATSDR, 2001).

Oral effects

The WHO has concluded that concentrations of asbestos in drinking water, resulting from using asbestos cement pipes, does not present a hazard to human health (WHO, 1986).

There is some evidence that oral exposure may lead to an increased incidence of gastrointestinal tumours (ATSDR, 2001) but increased gastrointestinal cancer rates have not been consistently shown to be associated with the presence of asbestos fibres in drinking water (IARC, 1987). The examination of exposure from chrysotile contamination in water, mainly from natural sources in the serpentine belts of the San Francisco Bay area, has shown an increase in the incidence of peritoneal and stomach cancers (IARC, 1987). The numbers of fibres found in water from this natural source have generally been much higher than numbers usually encountered in water distributed through asbestos cement pipes.

Exposures in the non-occupational environment

Inhalation is the important route of exposure for development of adverse health effects. Exposures in the occupational setting, particularly in the early history of asbestos mining and processing, involved much higher fibre concentrations and range of fibre sizes and shapes than are likely to be encountered in the non-occupational environment. As the bulk of studies on asbestos-related disease focus on occupational exposure to asbestos, these differences in exposure have major implications for the choice of analytical methodology and the overall risk assessment of asbestos in the non-occupational environment.

Asbestos can pose a health risk when fibres of a respirable size become airborne, are inhaled and reach deep into the lungs in sufficient quantities. The potential for airborne fibres to be released into the respiratory environment depends on the type of asbestos-containing material, its current use, location and condition. Fibre release is also dependent on the material being significantly compromised or disturbed to enable release. Inhalation exposure to asbestos is generally regarded as cumulative because of the long retention time of fibres in the alveoli.

Given the nature of the asbestos material generally encountered, it is most unlikely that the general public would be exposed to levels much higher than background, except in a few isolated instances, for example, during poorly managed demolition or renovation activities in homes.

Toxicity assessment

In addition to the degree of exposure (magnitude or intensity, frequency and duration), the physical properties of the fibres, including fibre type, size and shape are important determinants of asbestos-related diseases. The physical and chemical properties, persistence in the lungs and capacity to translocate across membranes are factors that underpin the intrinsic toxicity of the various asbestos types. In addition, the long latency for development of asbestos-related disease needs to be considered in any risk assessment.

Fibre size and shape influence the respirability and clearance of the fibres as well as the potential for translocation across cells and biological membranes. In terms of shape, fibres >8 μm long and <0.25 μm diameter, with an aspect ratio (length/width) ≥10 appear to be most dangerous. In terms of length, fibres >20 μm <100 μm long tend to be more carcinogenic. Fibres >100 μm long are not respirable and hence do not pose a risk, unless they are first broken down into shorter fibres. Fibres <5 μm do not appear to cause asbestos-related disease, or at least are much less potent than longer fibres.

All types of asbestos can cause lung cancer and asbestosis at higher and longer exposures than those required for mesothelioma to develop. Amphibole fibres, such as crocidolite, tremolite and amosite, are considered more potent than chrysotile and appear to be the critical fibres in the development of mesothelioma. Dose–response relationships have been derived which describe the link between asbestos exposure and mesothelioma, lung cancer and asbestosis in the occupational environment. A brief review is provided in Appendix I.

Attempts have been made to accurately quantify dose–response relationships and estimates of potency factors have been determined. However, the major limitation in these studies is the lack of accurate and reliable exposure data. Not only were exposure levels not determined in all cases, but also the analytical techniques have changed over the years and in many cases the sampling and measuring criteria (e.g. fibre size) have not been reported or were not known. This makes comparison of exposures between studies extremely difficult and estimates of potency factors more uncertain than if levels were comparable.

Data from a number of studies indicate there may be a threshold for the effects of asbestos, with both exposure and fibre properties affecting the findings. The evidence for a threshold seems to be strongest for the cases of asbestosis and lung cancer. An additional complication is that lung cancer seems to be associated with the prior development of asbestosis. However, consistent with worldwide practices for certain types of carcinogens, the shape of the dose–response curves for lung cancer and mesothelioma have been assumed to be linear at low doses for regulatory purposes.

Asbestos-related health effects result primarily from chronic exposures to asbestos, but relatively brief, high-level (Sluis-Cremer, 1991) and low-level (Hansen et al., 1998) neighbourhood exposures in the vicinity of a crocidolite mine or mill, can also cause these diseases. The increased risk of mesothelioma is dose-dependent (Hansen et al., 1997).

Epidemiological studies

The background incidence rate of mesothelioma in people without occupational, domestic or neighbourhood exposure to asbestos and with normal lung fibre content is about one per million person-years for either sex. The incidence rate of mesothelioma for Wittenoom (a mining town in the Pilbara region of Western Australia) residents with household contact and neighbourhood exposure has been estimated to be 260 per million person-years (Hansen et al., 1998). Wittenoom was located close to a crocidolite mine and was extensively contaminated with tailings. The incidence rate for residents living near an asbestos cement factory in Italy is estimated to be 73 and 114 per million person-years, for females and males respectively (Magnani & Leporati, 1998).

This non-occupational incidence rate is lower than reported for occupational groups. The small number of cases of asbestos-related disease collected, however, limits the value of some of the studies on which these estimates are based. This neighbourhood or domestic exposure involved unbound asbestos fibres, and while lower than the exposure found for people working with asbestos, it is more clearly definable than is the case for exposure in most non-occupational environments.

Risk characterisation

The concentration of asbestos is measured in fibres per millilitre of air (f/mL). Exposure to asbestos is measured according to the duration of exposure to air containing asbestos fibres. A person exposed to air containing 1 f/mL for one year, has had an exposure of 1 f/mL-year. Exposure of 5 f/mL-years could mean one year at 5 f/mL, 5 years at 1 f/mL, etc.

Short-term exposures to low concentrations of airborne asbestos are likely to be associated with very low health risks.

The general population will be exposed to asbestos fibres from diffuse ambient and point sources such as asbestos products or land contaminated with asbestos. Protective control measures are required when asbestos products or deposits are disturbed. Failure to control the release of fibres can result in short-term asbestos fibre levels comparable to those seen in a neighbourhood exposure situation.

While the available information provides qualitative descriptions of exposure, it does not give sufficiently reliable quantitative risk estimates of air concentrations resulting from activities that generate low levels of asbestos. Due to the lack of accurate and reliable exposure data, it has not been possible to determine an acceptable level of airborne asbestos in non-occupational environments, therefore the findings from studies in the occupational setting have been applied to the non-occupational setting.

The data from published studies generally shows that there is an increasing risk with increasing exposure for all industries and fibre types. The estimates of risk vary between studies and different forms of asbestos appear to pose different degrees of hazard (NICNAS, 1999:69). Table 1 summarises lung cancer risk estimates for different cohort studies with exposure to chrysotile (NICNAS, 1999).

Doll and Peto (1985) estimated the risk of lung cancer from chrysotile (predominantly) in the asbestos textile industry at one in one hundred (1%) at air concentrations of 1 f/mL per year, based on a linear extrapolation of the occupational data. Assuming different periods of exposure, they also predicted that the risk to people in offices, schools or homes with undisturbed asbestos-containing material is one in one hundred thousand (0.001%). In the case of lung cancer, smoking history modifies the estimates of asbestos risks because of the likely synergistic relationship. It is uncertain whether smoking and asbestos act synergistically at the low levels of asbestos exposure expected in non-occupational environments (Doll & Peto, 1985) but the possibility should be considered.

These limitations and the uncertainties do not allow accurate estimation of acceptable levels of exposure to asbestos fibres, therefore risk management decisions must be focused on limiting exposure to the greatest degree possible. Qualitative assessment of the potential to generate airborne asbestos fibres provides the most valuable information on which to base risk management decisions. In the absence of guidelines and standards for airborne asbestos, the need for sampling and analysis in the non-occupational environment is not critical other than to determine the presence and distribution of asbestos fibres.

Existing guideline levels

Owing to the lack of adequate data, the International Program on Chemical Safety (1988) concluded that it was unable to recommend an environmental standard. There has been little progress in the state of knowledge since the 1980s to allow a more accurate or reliable estimate of safe levels for asbestos. In reviewing the existing guideline values it should be noted that any guideline levels adopted must be measurable using a validated analytical method.

Air

Some air exposure limits that have been identified are:

- Occupational exposure standard (0.1 f/mL in Australia) and para-occupational sampling if using a limit of detection of 0.01 f/mL (NOHSC, 2002)
- Ambient air levels of
  - 0.02 f/mL in South Africa (Van Der Walt & De Villiers, 1996)
  - 0.033 f/mL proposed in Tasmania

A practical indoor air level of 0.001 f/mL (Norwegian detection limit) has been set in Norway (Daniel, 2000).

Table 1: Estimates of lung cancer risk from exposure to chrysotile in different industries

Study	Industry	Fibre type	Excess relative risk per f/mL-year
Dement et al., 1994	Textiles	Chrysotile	0.031
McDonald et al., 1983	Mainly textiles	Chrysotile, amosite and crocidolite	0.017[a]
Peto et al., 1985	Textiles	Chrysotile and crocidolite	0.015[b]
McDonald et al., 1993	Mining and milling	Chrysotile	0.0006[a,c]
Hughes et al., 1987	Cement products	Chrysotile Chrysotile and crocidolite	0.0071[a] 0.0076[b]
Berry & Newhouse, 1983	Friction products	Chrysotile	0.00058
McDonald et al., 1984	Friction products	Chrysotile	0.00053[a]

Source: NICNAS, 1999:69, as adapted from Stayner et al., 1996.
Notes:
a A conversion factor of 3 f/mL being equivalent to 1 million particles per cubic foot was assumed.
b Data are based on results for workers employed after 1951.
c Slope was estimated befitting a linear relative risk Poisson regression model to the standardised mortality ratio results reported by McDonald et al., 1986.

Soil

Imray and Neville (1993) suggested a level of <0.001 f/mL in air and <0.001 per cent in soil to classify a site as uncontaminated or unrestricted and suitable for all land uses (using information from an Institute of Occupational Medicine study (Addison et al., 1988)). However, suitable, readily available analytical techniques to quantify low levels of asbestos in soil have not been identified. Various methods are currently used to determine asbestos concentrations in soil. A consistent approach should be developed, validated and adopted throughout Australia.

Imray and Neville (1993:256) further argued,

> Since buried asbestos (left undisturbed) does not present a risk to health there is no scientific basis for setting an 'acceptable' level in soil.
>
> The risks depend on potential for disturbance and generation of airborne asbestos, which may be inhaled.

This position still holds today. Quantification down to trace levels of asbestos is not necessary for decision making in the majority of situations.

Other guideline levels identified include:

- Unofficial soil levels of 0.001 per cent have been proposed in the United Kingdom, below which no further action is required.
- Clean up levels between 0.25 per cent and 1 per cent are used by various regions of the United States Environmental Protection Authority.

- In Manukau City Council, New Zealand, where extensive remediation of asbestos cement fragments has occurred, a semi-quantitative estimate of 0.001 per cent asbestos content has been accepted as a guideline, based on the mass of fibres in handpicked samples and the mass of soil examined (Otness et al, 2003).
- The Australian Contaminated Land Consultants Association Inc. (NSW) (2001) has proposed a health investigation level for asbestos of 0.01 per cent fibres in soil.

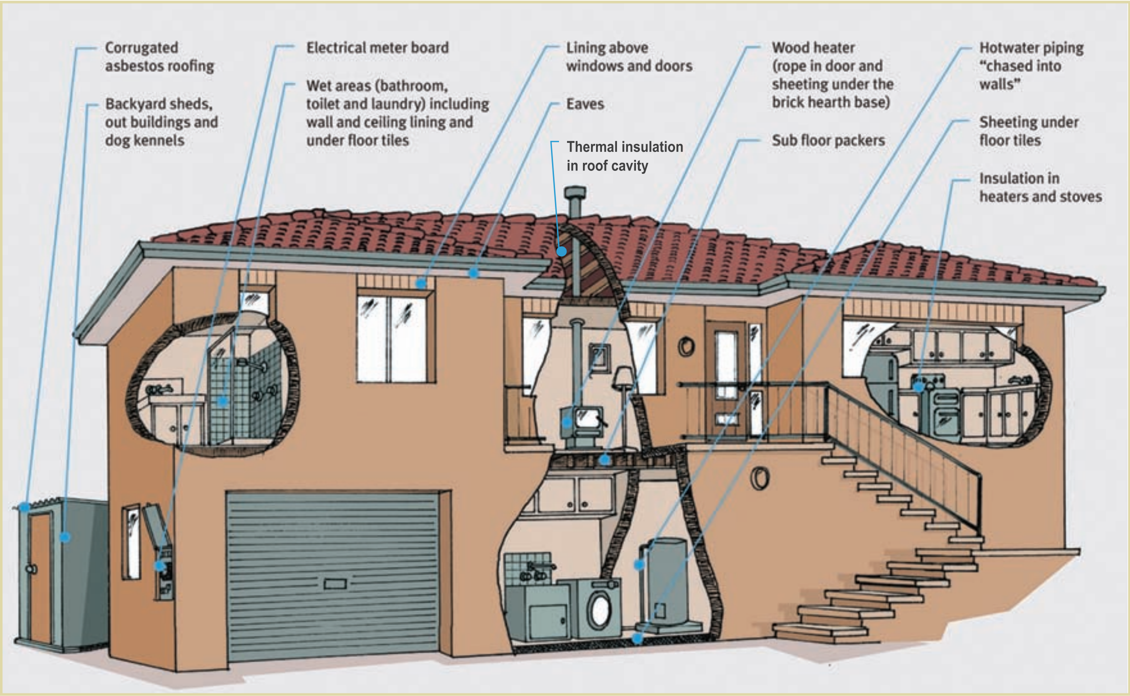
Other

The European Union and Australia have each set a cut-off of 0.1 per cent by weight asbestos in products for the purpose of carcinogenic classification of the products (Schneider et al., 1998; NOHSC, 1999). That is, products containing more than 0.1 per cent asbestos are classified as carcinogenic and need to be handled and labelled accordingly.

The European Commission (2000) is likely to propose a level of 10 mg/kg (0.001%) for aggregates produced from recycled construction and demolition waste. This supports the uncontaminated level of 0.001 per cent proposed by Imray and Neville (1993). Mixing of waste streams to meet this cut-off concentration is unacceptable.

Victoria has a 1 per cent by weight asbestos landfill criterion but under amendments made in December 2003 to the Occupational Health Safety (asbestos) Regulations 2003, now has a 0.001 per cent by weight limit for construction materials that contain asbestos.

Figure 3: Asbestos Products in Domestic Buildings



Chapter 3: Assessment and management of asbestos exposure from various sources

There are several possible sources of asbestos exposure in the non-occupational environment: asbestos cement products, floor finishes, insulation materials, mining and industrial sources, and contaminated sites.

Asbestos cement products

Asbestos has been used as a reinforcing agent in cement sheeting for walls and roofs; in cement building products, such as tiles, cold water tanks, pipes and gutters; and in insulating board used, among other things, as wall partitions, fire doors, ceiling tiles and electrical switchboards.

It was also mixed with cement to make lighter, stronger commercial and domestic building materials such as flat and corrugated sheets for cladding, roofing and fencing, moulded products such as flue pipes, guttering and downpipes, and high and low-pressure pipes for water distribution. Asbestos cement tiles have been used as flooring in larger commercial buildings. Typical locations for asbestos products in domestic buildings are shown in Figure 3.

The manufacture of asbestos cement sheeting and high-pressure piping ceased in the late 1980s and houses built since then are unlikely to contain asbestos. A list of common trade names for asbestos cement products and the last year of production for each product by James Hardie and Co. Pty Ltd is included in Appendix IV.

Asbestos cement materials in Australia typically contain 10–15 per cent asbestos by weight, bound in a cement matrix. Chrysotile is the most commonly used form of asbestos, although asbestos cement products may also contain a small quantity of amosite and/or crocidolite. There may be 3–5 per cent asbestos in fibrocement products manufactured during the phase out of asbestos in the late 1980s.

The release of fibres from materials such as asbestos cement used for construction is the main potential source of indoor exposure to fibres in domestic premises.

Exposure

Information on asbestos fibres in air is included for each source of potential asbestos exposure discussed to provide a general idea of the types of exposures encountered. The asbestos levels in air usually cannot be directly compared because of the different fibre types present and different sampling strategies, measurement sensitivity, analytical techniques, and counting rules used to determine air levels.

The contribution to air concentrations of fibres by undisturbed asbestos products will be very low. Nonetheless, the degree to which asbestos-containing materials contribute to the concentration of asbestos fibres in air will depend on the type and the condition of the material.

Background indoor air levels average around 0.0002 f/mL[1] (ATSDR, 2001), indicating that asbestos cement products in buildings, when undisturbed, do not contribute significantly to indoor air levels of fibres. However, increased exposure can occur when the building is demolished or renovated.

Fibres may be released if asbestos cement material is disturbed, for example, by using power tools. Asbestos fibre concentrations in air of 2–20 f/mL have been reported when sawing asbestos cement products with power tools and without ventilation; and between 2 f/mL and 4 f/mL during hand sawing (Brown, 1997). Therefore workers may be exposed to higher concentrations of airborne asbestos if they do not use suitable respiratory protection.

From the levels reported by Brown (1997), it could be inferred that air concentrations are about 10 000 to 100 000 times higher than background when working with asbestos cement products. However, this is not a valid direct comparison because of the variation in results obtained from different sampling strategies, sampling media and analytical techniques.

Because of the properties of asbestos, the nature of asbestos products used and the factors that influence the generation of airborne fibres, air sampling results will provide only a snapshot in time which, in most cases, will not be representative of exposure under various activities and conditions. Therefore, qualitative assessment of the distribution and conditions of the materials (see Appendix V) and potential for fibre release to air is a very important aspect of exposure assessment that needs to be undertaken in addition to any sampling and analysis.

Qualitative exposure assessment in any situation should include an initial visual inspection and investigation of any material containing asbestos to determine the potential to release fibres. A sample inspection checklist is available in Appendix V.

The use of trade names can hinder the detection of asbestos-containing materials. Materials may have also been painted, enclosed or encapsulated in buildings; therefore identification may require a thorough investigation, including sample collection for investigation (NOHSC, 1988).

Methods to assist in the detection of all fibrous materials suspected of containing asbestos in a building or site include:

- conducting a visual inspection of the area under investigation and assessing and recording the:
  - type of asbestos-containing material and its asbestos content
  - condition and age of material
  - wear and weathering
  - exposed surface area
  - accessibility/location
  - activity and movement

[1] Determined using transmission electron microscopy.

- determining the age of existing or demolished buildings or structures (fibre-cement products produced prior to the late 1980s would contain asbestos)
- checking building plans, property use and records
- interviewing building owners, occupiers or landowners who may have historical knowledge of asbestos-containing materials used
- collecting samples of the suspect material for analysis.

These factors should be considered in all situations where assessment of health risks from materials containing asbestos is required. Information on sampling and analysis is provided in Appendix II: Air sampling and analysis and Appendix VI: Sampling of asbestos products in buildings.

Factors that affect exposure from asbestos cement products

Many factors affect asbestos exposure from asbestos cement products: the type of material and its asbestos content, the material's condition, the exposed surface area, its accessibility and activity, and water damage and weathering.

Type of asbestos-containing material and its asbestos content

Where asbestos fibres are present in low concentrations and are bound within a stable material, such as asbestos cement, they are less likely to generate dangerous levels of airborne fibres than where they are friable and have a higher fibre content, such as sprayed coatings and insulation.

Condition of material

Although warps and/or cracks may indicate that the material has outlived its useful life in building products, such deterioration does not necessarily indicate a measurable increase in airborne fibres. Asbestos cement sheets tend to harden with age through hydration of the cement matrix and with natural weathering the sheets become more brittle. Brittle sheets tend to crack easily when subjected to pressure and present a danger if walked on (e.g. asbestos cement roofs). Fungal growths are common on unpainted asbestos cement roof sheets. The growth can cause surface deterioration and will slowly eat into the flashings and gutter linings. Moss and lichen growths may also cause a slight softening of the asbestos surface (Noy, 1995).

A pilot study of 13 schools in Western Australia by the Western Australian Advisory Committee on Hazardous Substances (WAACHS, 1990) showed that deteriorating asbestos cement roofs are common. Roofs more than about 20 years of age showed quite severe deterioration and visible asbestos fibres were commonly seen in gutters. Other asbestos cement materials (such as fences) were generally in good condition.

Exposed surface area

The larger an exposed surface area of material containing asbestos the higher the potential for generating airborne fibres, hence exposure.

Accessibility, activity and movement

Any circumstance or activity that has the potential to disturb material containing asbestos can lead to increased dispersal of fibres into the air. If the material is readily accessible it may be vulnerable to accidental or deliberate disturbance or damage.

Elevated asbestos fibre concentrations have been found in certain buildings as a result of abrasion or damage to asbestos cement material and dispersal of released material through human activities (HEI–AR, 1991).

The greatest risk is to those individuals who directly disturb sources of asbestos, e.g. through renovation or maintenance. The risk of inhaling airborne fibres decreases rapidly with distance from the source of the disturbance. Workers involved in building maintenance, remodelling, asbestos removal or site remediation could be exposed to elevated asbestos fibre concentrations unless appropriate precautions are taken. Activities using power tools or high power water jets present the greatest risk. The incidental risk to the general population is much lower because of the dispersion of any fibres generated with distance from the source.

Water damage and weathering of asbestos products

Weathering of asbestos cement products results in the dissolution of the surface layer of cement and exposure of fibre bundles and release of fibres into the environment by rain, hail, wind and mechanical action.

The concentration of asbestos fibres in air above weathered asbestos cement sheeting has been measured at up to 0.0012 f/mL (WAACHS, 1990). It was shown that, under experimental conditions, the highest concentration of asbestos fibres in run-off water was observed for roofs of intermediate age (10–17 years old) rather than recently installed sheets, or older roofs (25–35 years) of more weathered appearance. The study also found that visual appearance of the condition of a roof did not correlate with the number of fibres found in run off.

Run off experiments suggest that rain removes significantly more weathered asbestos from roofs than wind. Asbestos fibres have been found (comprising less than 5 per cent of the sample material) in gutters and around the point where water draining from the roof is discharged (rarely more than 1 per cent of soil) (WAACHS, 1990). Chrysotile was the predominant fibre found in samples of roof water run off. Air monitoring detected no respirable fibres in the vicinity of gutters and drains. Collection of roof water run off into soak wells was recommended to prevent local accumulation of asbestos fibre in accessible areas (e.g. bitumen courtyards).

The investigations of asbestos cement products (asbestos sheets from roofs and facades) conducted during 1984 and 1986 in the Federal Republic of Germany (Spurny, 1989) demonstrated that:

- asbestos cement surfaces corrode and weather as a result of aggressive atmospheric pollution (gases such as sulfur dioxide, aerosols and acid rain)
- the surface cement matrix of the material is destroyed and a thin (approx 0.1–0.3 mm) layer of free deposited asbestos fibres is built up
- wind disperses fibres into the ambient air. Fibre emission factors in the range 106–109 $f/m^2/h$ have been measured
- approximately 20 per cent of free asbestos fibres are dispersed into the ambient air and 80 per cent are washed out by rainwater
- analysis of bulk samples as well as of individual fibres showed chemical and crystallographic changes in the corroded chrysotile fibres
- measurements of asbestos fibre concentrations in the vicinity of buildings containing corroded and weathered asbestos cement products gave airborne asbestos fibre concentrations (for fibres longer than 5 μm) in the range of 0.0002–0.0012 f/mL.

Health risk

The risk associated with installed, undisturbed asbestos cement products are negligible, as the fibres are bound together in a solid cement matrix. Even weathered asbestos cement roofing does not release significant amounts of airborne fibres unless the material is significantly disturbed. In fact, if asbestos materials can be maintained in good condition, it is recommended that they be left alone and periodically checked to monitor their condition. It is only when asbestos-containing materials are disturbed or the materials become damaged that the risk to health is increased. When the materials become damaged, the fibres may be released and become airborne.

Home improvement/renovation, maintenance activities (such as plumbing or electrical work that involves drilling or cutting materials containing asbestos) and demolition of asbestos cement dwellings can lead to fibre release.

An isolated exposure to asbestos fibres of short duration is extremely unlikely to result in the development of an asbestos-related disease, as fibre concentrations are likely to be insufficient to increase cumulative lifetime exposure.

Risk management

High peak exposures to airborne fibres should always be avoided. The most effective risk management solution is to leave material containing asbestos in place unless disturbance of the material cannot be controlled or managed. Removal is likely to lead to an increased health risk, albeit a relatively small increase (HEI–AR, 1991).

Asbestos cement products should generally be left until demolition, redevelopment or removal.

In 1990 WAACHS included in its recommendations that:

> An asbestos cement roof, which has not deteriorated to an extent where physical safety or structural integrity is of concern, should not be replaced (p. 5).

Though durable, asbestos cement roofing does not last indefinitely. Roofing that has weathered to the point where it is structurally unsound and no longer waterproof should be replaced.

Health policy in each jurisdiction should include provisions for replacement of any material containing asbestos that has reached the end of its useful life.

Any building owner who is renovating or demolishing a building should have their buildings surveyed for asbestos-containing materials. When a property that has asbestos products within the home or on the property (e.g. asbestos cement fence) is sold, it is good practice to inform the new owner of the location of asbestos-containing materials.

Damaged or disturbed materials, where physical safety or structural integrity is compromised, should be repaired, covered, enclosed or removed as necessary. The sale and supply of second hand asbestos cement sheeting should be prohibited (asbestos cement sheeting is no longer produced).

There should be public education and information on the safe removal, collection, and transportation and disposal of asbestos cement materials and floor coverings by the public. Each jurisdiction should provide public information sheets that include legislative controls and/or any approvals required for handling and disposal.

Local governments should routinely attach information and conditions about handling asbestos safely to demolition licences or permits (see Demolition control – prevention).

The inspection form in Appendix V provides some guidance as to where asbestos products can be found in buildings.

Recommended maintenance of asbestos cement roofs

Regular maintenance should include:

- regular visual inspection of asbestos cement roofs for signs of deterioration and damage. It is not advisable to walk on a weathered asbestos roof as it may be structurally unsound
- annual cleaning of gutters and drains by wetting the waste material and collecting it in heavy-duty plastic bags for disposal at an approved landfill
- collection of roof run-off from drainpipes into soak wells, including domestic structures (WAACHS, 1990).

The roof should not be cleaned unless really necessary as asbestos fibres may be released. If cleaning is necessary (e.g. for aesthetic reasons or before applying surface coatings) a surface biocide can be applied, then the dead moss and algae removed using gentle brushing of the wet surface. Sanding, scraping or use of a wire brush or a high-pressure water jet is completely inappropriate. Cleaning an asbestos cement roof using a high-pressure water jet causes the cement matrix to disintegrate, releasing asbestos fibres. A vast amount of virtually unmanageable slurry, containing free asbestos fibres, is produced.

Walking on an asbestos cement roof can be highly dangerous, particularly if the roof has undergone significant weathering. Many people have been seriously injured falling through asbestos cement roofs while attempting to treat, repair or remove the roof. Coatings applied to asbestos cement roofs can hide roofing nails, which normally indicate where it is safe to walk (see next page).

Coating asbestos cement products

Though not considered necessary, surface coatings may extend the life of asbestos cement products and may improve their appearance.

Not all products are equally effective and it is necessary to distinguish between whether surface coatings are paints or sealants. While paints may effectively coat unweathered asbestos cement surfaces, for instance internal walls, they may not bond well to the surface of weathered asbestos cement sheeting as found on roofs. Paints therefore may have very little durability and it is recommended they not be used on weathered surfaces.

Sealants are coatings capable of penetrating the surface of weathered asbestos cement products and binding exposed asbestos fibres to the lower cement layer.

Modern coating systems generally consist of a sealant and one or more topcoats. A topcoat is necessary to protect the sealant from the effects of sunlight. Decorative finishes are also available.

When asbestos roofs are coated safe walk areas should be clearly marked.

Selecting a coating

Colour and texture make no difference and are a matter of personal taste. There are a number of factors to consider when selecting a coating – they are penetration and binding, durability, re-coating and cost.

Penetration and binding

The coating or sealant must penetrate the weathered layer and provide a strong bond to the hard cement substrate.

Durability

The coating must be resistant to sunlight, extreme temperatures, abrasion, wind and rain. Preferably, select a coating that comes with a written durability guarantee. A coating's ability to prevent lichen growth is important, as lichen growing under the coating can affect both its binding and its durability.

Re-coating

All coatings will deteriorate over time. Some coatings allow for successful re-coating later on, an important quality if an asbestos cement roof is to last longer than the coating. However, some products may require some cleaning before they can be recoated, and this process may release airborne fibres.

Work practices likely to generate airborne fibres must be avoided. If an asbestos cement roof is coated with a product that does not allow successful recoating, the owner or occupier may have to replace it.

Cost

There is considerable variation in the chemical composition of different coating systems, and therefore the cost. When extending the life of an asbestos cement roof by coating, one should consider also the expected life of the building. It may not be financially viable to expend large amounts on a building with a limited life expectancy.

Removal

Removal work can be dangerous, particularly for unskilled and inexperienced people who may not have all the appropriate equipment available to undertake the work safely, without posing a risk to themselves or other people. Risks include:

- falling through the roof
- generating unacceptable levels of airborne fibres
- no access to appropriate safety equipment
- contaminating the buildings and the environment with asbestos fibres
- inappropriate disposal of asbestos-containing material.

Use of experienced, licensed or contract labourers is recommended. Licensing requirements in each jurisdiction vary. Guidance is available in the *Code of Practice for the Safe Removal of Asbestos* 2nd ed (NOHSC, 2005). In cases where no licences are currently needed, jurisdictions should introduce them to ensure safe handling of asbestos products.

Reasonable measures should be encouraged and enforced in legislation to prevent or minimise fibre release by any person maintaining, removing, repairing or transporting asbestos cement products.

Home-owners who choose to deal with asbestos cement products themselves, as well as contractors, should follow these NOHSC recommendations and any state- or territory-specific legislative requirements and guidelines. The requirements for people using, handling, maintaining or removing asbestos cement are provided in Section 9 of the *Code of Practice for the Safe Removal of Asbestos* 2nd ed (NOHSC, 2005) and outlined in Appendix VII.

Floor finishes

Two types of floor covering may contain asbestos; vinyl floor tiles impregnated with asbestos fibre and fibre reinforced paper backing for linoleum produced prior to 1984. In the absence of information to the contrary, it should be assumed that these products contain asbestos and should be handled in a manner that minimises breakage and prevents release of fibres. Left undisturbed, these products do not pose a risk.

Exposure

Floor finishes are similar to asbestos cement products in that the asbestos fibres are bound within a stable material. Factors to consider when conducting a visual inspection are discussed on p. 15.

Generally, chrysotile asbestos was used as a reinforcing agent and may be at a concentration between 3–7 per cent for both asbestos vinyl and reinforced backing of linoleum. Machine buffing of vinyl floor tiles has been shown to result in 0.02–0.3 f/mL in air (Brown, 1997). This should be avoided. Personal air samplers have measured exposure resulting from removal by scraping and use of chemical solvent at <0.008 to 0.094 f/mL (Lange & Thomulka, 2000).

Health risks

As for asbestos cement products, exposure to asbestos from material in good condition is thought to be very low. Floor finishes that are no longer in good condition should be repaired or replaced to ensure that exposure remains as low as reasonably achievable. Precautions should be taken to control risks from elevated exposure to airborne fibres during renovation or removal of floor materials.

Risk management

Legislative requirements may vary in each jurisdiction. For example, in South Australia, where linoleum has been damaged, a homeowner can only remove 1 m^2.

Whenever practicable, floor surfaces should be left *in situ* and, if necessary, covered with non-asbestos containing finishes. Minor repairs to holes, cracks and splits may be required first.

Where it is necessary to remove, replace, repair or demolish floor surfaces or finishes that contain asbestos, sanding, dry sweeping, dry scraping, drilling, sawing, bead blasting, mechanically chipping or pulverising of existing flooring, backing, lining felt or residue adhesives, must be avoided.

Damp the surface with water before removing asbestos. This will help to minimise airborne dust and small sections at a time can be scraped. The use of hot air guns or solvents may introduce new non-fibre hazards.

Insulation materials and public buildings

Thermal and acoustic insulation materials were not routinely used in residential dwellings, although there have been some isolated cases.[1] If removal is required, it should be done in accordance with occupational health and safety legislation.

Public and commercial buildings may contain large quantities of loose, friable asbestos (e.g. insulation), which pose a significant risk of generating airborne fibres if disturbed.

Products of most concern from a health viewpoint include:

- sprayed-on fireproofing, soundproofing and/or thermal insulation
- acoustic plaster soundproofing
- insulation, e.g. of internal air-conditioning ducts, pipes, boilers, fire doors, heaters, oven doors
- sprayed-on fibre used to strengthen asbestos cement sheeting and decorative finishes.

Exposure

Non-occupational exposure to asbestos-containing materials in larger buildings (public and commercial) would be of a transitory, incidental nature. Air movement, human movements, or building vibration may potentially cause fibre release from thermal or acoustic asbestos insulation materials.

Well-maintained public buildings have been found to have low indoor air concentrations of asbestos fibres; levels are similar to those found generally. The Health Effects Institute (HEI) conducted a review of asbestos in public and commercial buildings (HEI–AR, 1991). The review summarised asbestos fibre concentrations (fibres longer than 5 μm/mL) from 1377 samples of indoor air in 198 buildings.[2] The mean value for all the data is 0.00027 f/mL, including higher values sampled during building maintenance.

Corn (1994) showed maximum airborne asbestos concentrations in United States schools up to 0.0023 f/mL (by transition electron microscopy, >5 μm in length). There was no correlation between asbestos concentration in air and type and condition of asbestos-containing material present (materials containing asbestos included insulation, lagging, acoustic ceilings, tiles); whether the space was covered; whether sweeping was noted; type of school or year of construction; or air flow in the same area.

Asbestos was undetectable by scanning electron microscopy (detection limit of 0.002 f/mL) outdoors near Western Australian schools that had asbestos cement roofs (WAACHS, 1990).

Health risks

The health risks from transitory exposure in public and commercial buildings arise primarily from exposure to asbestos cement products. A review of the literature by HEI–AR (1991: 1–11) concluded that the estimated lifetime risks were comparable for continuous outdoor exposure, exposure in schools containing asbestos cement products and public buildings containing asbestos cement products.

Risk management

Occupational health and safety legislation in each state and territory and the *Code of Practice for the Safe Removal of Asbestos* 2nd ed (NOHSC, 2005) covers the management of asbestos-containing materials in public and commercial buildings. Non-occupational exposure can be minimised by ensuring compliance with these regulations.

Mining and industrial sources

The main Australian centres of asbestos mining were the crocidolite deposits of the Hamersley Ranges in Western Australia and chrysotile deposits at Baryulgil and Woods Reef in New South Wales (NICNAS, 1999). A summary of the history of asbestos mining activities in Australia is shown in Appendix VIII.

[1] Ceiling insulation in approximately 1100 homes in the ACT, since removed, and another 100 or so homes in nearby NSW towns (Brown, 1997).
[2] Determined using transmission electron microscopy.

Chrysotile was mined in Australia for over 100 years until 1983. Mining in Australia was a relatively small activity (only about 5 per cent of asbestos used in Australia was mined locally) as asbestos was mainly imported.

Exposure

Wittenoom residents (in Western Australia) were exposed to contamination from crocidolite fibres from milling operations and the extensive use of mill tailings in the town. Asbestos fibre concentrations of up to 0.21 f/mL were measured (using personal sampling) for residents undertaking normal daily activities (Public Health Department, 1977; unpublished). The tailings were used on the yards of houses to suppress dust and reduce muddiness. They were also used for paving roads, driveways, car parks and school playgrounds, and on the racecourse (Nevill, 1994).

Airborne asbestos fibre concentrations have been measured in the vicinity of asbestos processing plants. Concentrations of airborne asbestos fibres were within the ranges of those observed in urban environments (from 0.0001 to 0.01 f/mL).

Health risk

Studies in South Africa and Australia show an increased risk of mesothelioma in people living near crocidolite mines (Hillerdal, 2001). However, an increased risk of lung cancer has not been identified in populations near mines or factories processing various types of asbestos (Bignon, 1989).

The World Health Organization (WHO, 1986) states the risk of pleural plaques and mesothelioma in populations near mines or factories processing various types of asbestos may be increased from neighbourhood exposure to asbestos. This conclusion is based on findings at a time when factories emitted high levels of airborne fibres.

The mining of crocidolite in Western Australia has had a considerable impact on the incidence of mesothelioma in Australia. A non-occupational cohort study of Wittenoom residents by Hansen et al. (1998) shows that the incidence of mesothelioma increased significantly with time following first residence at Wittenoom and with increased exposure to crocidolite.

The crude incident rate of malignant mesothelioma for Aboriginals in Western Australia has been estimated to be 50 per million person-years for those aged 15 years or over (Musk et al., 1995). With the exception of exposure to naturally occurring erionite in Karain, Turkey, this is five to 10 times higher than any of the other population-based rates. All cases reported by Musk et al. (1995) occurred in Pilbara residents.[1] The majority of cases have had some occupational exposure in the transport of asbestos from Wittenoom. Non-occupational exposure has been in people living close to Wittenoom, and in one case, from childhood exposure to storage sheds in Point Sampson, on the northwest coast.

An increased risk of mesothelioma has been shown in people living close to an asbestos cement factory (Magnani et al., 2001) and within 2 km of asbestos mines, asbestos textile and asbestos cement plants in Europe (Magnani et al., 2000). The type of asbestos fibres was not identified.

There have been numerous reports of mesothelioma cases in spouses of asbestos workers, possibly from cleaning contaminated work clothes.

Risk management

Cessation of asbestos mining and manufacturing of asbestos cement products, together with current occupational health and safety practices in Australia have essentially eliminated this type of exposure in the workplace. However, the latency of asbestos-related diseases means that people previously exposed may still develop asbestos-related diseases. Areas affected by previous mining or industrial sources need to be managed according to contaminated site guidelines.

[1] Approximately 40 000 Aboriginals live in Western Australia, of whom 6000 live in the Pilbara region.

Sites contaminated with asbestos

The need to regulate procedures for the management and disposal of asbestos wastes has become a priority in the last 30–40 years, as the incidence and awareness of asbestos-related diseases has increased, and as asbestos-containing materials come to the end of their useful life. Past practices have resulted in widespread, uncontrolled disposal of asbestos waste throughout urban and rural environments. The ready availability and widespread use of asbestos-containing materials in buildings, and their subsequent demolition and decommissioning, as well as the mining, handling, transport and processing of asbestos, have increased the asbestos burden in the environment including land contamination.

As contaminated sites are redeveloped into residential blocks, there is a need to assess and manage the likely risks posed by asbestos contamination.

It is impractical to propose that a site can be 'free' of asbestos fibres. Risk assessment and management is required before sites can be declared acceptable for unrestricted use. Additionally, asbestos cement products mixed with building waste are of concern and raise problems regarding acceptable levels for recycling and disposal.

Situations where sites should be considered potentially contaminated with asbestos include:

- industrial land, e.g. asbestos cement manufacturing facilities, former power stations, rail yards and shipyards, especially large workshops and depots
- discarded asbestos waste at old waste disposal sites or other locations, e.g. asbestos cement products, building waste and insulation material
- asbestos waste from mining or manufacture of asbestos products used as infill
- fire and storm damaged buildings
- urban land with fill of unknown composition
- sites where buildings or structures have been demolished or renovated, including residential land
- disused services with asbestos concrete piping, e.g. water pipes, telecommunications trenches or pits, etc. usually found within 1 m of the surface.

Soil guidelines

The setting of soil guidelines is complicated by the absence of reliable and validated data on the relationship between soil and air levels. The variable composition of many sites and various types and conditions of asbestos waste creates difficulty in developing representative sampling plans and interpreting the results. Expensive sampling and analysis plans that add little value to the risk assessment and management decisions should be avoided.

Regulators should only use any guidelines that may be established to enable classification of contaminated sites and to provide permission for development (not to determine health risk).

Exposure assessment

Health risks from asbestos-containing materials in soil will depend on the potential for asbestos fibres to be disturbed, become airborne and be inhaled. If the material is readily accessible it may be vulnerable to disturbance by people, vehicles or objects. For example, vehicle movements or construction work may release the fibres or dust.

Air or soil sampling results will provide information on the extent of the contamination but will also represent only a snapshot in time which, in most cases, will not be representative of exposure under various activity and conditions. Therefore, qualitative assessment of the distribution of the materials and potential for fibre release remains an important aspect of exposure assessment. However, there are situations in the non-occupational environment where a precautionary approach to the health risk may be warranted and where appropriate investigation, sampling strategies, experienced laboratories and validated methods are needed to provide useful data for assessing the risk (Sébastien, 2001).

In the case of land contaminated by loose asbestos fibres or industrial/mining tailings, sampling and analysis will be the major tools in determining the geographical extent of contamination. However, these data may not be very useful in assessing the likely exposure unless the potential for fibre release can be estimated.

Qualitative exposure assessment will yield valuable information about the location, nature and the extent of the materials containing asbestos and their potential to release fibres into air. ZThe assessment should include:

- A desktop investigation, including a detailed site history and identification of site characteristics (location, layout, buildings). The desktop investigation should:
  - include interviews with people with knowledge about the site and the source, type and amount of asbestos, e.g. building owners, occupiers or landowners who may have historical knowledge of asbestos-containing materials used or the nature of the land contamination
  - determine the age of existing or demolished buildings or structures (fibre-cement products produced prior to the late 1980s would contain asbestos),
  - review building plans, property use and records.
- A preliminary visual inspection and investigation of the surface and exposed areas of the site and of any material containing asbestos. Random digging may be more important than systematic sampling in determining the nature and extent of surface contamination because of the likely variable distribution. Samples should be taken if necessary, to assist with identifying or confirming the type of asbestos present. The visual inspection of the area and preliminary assessment should determine the:
  - type of asbestos-containing material and its asbestos content
  - amount of material containing asbestos
  - condition and age of material
  - wear and weathering
  - soil type and the state of the site surface, e.g. paved, grassed or exposed, and moisture content in the soil
  - exposed surface area
  - accessibility/location
  - activity and movement
  - depth and distribution of asbestos-containing material.

These and any other relevant factors should be considered in all situations where management of health risks from materials containing asbestos is required, including asbestos waste and sites contaminated with asbestos material.

A sample inspection checklist is available in Appendix V. Information on sampling and analysis is provided in Appendix II: Air sampling and analysis and Appendix III: Soil sampling and analysis.

Type of asbestos-containing material and its asbestos content

Where asbestos fibres are present in low concentrations and are bound within a stable material, such as asbestos cement, they are less likely to generate dangerous levels of airborne fibres than where they are friable.

The type of asbestos is also important. In most non-occupational environments the main asbestos contaminant is chrysotile. The exceptions are areas such as the Pilbara, Western Australia, where the main type of asbestos present in the general environment is crocidolite.

Condition of material

Friable material has a greater potential for asbestos fibre release.

Some sites may contain asbestos wastes that are friable such as asbestos fibres, tailings or insulation material, and these present a greater potential for exposure. However, asbestos-containing material that has been mixed with cement or other binding agent, has much less potential for fibre release.

Exposed surface area

A larger exposed surface area of material containing asbestos presents an increased potential for exposure to higher numbers of released airborne fibres.

Accessibility, location, activity and movement

Any circumstance or activity that has the potential to disturb the material containing asbestos can lead to an increase in the dispersal of fibres into the air.

If the material is readily accessible it may be vulnerable to accidental or deliberate disturbance. Vehicle movements or construction work may release the fibres or dust.

Important considerations include:

- the position of the site in relation to housing, schools
- the present use of the land
- the ease of public access
- proposed future use of the land, including construction activities.

Wind erosion and water drainage on contaminated sites

Van Der Walt and De Villiers (1996) conducted laboratory and field experiments to examine asbestos fibre concentrations arising from wind erosion of asbestos tailing dumps in South Africa. They found that minimum wind disturbance at 2.7 m/s resulted in measurable asbestos fibre concentrations, (0.008 f/mL chrysotile and 0.023 f/mL crocidolite) and concentrations increased with wind speed. Furthermore, they suggested that asbestos-containing wastes that are insufficiently covered or capped, such that weathering, erosion, work or other activities may disturb materials and release fibres into the air, should be rehabilitated.

There is no significant migration of asbestos fibres through the soil, other than from human or major geological disturbance. Consequently, the risk for groundwater contamination is low. In addition, ingestion of asbestos is not of concern.

Uncontrolled drainage of water from areas that have been contaminated with asbestos fibres may result in lateral or vertical movement of fibres into surface watercourses or aquifers. This dispersion of asbestos fibres from the main area of contamination may lead to unknown exposure of asbestos fibres in air when contaminated areas are subsequently dried and disturbed.

Health risk

An exposure assessment will need to be conducted for each contaminated site. Any associated health risks will vary depending on individual site conditions. The exposure assessment will provide the most significant information, whether qualitative or quantitative. Qualitative assessment of exposure may provide the most useful guidance. General guidance is also be found in Existing guideline levels (p.p 8–10) and Appendix I.

Risk management

Risk management options to control exposure to non-occupational sources of asbestos fibres should be reasonable, appropriate and acceptable at a site level, to the decision-making agency in each state or territory. Consideration of both future building use and land use is critical in determining the most viable control strategy. There need to be appropriate management strategies and processes in place for the propagation of information to future landowners or occupiers to avoid the disturbance of material containing asbestos.

Risk management options to abate the potential for release of airborne fibres need to consider:

- proposed and current land use
- current or potential child occupancy or access
- information from the risk assessment
- the classification of contaminated land and its effect on property values
- available technology and cost
- community support or concern.

Under the National Environmental Protection (Assessment of Site Contamination) Measure (National Environmental Protection Council, 1999) the preferred order of options for any site clean up and management is:

- on-site treatment of the soil so that the contaminant is either destroyed or the associated hazard is reduced to an acceptable level
- off-site treatment of excavated soil, which is either returned to the site, removed to an approved facility or used as landfill.

Other options are:

- isolating the soil by covering with a properly designed barrier
- choosing a less sensitive land use to minimise the need for remedial works
- leaving contaminated material *in situ* providing there is no immediate danger to the environment or community and the site has appropriate controls in place
- removing contaminated soil to an approved site or facility followed, where necessary, by replacement of clean fill.

The most practical and reasonable approach for managing any health risk should be selected.

Depending on the form of the asbestos contamination, on-site or off-site treatment of the soil might not be a viable option. For example, while these options could be used for removing asbestos cement materials from the soil, they would be impractical in cases where the soil is contaminated with friable or loose asbestos fibres. Imray and Neville (1993) discussed treatment options that could be used, such as compression and solidification of asbestos cement fragments. Sieving of soils for the removal of fragments has also been used. Other options could include treatment on-site by mixing with cement slurry to stabilise the asbestos (depending on the type/form of asbestos present). However, removing asbestos contamination (other than asbestos cement fragments) from soil is difficult, usually impractical and potentially very costly. Also, the additional handling, transportation and processing of asbestos waste can increase risks of dispersal of fibres to air and exposure and should be avoided.

On-site containment of asbestos contamination is the preferred option, but may not meet the expectations of all stakeholders. Nonetheless, it may be more appropriate to deal with the perceptions that might arise from such management options rather than do additional sampling and analyses that might not add much value to the process. On-site containment should only be considered if the restrictions are appropriately recorded (e.g. land title and/or planning certificates) and can be enforced. Information on any restrictions should be available so people are properly informed when making decisions about purchasing or developing the land.

In all cases where asbestos contaminated soil is to be handled, appropriate occupational health and safety procedures and monitoring requirements need to be followed to ensure the safety of workers and bystanders, including neighbourhood residents.

Regular monitoring should be part of a 'total control' strategy applied to all possible sources of exposure or fibre release on the site. On-site washing facilities and showers should be provided for people who may have been exposed to asbestos fibres, as well as facilities for disposal of contaminated clothing. Vehicles and equipment and disposable personal protective clothing need to be washed down on-site. The wash water should be cleaned using an appropriate filter, the water discarded in an appropriate manner and the filter and its contents disposed of as asbestos waste. People undertaking removal work should be adequately trained and supervised in accordance with occupational health and safety legislation and the NOHSC revised codes of practice.

Dust suppression is required when excavating and removing contaminated material.

Static perimeter monitoring should be carried out to ensure that spread of asbestos off-site is adequately controlled (see Appendix II). This reassures those outside the site and acts as a warning in case significant quantities of dusts are produced. If such conditions occur, the method of working may need to be changed or the work suspended.

Isolation by barrier

This option may be a suitable method for containing asbestos fibres or asbestos-containing materials on site. Barriers may consist of membranes, clean fill, buildings, hard structures, vegetation cover or a combination of these.

Isolate asbestos-containing material by barrier when:

- such isolation will stabilise material and prevent disturbance and release of asbestos dust
- erosion and drainage can be controlled
- the area will not be significantly disturbed in the future
- removal is difficult or not feasible.

The disadvantages are:

- hazard remains (although risk is reduced)
- cost for large areas may be near removal cost
- management plan and public record required
- may affect property values.

Permanent hard cover in the form of buildings, roads, pavements and car parks is an effective long-term method of dealing with the contamination, which allows the land to be used without imposing a health risk on the community.

Urban redevelopment requires decisions be made on long-term, practical management strategies for asbestos-contaminated land. For example, contained asbestos material can be removed from land under private ownership. When contamination occurs over a whole site it is preferable, and easier to manage, if the contaminated soil is consolidated and reburied in a discrete location then isolated by barrier. Reburial of the material containing asbestos elsewhere on the development site under permanent hard cover, which is unlikely to be disturbed (buildings, roads, pavements and parking areas) or change ownership, is an effective, practicable long-term solution. Industrial or commercial developments are preferable to residential development on sites of this type.

Depth of barrier

In cases where hard covers are not feasible, the required depth of clean fill depends on the potential for disturbance during future land use. A geotextile barrier (woven plastic-polymer mat or sheet) can be placed to separate asbestos-containing material from clean material and to alert to the presence of a hazard.

The depth of a barrier must be decided on a case-by-case basis. For example, 0.5 m may be sufficient where activities are limited to gardening, but 1–2 m may be needed to allow for service providers' intrusion into soil (e.g. telephone, electricity, gas, sewerage or roads).

Any repair, cover or sealing will need to be durable, prevent erosion of asbestos fibres and remain undisturbed.

Vegetation cover

Well-established and properly maintained vegetation can provide adequate protection in some circumstances (Inter-departmental Committee on the Redevelopment of Contaminated Land, 1990). It is advisable to inspect the site periodically to check that the underlying material is not disturbed or the vegetation cover damaged (e.g. by fire).

The frequency of inspection depends on the land use and the likelihood of disturbance. Land that is abandoned or out of use may need to be inspected more frequently than sites industries still use. Where necessary, warning signs and secure fencing should be provided to restrict access. At some sites, the local authority may decide to carry out the inspections itself and undertake any immediate work needed to protect the public but where the land is still in use the responsibility lies in the first instance with the landowner or occupier.

Management plan

A management/control strategy needs to be developed for any on-site containment of asbestos, including:

- establishment of a public record. (A public record should be kept of any sites that are contaminated with asbestos-containing materials to ensure buried sites are not unknowingly disturbed in the future. The record should contain details of the site and the type and condition of any asbestos products found and should be made available for inspection when appropriate)
- maintenance of any hard cover surface
- prevention of water and wind erosion (may be controlled through such measures as adequate site drainage, revegetation, hydro mulch)
- ensuring membrane integrity. (Any work undertaken at or below the warning barrier should be undertaken following safety precautions outlined in a management plan and the barrier should be repaired/replaced into its original position)
- processes developed for alerting future owners and workers
- appropriate design by qualified and competent personnel, taking into account the geological conditions.

While a management plan is essential for ongoing management of these sites, the plan will only be as good as the triggers and procedures put in place to ensure that the plan is activated at the right time. People responsible for overseeing the management of the sites will need to set up administrative or legal procedures to ensure compliance.

Choosing less sensitive land use

In the absence of surface contamination, controlling activity on sites contaminated with asbestos is one way to reduce risks of fibre exposure. Therefore, it may be necessary to impose restrictions on the redevelopment of the site and land use. The long-term use of such sites may be restricted to those uses that do not require subsequent or frequent excavation for any purpose after the development is completed. For example, industrial or commercial developments, car parks, parks, ovals, recreational areas etc. are preferred to residential developments on sites with asbestos-containing materials.

An isolation barrier can be used in conjunction with this option.

Leaving asbestos-containing material *in situ*

In determining whether this is the most practical management option, it is necessary to consider what amount of asbestos fragments or fibres in the soil constitutes an appreciable risk to health. This is problematic given the uncertainties in quantifying human exposure from asbestos-contaminated soil. While it appears unlikely that low intensity, infrequent exposure to airborne asbestos fibres will induce asbestos-related health effects, it is not possible at this time to suggest a definitive safe level of exposure.

Leave asbestos-containing material *in situ* when:

- there is negligible risk of/from exposure
- asbestos waste is stable and not liable to be disturbed or eroded.

The disadvantages are:

- hazard remains
- potential for concern in the community
- the need for a management plan and public record
- possible effect on property values.

Where the risk has been assessed as being relatively low, the management option may simply be to relay this to the occupants of the site, so that they are aware of the presence of the hazard and the conclusions made regarding the risk (enHealth Council, 2001).

Asbestos cement fragments in soil

As discussed by Imray and Neville (1993), removal of asbestos cement fragments mixed with other fill involves the excavation and disposal of considerable amounts of other material. In most situations this is uneconomic. In these situations, isolation and on-site management with appropriate management plans is the most reasonable, cost-effective risk management strategy.

When fragments of asbestos cement are found on the surface, or at depth, it may not be necessary to measure the actual concentration present. The type of asbestos present should be confirmed by microscopy. The whole area where fragments are located should be regarded as contaminated, and action taken. If the proportion of material present is too low to enable fragments to be observed, a soil sample may need to be analysed to determine whether free fibres are present.

Action may be taken to make the area safer by reducing the number of fragments present to levels that do not constitute a health risk and are aesthetically acceptable. An average of 0.001 per cent by weight asbestos in soil has been applied in New Zealand and Western Australia by calculating the approximate weight of asbestos fibres within the asbestos cement fragments and averaging this over the affected soil. This is a very conservative approach to exposure assessment as it assumes that all asbestos fibres within a fragment will become released as respirable fibres.

'Sieving' of bonded asbestos-containing material fragments (various methods of removing large sized material, for example, by using a grated bucket on a front-end loader) has been used in some situations. It is to be discouraged, as it leads to disturbance of the soil containing asbestos fragments and considerable asbestos-containing material can be left behind. It is more appropriate to use screening (use of a mesh so that larger fragments do not fall through lengthwise, as can occur with some 'sieving' methods), with dust-suppression, to remove oversize material. Any removed material must be considered asbestos waste, subject to landfill criteria in each jurisdiction. Case Study 1 describes an example of this situation.

Dust-suppression techniques used during disturbance of any soil (e.g. building developments) to prevent nuisance dust and to comply with occupational health and safety management plans should be sufficient to control worker exposure to asbestos.

Case study 1: Remediation of low level asbestos contaminated soil – City of Bayswater

Trace amounts of residual asbestos-cement fragments (up to 70 mm wide) were identified in on-site soil during the screening of otherwise good quality fill at a residential land development site in Bayswater, Western Australia. To meet the environment agency requirements of a 'near zero' concentration of asbestos, either the screened soil would have to be remediated to remove the asbestos or the soil taken off site and replaced with clean fill. The former was considered the only option because the cost of disposal and soil replacement was prohibitive.

There was no precedent for remediation of asbestos-contaminated soil in Western Australia for residential developments. Therefore, four investigational stages were undertaken:

1. Establishing a methodology for measuring asbestos concentrations in soils and conducting a health risk assessment of asbestos materials on the site
2. Developing an effective cleanup procedure to separate the asbestos from the soil
3. Gaining approval from the environment and health authorities in Western Australia on the methodology for assessment and a proposed threshold level for asbestos cement materials in soils
4. Performing validation testing of the soil to ensure criteria had been met.

A grid sampling soil survey was conducted based upon the general approach recommended by the Department of Environmental Protection in *Contaminated Site Guidelines for the Development of Sampling and Analysis Programs* (July 2000).

Soil samples were collected by hand augering to approximately 0.8 m depth on a square grid of 8 x 8 m^2. Where asbestos fragments were identified they were classified (either as cladding or corrugated sheeting), measured and weighed. The average asbestos concentration in soil was estimated by assuming: 15 per cent by weight asbestos in the cemented fragments; an average bulk density of soil of 1.65 kg/L; and an average soil collection volume of 9 L per hole.

Where asbestos fragments were identified, the sampling grid was reduced to 4 x 4 m^2. It was recognised that the heterogeneous nature of the asbestos occurrence made representative sampling difficult, with the calculated concentration approximate at best. However, the 95 holes excavated on the six lots gave an average asbestos concentration of 0.003 per cent by weight with a range of 0.001–0.006 per cent by weight. This is a rough estimate for concentrations of asbestos in the soil.

A remediation process was developed in which the soil was to be screened through a medium mesh screen (nominally 20 mm) to separate the asbestos fragments into the oversize fraction. Continuous visual monitoring of the undersize fraction was required to confirm that the asbestos fragments were efficiently removed. The 'treated' undersize fill material was then to be spread and compacted over the site and 0.4 m of clean capping material added. Although the risk of asbestos fibres being released from the cement matrix and becoming airborne during the works was low, para-occupational monitoring for respirable asbestos dust was to be conducted during screening to confirm that control measures were adequate.

The WA Department of Health (Western Australia) and the WA Department of Environmental Protection approved the methodology for measuring asbestos concentrations in soil, the proposed remedial measures and set a threshold limit for asbestos concentration in soils of less than or equal to 0.001 per cent by weight. This target level was not based upon a qualitative nor quantitative health risk assessment but determined on the basis that the total amount of asbestos in the soil at this concentration would, theoretically at least, be perceived to be acceptable. Validation testing of the soil was required upon completion of the works, using the same methodology as used for the initial on-site assessment of the asbestos concentration.

The remediation works were carried out as proposed with soil screening conducted using variable screen sizes down to a size of 7 mm. The validation testing indicated the target average concentration of asbestos to be less than or equal to the 0.001 per cent by weight in the 'treated' fill. The asbestos fragments were hand picked from the oversize material during the screening to enable the oversize stockpiles to be classified as inert waste for disposal at a 'non-asbestos' landfill. The asbestos remnants were bagged and disposed of according to Department of Environmental Protection requirements at an approved asbestos waste landfill site.

At the final soil concentration, the health risk associated with the type and quantity of remaining asbestos cement material on the proposed residential site was considered to be low.

The assessment and remediation methodology used was site-specific in that only asbestos-cement building material waste was present on the site. The sandy soil was fine enough to be screened through a 7 mm screen and asbestos was hard-bonded building products and not friable insulation. If other forms of hard asbestos were present, e.g. asbestos in vinyl tiles or electrical switchboards, then a different concentration factor would have been required for the asbestos fragments.

Removal of soil contaminated with asbestos

This option should be considered when all other options are unsuitable as it poses the highest risk of generating airborne fibres, and the problem is relocated elsewhere. However it may be the most appropriate strategy if enforcing any restrictions into the future would be problematic.

In cases where this option is the most appropriate, excavation of the asbestos-contaminated area should include the removal of additional soil up to 30 cm in all directions. Soil not removed should be confirmed as uncontaminated by sampling or visual inspection. Any material used as back fill should be uncontaminated and of a quality consistent with jurisdictional criteria for the current and intended use of the land.

Remove asbestos-contaminated soil when:

- surface material is present that is likely to be released
- material is subject to wind or water erosion and drainage cannot be controlled
- the area is likely to be significantly disturbed in the future
- the area is being redeveloped for other potential uses and will be excavated – this provides opportunity to remove all contamination.

The disadvantages are:

- increased risk to people removing material – occupational health and safety management plan and monitoring required
- potential for elevated exposure to public during removal work
- high cost
- relocation of contaminant.

Surface contamination

The main sources of surface contamination are from buildings containing asbestos (e.g. from breakage of products, demolition) and from dumping of asbestos waste. The presence of asbestos cement fragments on some soil surfaces may cause concern. However, if the asbestos fibre is reasonably well fixed into the cement matrix and not mechanically disintegrated into dust, it does not present a significant dust hazard. To alleviate concern, visible asbestos fragments should be placed in heavy-duty plastic bags and disposed of in an appropriate manner.

Friable material may be present on the soil surface following inappropriate cleaning of asbestos cement roofs. Case Studies 2 & 3 deal with this situation.

Records

Records of contamination found and all actions taken with respect to disposal, retention on-site and covering, should be kept and cross-referenced to documents concerned with land ownership, planning and land use.

Public record

A public record of the investigation should be kept even when no further action is required. This gives assurance to property owners/occupiers and prospective purchasers. The wording used should convey an awareness of risk and appropriate advice to prospective purchasers. An example might be:

> This site was in an area investigated for asbestos-containing materials in soils. Following the investigation this site is deemed suitable for residential use and there are no additional or special restrictions on its use.

Alternatively there should be an onus for the owner and/or occupier to inform any prospective purchaser of the results of the investigation.

Case study 2: Contamination from cleaning an asbestos cement roof – Western Australia

An asbestos cement roof was cleaned with a high-pressure water jet in a medium density residential area where the roof ended at the boundary of the property. There was gross contamination of the building and surrounding areas, including gutters, walls, driveways and also the backyard and gardens of the neighbouring property. This resulted in exposure of the property owner who performed the work and potential exposure of others, including the close neighbour. The neighbour was very concerned, particularly about potential exposure to their children.

Subsequent clean-up operations proved very expensive.

Actions taken

- It was necessary to remove all visible contaminated slurry
- Agreement was obtained from all stakeholders on clean up and final inspection
- All hard surfaces were thoroughly cleaned down using wet methods and an approved vacuum cleaner, with a high efficiency particulate air filter, to collect the contamination on driveways and structures
- The affected layer of topsoil was removed (approximately 50 mm). Garden beds/plants were removed and replaced
- Waste material was placed in a lined removable bin, covered and taken to an approved landfill. All of the material was asbestos waste

- Testing by a NATA approved laboratory was used to alleviate concern regarding level of clean up and to validate that the site has been cleaned as far as is reasonably practicable (i.e. asbestos not detected)
- The property owner was successfully prosecuted under the Health (Asbestos) Regulations 1992, which prohibit the use of high-pressure water jets on asbestos cement products.

Case study 3: United States Environmental Protection Authority management of various contamination settings

(Arnold Den communication)

The United States Environmental Protection Authority has dealt with a number of sites where the soils contained asbestos. The sites have included asbestos contaminated vermiculite in houses and soil (Libby, Montana), land that had asbestos laden buildings demolished and new housing developments built on the asbestos laden soil (Oregon), and, in California, communities built in areas of naturally occurring serpentine or amphibole asbestos deposits.

Determination of a safe level in soil, or what soil to use to cap the asbestos sites, was difficult. The Environmental Protection Authority found (Libby, Montana, El Dorado county, California) that disturbances of dry soil with very low levels (much below the 1 per cent level defined in United States regulations) of asbestos can create very high localised levels of asbestos in the air.
As an example, a school district was cleaning up soil on its campus (it was built on top of a tremolite deposit) and some soil samples were collected on a baseball infield (all exposed dirt). The average asbestos level in the soil was 0.08 per cent, yet when children simulated playing in the infield (activity based monitoring) the personal monitor on the individual doing the activity recorded a value of 0.1 f/mL in the air.[1]

The Environmental Protection Authority has other examples where low levels of asbestos in soil, when disturbed, caused excessive levels of airborne asbestos. The California state Environmental Protection Authority has used the Addison/Australian soil recommendation of 0.001 per cent for the remediation of a soccer field built over an actinolite laden area.

They have also used that level in their state-wide interim guidelines for schools being built in areas of naturally occurring asbestos (EPA/600/R-93/116).

[1] Using transmission electron microscopy.

Other sources

Asbestos fibres were added to many common building materials in Australia up to the 1980s to provide strength, insulation or fire proofing. Asbestos has been reported as being used in more than 3000 products (NOHSC, 1988). Asbestos fibres have been mixed with cement, talc, clay, chalk, paper, pitch, rubber, sand, calcium silicate, diatomaceous earth, a wide range of resins, paint and other materials. In addition to its use in asbestos cement products and floor finishes asbestos has mainly been used in:

- certain yarns and textiles, e.g. fire blankets
- consumer products, e.g. hair dryers, oven mitts, irons, whitegoods
- durable friction products such as gaskets, brake linings and clutch facings
- decorative coatings applied as textured ceilings.

Most of the asbestos present in today's urban environment probably results from the construction, use, demolition and breakdown of asbestos-containing materials and use of friction products, such as brake pads (WHO, 1986; Ferguson, 1990).

However, natural sources can also contribute to dispersal in the environment. The total amount of asbestos released to the air from natural sources is considered to be greater than that generated from industrial sources (WHO, 1986). A study of the Greenland ice cap showed that airborne chrysotile existed before it was used commercially (WHO, 1986). Disturbance of natural deposits can occur not only from human activities such as agriculture, construction, mining and public works, but also by geological and climatic conditions. However, the contribution of natural sources to urban contamination is minimal.

Exposure

Assessing exposure from consumer products or yarns and textiles containing asbestos is similar to assessing asbestos cement products. Where asbestos fibres are contained or bound within a stable material or product they are unlikely to generate hazardous levels of airborne fibres.

Fibre levels in ambient air determined using transmission electron microscopy average around 0.0001 f/mL (ATSDR, 2001) and can be up to 0.01 f/mL or higher (WHO, 1986). For example, asbestos levels 0.006 f/mL or below were found at London intersections. Levels of 0.5 particles/mL (small bundles of fibres together with other material) were measured in the immediate vicinity of an intersection braking area of the Tullamarine freeway (Alste et al., 1976). At 30 m from the nearest traffic, particle concentrations were below the limit of detection (NICNAS, 1999). The fibres/particles from asbestos brake emissions were found to be small bundles of fibres, relatively short in length.

Fibre levels measured in air at remote rural locations are generally below detection limits.

Urban residents in Australia, the United Kingdom and North America with no evidence of asbestos exposure have been shown to have asbestos fibres in their lungs at levels of up to one million fibres per gram of lung tissue (Berry et al., 1989). The fibres are mainly amphiboles. This may be because chrysotile is much more readily cleared from the lungs. Non-asbestos mineral fibres are also present in the lung in the general population.

Increased risk of asbestos-related disease from exposure to disturbed natural deposits containing either erionite (non-asbestos fibre) or tremolite has been identified in the general population in Corsica and Cyprus, and farmers in rural areas in Austria, Bulgaria and Turkey.

Exposure to airborne asbestos fibres can occur from the weathering of natural deposits or from domestic use by local people. Natural mineral deposits containing asbestos fibres have been used in whitewashing houses in Greece, New Caledonia and Turkey and in cutting quarry stones (tremolite-actinolite) used in the local building industry in eastern Sicily (Hillerdal, 2001; Goldberg, 2001). Clay deposits containing crocidolite are found in two areas of China. There have been indications of asbestos-related health problems in both areas where residents use the crocidolite clay extensively in their homes for making stoves, bricks and tiles (Hillerdal, 2001). Air fibre levels up to 0.01 f/mL have been measured in areas with natural deposits. Activities such as sweeping the floor in homes that have been whitewashed have resulted in measured air levels up to 78 f/mL (Hillerdal, 2001).

Health risk

The risk of mesothelioma and lung cancer from exposure to asbestos in the general, non-occupational environment has been described as undetectably low (McDonald et al., 1989; WHO, 1986; Commins, 1989; Hillerdal, 1999). The low background incidence of mesothelioma combined with ubiquitous presence of asbestos fibres in the lung (see Exposure) suggests that some people can harbour fibres in their lungs without harm.

The authors of these studies have not addressed exposure to higher levels in non-occupational environments where there may be an increased risk from disturbance of natural or point sources of asbestos (e.g. as reported by Hillerdal, 2001).

The continued use of chrysotile on friction surfaces, gaskets and seals for critical industrial applications is not expected to present a significant hazard to public health (NICNAS, 1999; Wong, 2001).

However, there is some evidence that background incidence may be increasing. The rates in women together with mesothelioma rates in people without reported occupational or extraordinary environmental exposure to asbestos appear to have increased (NOHSC, 2001).

Another interpretation of the data is that this increase may reflect an increase in awareness, improved record keeping and diagnoses and awareness of specific domestic exposure (in households with asbestos workers) or neighbourhood exposure (near mining or processing point sources) that occurred in the past.

Risk management

Damaged consumer products and yarns and textiles containing asbestos (e.g. fire blankets, oven mitts) should be replaced.

Chrysotile was used in the manufacture of friction materials, such as brake disc pads, brake linings and in industrial gaskets. The use of asbestos in these products in Australia was phased out in April 2003. Inhalation exposure should be avoided during replacement of brake pads/shoes during non-occupational car maintenance. Do not sand or scrape off dry. Personal protective equipment, including a disposable class P1 or P2 half-face respirator and coveralls should be worn.

An Australian standard exists (AS/NZS1715) for 'Selection use and maintenance of respiratory protective devices'. A standard also exists for respiratory protection devices themselves (AS/NZS1716). Any respirator purchased should be clearly marked with AS/NZS1716 to show it meets this performance standard. The 'paper type' disposable masks widely sold in hardware stores and supermarkets do not meet this standard. Asbestos fibres can easily slip through the pores in paper masks.

Decorative coatings should be contained using a sealant or plaster rather than removed. If the coating is applied to a plasterboard surface, the whole board may be removed in pieces large enough for convenient handling and disposal. If the surface finish only is to be removed, the chance of generating and inhaling dust can be reduced by soaking the surface with warm water and scraping off wet. These surfaces should not be sanded or scraped off when dry. Personal protective equipment, including disposable class P1 or P2 half-face respirator and coveralls should be worn.

Chapter 4: General guidelines for risk management of asbestos

Immediate remedial action

Where it is demonstrated that there is a potential for people to inhale airborne asbestos fibres, all practical steps should immediately be taken to control exposure. For instance:

- high risk areas should be isolated and secured against public access
- any activities resulting in the release of airborne asbestos fibres should cease
- temporary encapsulation (sealing) of the high risk area can be provided where the source of asbestos fibre is from building materials
- a temporary cover can be placed on asbestos-containing material in soil that presents a high risk of airborne fibre release and that cannot be removed immediately
- dust should be suppressed by wetting the soil
- site drainage should be arranged where there is a potential for water erosion
- warning signs should be provided at access points to high risk areas.

Labelling and warning signs and occupational health and safety

Materials containing asbestos in buildings should be labelled following identification. *Code of Practice for the Management and Control of Asbestos in Workplaces* (NOHSC, 2005) applies for public and commercial buildings. All warning signs should comply with Australian Standard 1319 (Standards Australia, 1979). An alternative international (Council of the European Communities 1983) symbol may be used for labelling of asbestos-containing products.

Warning signs should be placed at the entry to sites where asbestos removal or site remediation is occurring. Examples of the wording for labels and warning signs, recommended by the NOHSC Codes of Practice, are:

CAUTION

CONTAINS ASBESTOS FIBRE

AVOID CREATING DUST

SERIOUS INHALATION HEALTH HAZARD

CAUTION ASBESTOS

RESPIRATORY PROTECTION MUST BE WORN

NO ADMITTANCE – ASBESTOS

REPORT TO SITE/PROPERTY MANAGER

During any asbestos removal or site remediation, the work area should be secure and those not engaged in removal work should be kept away. Those working should take appropriate protective measures, i.e. wear disposable coveralls and a suitable dust mask. An air monitoring program should be in place for personal and para-occupational sampling.

An asbestos-approved vacuum cleaner, compliant with AS3544, fitted with high efficiency particulate air filters (normal household vacuum cleaners do not contain suitable filters), must be available to clean the work area at the completion of any work inside buildings and other structures.

People should not leave the 'dirty' area until they have showered and placed disposable personal protective equipment and other potentially contaminated items into sealed, labelled plastic bags for safe removal and disposal.

Demolition control – preventing exposure

The quantity of asbestos waste is increasing as materials containing asbestos are phased out or reach the end of their useful life. The removal and disposal of potentially damaged and friable material presents the greatest risks of future fibre exposure to the general population. The presence of hazardous waste in building waste streams inhibits recycling and potentially leads to sites contaminated with hazardous waste products (European Commission, 2000).

The obligation for inspecting building structures before renovation, removal or demolition should rest with both the property owner/occupier and demolition contractor. The owner/occupier should be required to monitor the management, removal, handling, transport and disposal of asbestos waste.

The engagement of a reputable demolition contractor, experienced in the removal of asbestos, should be encouraged. Members of the public who undertake their own demolition of structures containing asbestos-cement products should be subject to the same conditions as demolition contractors.

The local government or appropriate approval agency can play a major role in ensuring the protection of public health during demolition. Control can be achieved through health policy, and education and/or demolition licences that impose conditions on the removal, handling and disposal of asbestos waste. Local government or approval agencies should have sufficient power to refuse to issue approval for demolition, require amendments or impose conditions (with adequate appeal options) to ensure minimal release of asbestos fibres to air. In addition, environmental health professionals can provide advice to residents on the health risk from asbestos release during the demolition.

Conditions for approval may include a management plan incorporating the following measures:

- Councils should require that an initial asbestos survey be conducted before demolition, and ensure as part of any demolition approval that asbestos removal is undertaken in accordance with jurisdictional requirements. While a survey should be as thorough as possible, in practice it is not feasible to perform the type of exhaustive sampling which would be required to guarantee that premises are completely free of asbestos. For example, asbestos may be in inaccessible parts of the building. Contractors should be aware that the extent of contamination might not be apparent until the work is underway.
- Appropriate measures should be used to prevent the release of dust containing asbestos fibres into the atmosphere (i.e. compliance with NOHSC Codes of Practice, state or territory legislation and any other precautions unique to the demolition site).
- Material containing asbestos should be separated from other waste.
- Information on the amount of asbestos-containing material to be disposed of and the disposal site location should be recorded.
- Site audits or inspections should take place before, during or after demolition.
- Methods of informing nearby residents on the measures being taken to control the release of asbestos fibres should be planned.
- There should be static perimeter monitoring.

Evaluation and review of risk management strategies

Material, air and soil sampling may be used to validate controls and to verify that management strategies implemented were adequate, but in most non-occupational environments this will not occur. Timely reviews of any management plans developed and implemented should be undertaken.

Effectiveness of control measures used to prevent fibre release

Dust-suppression measures need to be put into place when handling asbestos products and soil contaminated with asbestos, to eliminate or minimise the generation of dust containing asbestos fibres. Air monitoring should be used to assess the effectiveness and adequacy of the dust-suppression measures.

For these purposes, a sampling plan for monitoring total suspended particulates (asbestos and non-asbestos particles) may suffice to assess the effectiveness of dust-suppression measures. If monitoring for asbestos fibres is considered necessary, the membrane filter method is acceptable (see Appendix II). Using this method means that sample results will be readily available and sufficiently accurate. Additionally, a sufficient number of samples can be taken as the cost and availability of membrane filter analysis is better than for transmission electron microscopy. Dust-suppression measures should be such that air levels of asbestos are below the para-occupational sampling limit of detection of 0.01 f/mL (NOHSC, 1988) and that particulate matter is below levels set by the relevant authority (e.g. PM10, PM2.5, TSP).

Appropriate remedial measures should be taken any time dust is visible on-site. A log recording the time, duration, location and probable cause of visible dust emissions, as well as any remedial measures applied, should be maintained. The log data should be reviewed to ascertain if there is a relationship between the visible emissions and asbestos fibre counts (Procedure C-10, USEPA, 1997).

Transport, disposal and recycling of asbestos waste

The transport and disposal of asbestos waste must comply with the relevant legislation. Approval for transport of waste is required in most jurisdictions. All asbestos waste should be separated from other materials, wrapped in heavy-duty polyethylene bags, at least 0.2 mm thick, or otherwise contained to prevent the release of airborne fibres, and must be labelled appropriately. In cases where the asbestos contamination cannot be isolated, appropriate measures should be taken to minimise the generation of airborne fibres during the transfer, packaging, transport and disposal of the waste. Asbestos waste should be transported in a covered, leak-proof or lined vehicle to prevent any release of airborne fibres. Any vehicle used to transport asbestos waste should be cleaned before leaving the site at which the material is removed from the vehicle.

The implementation of asbestos and/or hazardous waste collection days by local government authorities may assist in appropriate disposal of asbestos waste products in the community. This involves members of the public taking their asbestos and/or other hazardous waste on a specified day to a local, central location that is able to collect all the material safely and then dispose of the material in an approved manner. It is important that householders also transport asbestos waste in a safe manner.

Landfill sites must be properly managed and illegal dumping must be made subject to penalties. Careful consideration needs to be given to classification of asbestos waste. The re-excavation of a landfill site where significant quantities of asbestos waste are deposited should only be done after reference to the records on the nature, distribution and quantities of asbestos waste required under the relevant State and Territory Legislation.

Transporting large amounts of waste

Fibre release should be prevented during transport by lining and covering any skips or heavy haulage vehicles if there is a potential for fibre release. Controlled wetting of waste would also reduce dust emissions. A vehicle wash down area should be established at the loading and disposal site, which itself should have an appropriate bund for collecting run-off asbestos material.

Recycled waste

Traces of asbestos may be found in material that is recycled, as it is difficult to remove every possible waste material that may contain asbestos before demolishing a building. In 1998 the Netherlands applied a threshold of 10 mg/kg (0.001%) to aggregates produced from recycled construction and demolition waste.

This is the only guideline that has been identified. The European Commission is likely to propose this level in the future; in the interim this level can be adopted in Australia. Mixing of waste streams to meet this cut-off concentration is unacceptable. Waste that is free of asbestos should not be mixed with waste that may contain asbestos.

Fires and natural disasters

There is no evidence that fires or natural disasters involving damage to asbestos products cause significant public exposures, although there may be significant community concern. Deposits of material should be investigated, and advice on precautions for removal and adequate disposal provided.

Asbestos fibres change their mineral structure after prolonged heating, often losing their fibrous nature and mechanical strength. The degraded material does not pose a risk to health.

Although asbestos is typically used for its fire protective and non-combustible properties, fires and explosions in buildings can lead to the exposure and release of fibrous materials contained therein. As a result, airborne concentrations of respirable dust will be elevated, with the possibility of localised high concentrations in the vicinity of the damaged building. However, at the temperatures generated within fires, asbestos is thermally unstable. Blue asbestos starts to decompose at temperatures in the region of 450°C, and brown and white at 400°C–600°C. Although the asbestos is still fibrous in appearance, the fibres readily disintegrate to a fine dust that is of lower pathogenicity than the original fibres.

Some asbestos may be deposited as larger pieces. Whilst smaller fragments including fibres will eventually settle out, the respirable fraction may travel considerable distances in some circumstances. In the open, rainfall will act as a cleaning mechanism and therefore the climate, season and weather conditions will all influence the degree and duration of any potential exposure. The use of water/foam in controlling the fire will also inhibit the potential spread of fibres and therefore before clean up commences it may be advantageous to regularly moisten the area during the interim to prevent it drying out. (Scottish Centre for Infection and Environmental Health, 2001)

Asbestos-containing material that is not burned results in potential hazardous fibres within the fire debris. These fibres can be identified through standard material sampling procedures if required.

Where materials containing asbestos are reasonably suspected to be present, and results of sampling are inconclusive, it should be assumed that asbestos fibres are present and precautions for removal undertaken.

All emergency personnel attending an emergency site should be informed of any hazards present, including asbestos. Protective equipment must be worn. District and local emergency preparedness plans should provide contact information on local licensed asbestos removal contractors. The public should be informed of potential sources of exposure to asbestos, associated health risks and action taken to manage the situation. It may be necessary to exclude the public from the site. In some cases monitoring fibre levels after the incident may be useful in reducing public concerns (Department for Environment, Food and Rural Affairs, 1999).

Local emergency plans need to identify NATA-accredited laboratories and have procedures for ensuring environmental health officers are involved in sample collection, interpretation and communication of results, clean up and disposal. Local environmental health services should be called out whenever there is potential harmful environmental contamination.

Risk communication

Exposure to asbestos in the non-occupational environment is usually involuntary and any adverse health effects, if they eventuate, will not be known until some time after the initial exposure.

Of the asbestos-related diseases, mesothelioma is the most dreaded as there is no cure, it is debilitating and, once diagnosed, life expectancy is very short. These factors all contribute to increased anxiety and fear in someone that has potentially been exposed to asbestos fibres. These factors together with possible misinterpretation and misunderstanding, make it difficult to effectively communicate the risks associated with low non-occupational exposures to asbestos.

Asbestos is often used as an example to claim government and industry deny that a material causes harm, only to find many years later that it can result in a significant health impact. This perspective should be acknowledged and current methods for managing hazards discussed. The ongoing public concern, particularly regarding mesothelioma risk, makes it imperative for government agencies to provide accurate and timely information on associated risks.

There is increasing public concern regarding the effects of environmental contaminants on human health and the protection of our environment. Advances in technology enable the identification and measurement of very small concentrations of contaminants. This can be problematic when coupled with the desire for contaminant-free environments. However, an asbestos-free environment cannot be achieved because of its natural occurrence and the lack of available technology to identify and remove all contamination from past and current uses of asbestos and asbestos-containing materials. This, however, may be of little comfort to an individual, or their family or relatives, who may have been exposed to asbestos during the course of their lives.

Any affected individual or community should be involved and kept informed at each step of inspection, risk assessment and risk management. Effective risk communication is more likely to be achieved if an explanation of the risk is provided in a sensitive and caring manner. This is particularly important with asbestos, as the legacy of occupational exposure in asbestos mining, manufacturing, shipbuilding, etc. has resulted in many people knowing someone or about someone who has developed an asbestos-related disease.

The belief that 'one fibre can kill' compounds the problem of risk communication. While this claim is not supported by scientific evidence, it underpins the fear and anxiety about asbestos exposure. Asbestos fibres are widespread in the environment and normal healthy lungs contain a significant loading of fibres. In a 70-year-old lung there can be up to one million fibres per gram of lung tissue (Berry et al., 1989). Nonetheless, the incidence of asbestos-related disease is extremely low, except in cases of high occupational or para-occupational exposure. The small burden of fibres resulting from this background exposure appears to be tolerated, so the theory that one asbestos fibre kills is unrealistic. The problem is further compounded by the need to protect workers handling materials containing asbestos or contamination. The community may be concerned for their own safety if they see workers wearing protective equipment when they themselves are not so protected. It may be necessary to explain that the workers wear protective equipment as they handle asbestos products or contamination frequently and are closer to the source of dust. Workers are thus at greater risk of breathing levels of asbestos dust that could cause them harm over a prolonged period.

Generic information on risk communication strategies is available in the *Environmental Health Risk Assessment Guidelines* recently published by enHealth Council (2002). It is recommended that individual jurisdictions develop an information package for distribution to residents on asbestos risks, identification, handling and removal.

Health surveillance

The Australian mesothelioma surveillance program began on 1 January 1980. An Australian Mesothelioma Register Report is produced annually by the National Occupational Health and Safety Commission (NOHSC). The Western Australian Mesothelioma register and New South Wales Dust Diseases Board include detailed occupational and environmental exposure histories for mesothelioma cases reported in those states.

Where people may be occupationally exposed to asbestos, including during contaminated site remediation, the *Guidelines for Health Surveillance* for asbestos available from the NOHSC should be followed.

Health surveillance is not generally recommended for non-occupational exposure to asbestos. Medical examinations of people recently exposed to asbestos cannot reveal the presence or absence of any evidence of impending health problems related to the exposure. Health surveillance options for significantly exposed populations (e.g. mining towns) have included radiography and measurement of asbestos bodies or fibres in bronchioalveolar lavage fluid or sputum.

The usefulness of screening for pleural abnormalities with chest x-rays is limited (ATSDR, 1995; Hillerdal, 2001). Pleural abnormalities are common (4–5% males in industrialised societies) and are only a crude indicator of exposure levels (Hillerdal, 2001). Very strict criteria must be used to avoid uncertainties and concerns over diagnosis.

Put simply, radiological tests, lung lavage and respiratory tests are not specific for asbestos-induced lung injury; definitive diagnosis of disease is generally determined post-mortem. Health counselling may be appropriate where a heightened sense of concern exists for individuals possibly exposed to significant levels of asbestos fibres.

Appendix I: Risk characterisation of asbestos fibres

The human health effects from exposure to asbestos are well documented. There are many reviews available that give detailed information on the health risks of asbestos-related diseases. These include:

- Doll, R & Peto, J 1985, Asbestos. *Effects on health of exposure to asbestos*, Her Majesty's Stationery Office, London
- Agency for Toxic Substances and Disease Registry 1995, *ATSDR Toxicological Profiles*: Asbestos, ATSDR
- World Health Organization 1986, *Asbestos and Other Natural Mineral Fibres* EHC 53, WHO, Geneva
- Bignon, J 1989, 'Mineral fibres in the non-occupational environment' in J Bignon, J Peto & R Saracci, 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications, No. 90, Lyon.

The information contained in these guidelines gives an overview of health risks associated with exposure to asbestos in non-occupational environments. In addition, controversial issues and uncertainties associated with the characterisation of the risk are highlighted.

The relationship between fibre properties and toxicity

The physical properties of asbestos fibres, including the fibre diameter, concentration and durability are considered the most important factors in respirability and carcinogenic potency (Stanton et al., 1981; WHO, 1986; ATSDR, 1995).

Once in the lung tissue, other physical and chemical factors such as fibre length, reactivity of fibre surface and chemical composition influence biological and carcinogenic activity (Rosenthal et al., 1988; ATSDR, 1995).

To be able to reach the lungs an inhaled particle must first pass primary defence mechanisms. The nose will filter out and remove the larger inhaled fibres and the cilia and mucous membranes in the trachea and bronchioles (throat and lung passages) will also remove fibres. Only a small percentage of inhaled particles are deposited in the lungs. Small particles may not adhere to lung surfaces during inhalation and are subsequently exhaled. Remaining fibres may also be cleared from the lungs by macrophages.

The extent of damage in the lung or mesothelium is commonly associated with asbestos fibre durability and persistence in the lung. Biopersistence depends on the solubility of the fibre, degree of deposition in the lung, ease of translocation to the pleura, clearance efficiency and surface properties (Davis, 1989).

The importance of biopersistence in carcinogenesis has been questioned (McDonald, 2001). The ability of asbestos fibres to initiate toxicologically significant changes before the fibres are cleared from the lungs is unknown. This creates uncertainty about the usefulness of lung burden studies in the assessment of the effective dose. The mechanism/s of action of asbestos fibres at the molecular level are still unclear. What seems clear, is that no single mechanism can account for all the biological effects caused by asbestos (Fubini, 2001).

Fibre size

Respirable airborne asbestos fibres of 5–100 μm in length, with diameters less than 1.5–2 μm, and with aspect ratios of more than 5:1, appear to have the greatest adverse effect (Doll & Peto, 1985).

Studies that cover a large number of fibres of different types and sizes show that the most highly carcinogenic fibres are likely to be those >8 μm length and <0.25 μm diameter (Stanton et al., 1981; Berman et al., 1995). Reviews of these studies found that an aspect ratio ≥10 may be the most significant determinant of whether fibres are carcinogenic or not (Bignon, 1989; Addison, 2001). Berman et al. (1995) observed that the hazard increases with increasing length, and longer fibres (>20 μm) tend to be more carcinogenic. However, no specific dimension used to classify hazardous fibres has been able to be correlated with the potency of fibres or to discriminate between fibres that have an effect and those that do not (Bignon, 1989; Doll & Peto, 1985).

The diameter of asbestos fibres is the most important property relating to respirability. The smaller the diameter, the greater is the potential for inhalation and penetration deep into the lung (WHO, 1986). There is no evidence of a cut-off point for respirability of fibres with diameter down to sizes of 0.05–0.1 µm or less. This is important for determining the specifications of analytical techniques used to count fibres.

Intermediate length fibres (5–15 µm) seem more likely to translocate to mesothelial sites because of their size (Lippman, 2001). Short fibres and large diameter fibres are cleared more readily from the lungs (Davis, 1989). Animal studies suggest that short fibres (1–2 µm) may not be carcinogenic (Doll & Peto, 1985; Davis, 1989) although some authors dispute this.

Fibre counts used in occupational settings are given in terms of fibres longer than 5 µm, a diameter less than 3 µm with a 3:1 aspect ratio (NOHSC, 1988); these are sometimes called regulated fibres.

Fibre type

All types of commercially available asbestos have been shown to cause lung cancer (WHO, 1986). Chrysotile is generally considered to be a less potent carcinogen than amphibole fibres (Doll & Peto, 1985; WHO, 1986, Berman & Crump 1999; Fubini, 2001).

Amphibole fibres consist of thin, long, needle like fibres; therefore, they readily penetrate into the lower lung. Once inhaled, amphiboles are very durable and resistant to the lung's clearance mechanisms. They are more likely to split longitudinally and macrophages cannot easily engulf the longer amphibole fibres. The increased length and persistence in the lungs is considered to increase their toxicity (WHO, 1986; ATSDR, 1995). While amphiboles have been shown to cause lung disease and cancer after short but intense exposures, chrysotile related illness is generally associated with very high, long-term exposures (Berman & Crump, 1999).

In general, chrysotile comprises curly fibres, which can occur in bundles and are, therefore, more likely to be intercepted in the upper airways or nose. The chrysotile fibres are also less likely to become airborne to the same extent as the straight amphibole fibres. Chrysotile fibres are not as durable as amphibole fibres and are more likely to fragment into shorter fibrils, which are more readily cleared from the lungs by alveolar macrophages (Davis, 1989). In part, this is why chrysotile is considered to be less carcinogenic than amphibole fibres.

Hodgson and Darnton (2000) reviewed several occupational cohorts and concluded that the risk of mesothelioma for chrysotile, amosite and crocidolite is 1:100:500 respectively (i.e. the risk from crocidolite could be 500 times higher than for chrysotile). Other estimates of increased mesothelioma risk from mixed amphibole exposure are variable (3–5, 15 and 30 times the risk from chrysotile alone) (Berman et al., 1995; Churg, 1988).

Chrysotile can cause both pleural mesothelioma and lung cancer. However, when exposure has been predominantly limited to chrysotile, the proportion of deaths attributed to mesothelioma, and the ratio of the number of mesotheliomas to the excess number of lung cancer deaths, are lower. There does not seem to be an increased risk of mesothelioma through non-occupational contact in chrysotile mining communities or in household members of chrysotile workers (Doll & Peto, 1985). In addition, McDonald (2001) and Doll and Peto (1985) have questioned whether chrysotile can cause peritoneal mesotheliomas.

McDonald (2001) proposed that the presence of tremolite fibres in asbestos deposits might have contributed to the few cases of mesothelioma among Canadian asbestos miners.

The data reviewed through an extensive search of the literature by Churg (1988) are consistent with the view that tremolite is the causative agent of the supposed chrysotile-induced mesothelioma. There is a strong association between the development of mesothelioma and exposure to crocidolite and erionite fibres, but the association with mesothelioma is weaker for other amphibole fibres, such as amosite (Doll & Peto, 1985).

Appendix 1

Mechanisms of fibre toxicity

A review of the mechanisms of fibre toxicity indicates that the mineral fibre type is important in determining the outcomes of asbestos-related disease. The surface of the asbestos fibres interacts with cells and tissues to cause biological effects. The surface of asbestos fibres may also acquire contaminants from the environment or from within the body, progressively changing its chemical nature.

Asbestos fibres appear to induce asbestosis through a process of chronic inflammation. As the inflammation continues, fibroblast proliferation occurs and excess collagen is deposited in the lung in the area of the offending fibre. Continued exposure and fibrosis results in asbestosis.

Lung cancer is usually associated with chronic inflammation also. The inflammatory response triggered by the fibres continues after exposure.

The Agency for Toxic Substances and Disease Registry (1995) outlines some generalised hypothetical mechanisms for the increased incidence of lung cancer with smoking as:

- smoking inhibiting the clearance of fibres
- asbestos fibres adsorbing carcinogenic substances present in the smoke and increasing the levels of these substances in the lungs
- asbestos promoting development of tumours initiated by tobacco smoke.

Mossman and Churg, (1998), Osinubi et al. (2000), Driscoll (2001) and Fubini (2001) discuss the more specific hypothetical mechanisms of fibre-induced toxicity and carcinogenicity that may be summarised as follows:

- Fibres generate free radicals that damage DNA.
- Fibres interfere physically with mitosis. Demonstrated chromosomal aberrations and gene mutation may be related to physical interference with chromosome segregation by the asbestos fibre during the mitotic process.
- Fibres stimulate proliferation of target cells.
- Fibres act to enhance activation and delivery of chemical carcinogens. The mineral fibres include fibrous and non-fibrous mineral contaminants and surface contamination by exogenous and endogenous substances.
- Fibres provoke a chronic inflammatory reaction leading to prolonged release of reactive oxygen species, cytokines and growth factors. This is the most prominent mechanism hypothesised to account for fibre carcinogenesis.

Exposure–response assessment

Current estimates of exposure–response relationships are derived from occupational studies; these use mining and manufacturing cohorts who were exposed to high concentrations of airborne asbestos fibres over many years (HEI–AR, 1991). Ferguson (1990) predicts that workplace atmospheric levels of asbestos would have been well above 100 f/mL, before more stringent workplace practices were introduced.

Current concern involves potential cancer risk from exposures far lower than those that occurred in historical occupational exposures. The main approach to estimating risks in the non-occupational environment is the extrapolation of exposure–response data to lower environmental levels using mathematical modelling.

Studies that provide reliable exposure–response information on the inhalation effects of asbestos in humans are summarised in Table 3-1 and Figure 3-1 in the ATSDR *Toxicological Profile for Asbestos (2001:26–38)*.

There are many uncertainties, some unique to asbestos, in predicting lung cancer and mesothelioma rates in the non-occupational environment by extrapolating from estimates derived at high occupational exposures to low exposure levels. Such extrapolations may not be entirely appropriate and need to be used cautiously. In addition, estimates from exposure–response relationships based on occupational exposures have, in the past, tended to overestimate the risk from environmental exposures (ATSDR, 1995).

The limitations of risk estimates have been outlined by a number of different authors. Uncertainty in risk assessment from asbestos exposure in the non-occupational environment is attributed to:

- use of occupational data from high exposures that are not likely to be found in non-occupational environments
- extrapolating down to environmental exposure levels of asbestos, i.e. at levels 100–1000 times lower than occupational exposures
- the mathematical models used may overestimate the dose–response gradient
- doubts about the assumption that there is no threshold
- the contribution of various properties that lead to biological effects, e.g. chemical composition, bio-persistence, fibre type and size
- the variation of fibre types and sizes found in different environments, e.g. natural sources and different industrial processes such as mining and textile, insulation and asbestos cement manufacture. The non-occupational setting contains unknown fibre mixtures, including other natural fibres, synthetic mineral fibres and non-mineral fibres (Ferguson, 1990) that comprise a larger portion of the fibres present in air and soil samples than asbestos fibres. There is also a low contribution by amphibole fibres to environmental exposure scenarios
- composition (fibre type and amount) and state of the end product, e.g. friable or in a stable matrix such as asbestos cement
- the behaviour of asbestos in the environment. It can be more heterogeneous than other materials, does not leach through soil, but may be distributed by water and wind erosion
- age at first exposure and duration of exposure. There are long latency periods between exposure and development of disease. It is not possible to determine the fibre type and level of exposure that caused the disease. As a result, risk estimates are shown to be related to duration of employment rather than intensity of exposure (McDonald, 2001)
- individual susceptibility to disease, e.g. pre-existing respiratory disease conditions and genetic factors
- different concentration measurements, limited exposure data and different analytical techniques, making comparisons between studies and estimation of exposure for risk assessment extremely difficult. Estimates of the conversion factors used to combine counts of particles with counts of fibres are considered unreliable
- biological clearance and defence mechanisms being ignored as it is assumed that the levels of exposure correspond to tissue dose
- lung cancer not being specific to asbestos exposure and the presence of other confounding factors. The use of appropriate reference populations is critical to determine attributable risks
- the difficulties and unreliability of mesothelioma diagnosis and the small numbers of cases for mesothelioma found in most individual studies.

With several exceptions, these sources of uncertainty are common to risk assessment of chemicals in general, particularly the estimation of risks by extrapolating from the effects seen at relatively high doses in occupational or experimental animal studies to the low environmental levels reported in urban and rural environments.

The heterogeneity of the fibre size and shape, the physical nature of the fibres, persistence in the lungs, capacity to translocate across membranes and long latency for the development of asbestos-related diseases are unique properties of asbestos that give rise to additional uncertainties in risk assessment.

Asbestosis and pleural plaques

Mossman and Churg (1998) conclude that it is clear from epidemiological, fibre-burden and experimental studies that the lung is able to deal with a considerable number of fibres and particles without the development of asbestosis.

These authors also concluded that significantly increased mortality rates associated with asbestosis or other non-malignant respiratory disease have been reported in groups of exposed workers with cumulative exposure estimates greater than 25-100 f/mL-years.

Doll and Peto (1985) endorsed the Ontario Royal Commission suggested threshold for asbestosis of 25 f/mL-years. This calculation is based on total cumulative exposure and does not take into account asbestos fibre removal from the lungs.

The relationship between dose and response for pleural plaques is much weaker than for asbestosis. A good correlation has been shown between pleural plaques and asbestos fibres in the lungs; however, there is a large variation. Plaques are associated with a wide range of asbestos burdens, which overlap those of the control population (Hillerdal, 2001).

Lung cancer

The risk of lung cancer from asbestos exposure seems to be associated with the level and duration of exposure, length of time since first exposure, the fibre type and the type of industrial process, and the prevalence of exposure to tobacco smoke and other lung carcinogens.

The major cause of lung cancer is tobacco smoke and the number of asbestos-related lung cancers is affected by the prevalence of smoking in an exposed population. Exposure to asbestos will increase the risk of lung cancer in a dose-related manner in both smokers and non-smokers. However, the risk of asbestos-induced lung cancer in non-smokers is considered lower than in smokers. Most of the data points to a synergistic relationship between smoking and asbestos.

A linear dose–response relationship has been adopted for lung cancer risk estimates at low exposures. This approach assumes that there is no threshold below which there is no risk of asbestos-induced lung cancer. Dose–response data from epidemiological studies lack the statistical power to detect small effects at low doses, so it is not possible to show empirically whether or not there is a threshold for asbestos-related lung cancer.

There is great variation in the estimates of lung cancer risk reported in studies (Berman et al., 1995). Doll and Peto (1985) used two sets of data from the studies on textile workers in South Carolina and Rochdale to develop an exposure–response relationship for chrysotile and lung cancer. Using linear extrapolation, they estimated a 1 per cent increase in the standardised mortality ratio for lung cancer per year of exposure to 1 f/mL (regulated fibre). The potency of chrysotile in these studies is much higher than in others, presumably because of the longer fibres generated in the textile industry. Based on these data, the lifetime risk of death is estimated to be 1 in 100 000 for people in buildings with material containing asbestos, such as an office (five-day week for 20 years), school (five-day week for 10 years) or home (lower levels for a longer period). This equates to one death a year in Great Britain.

Contributions to the risk from duration and intensity are assumed to have equal weight. Vacek and McDonald (1991) believe that, unless this assumption is proved to be correct, extrapolations based on cumulative exposure are likely to be misleading. They conducted a study to determine the effect of exposure intensity on risk. The limitations of the study include the use of a small data set and absence of information on smoking. The results were consistent with a relationship in which risk is absent at low concentration, increases rapidly as concentration increases and levels off at high concentrations. They suggest that attempts should be made to separate the effects of intensity and duration in epidemiological studies, whenever data are available; this would assist in setting guidelines in terms of intensity of exposure. Given the small data set, no conclusion is possible on whether or not this study demonstrates the existence of a threshold.

Magnani and Leporati (1998) did not find an increase in lung cancer deaths in the population surrounding an asbestos cement-manufacturing town in Italy, contrary to the findings for mesothelioma in the same town, thus suggesting a threshold for lung cancer. However, air levels of asbestos were not quantified in a way that would allow the determination of the level at which lung cancer could not be detected. In a review of the literature, Hodgson and Darnton (2000) also suggest that the cancer effect may not be linear, hence that there may be a threshold.

Further, it is argued that since lung cancer seems to be associated with asbestosis, and since there is a threshold for asbestosis, then there is likely to be a threshold for lung cancer. Lung cancer has also been shown to have a similar dose–response relationship to asbestosis for the same fibre types. It is possible that the carcinogenic process induced by asbestos is consequential to the chronic inflammatory process producing asbestosis (Hodgson & Darnton 2000). While these authors have suggested that there may be a threshold for lung cancer, they have stopped short of suggesting what the threshold may be.

Mesothelioma occurs at lower levels of exposure than lung cancer (see below). Thus management strategies designed to protect against mesothelioma will also be protective against lung cancer.

Mesothelioma

The time since first exposure has been shown to be the most significant factor in the induction and development of mesothelioma (Doll & Peto, 1985; Hansen et al., 1998; Hillerdal, 1999). A model used by Doll and Peto (1985) indicates that the risk from continuous exposure to levels that cause mesothelioma is mainly determined in the first 10 years of exposure. Their model predicts that risk of mesothelioma increases rapidly with continuous exposure up to 10 years, slowly with increasing exposure for 10–19 years and then hardly at all. The death rate from mesothelioma has been found to increase in relation to about the third or fourth power of time since first exposure to asbestos.

The risk is assumed to be directly proportional to the level of exposure for an exposure of fixed duration at a given age (Doll & Peto, 1985; Hodgson & Darnton, 2000).

Although asbestos is widely found in the environment, an increased risk of mesothelioma as a consequence of general environmental exposure has not been demonstrated in studies examining environmental exposures (WHO, 1986; Gardner & Saracci, 1989; Magnani et al., 2000). Cases of mesothelioma have been observed in individuals occupationally exposed, living in the neighbourhood of asbestos factories and mines and in people living with asbestos workers (Hillerdal, 1999).

A multicentric population-based case-control study was carried out by Magnani et al. (2000) to measure the risk associated with low-intensity, non-occupational exposure to asbestos, domestic and environmental exposure, excluding all occupational exposure. A detailed exposure questionnaire was used to estimate exposure, which was categorised as no exposure, low probability, high probability, or unknown exposure, based on contact or activities that might have led to contact with asbestos. However, there was no estimate of the levels or types of asbestos fibres in each of the categories to which people might have been exposed. This database is one of the largest investigated for non-occupational exposure, with a total of 215 histologically confirmed cases of mesothelioma and 448 controls. There was a statistically significant increase in the risk of mesothelioma in people either living within 2 km (but not between 2 km and 5 km), of an asbestos mine or manufacturing facility, or with domestic exposure. Domestic exposure included cleaning asbestos-contaminated clothing and exposure to materials containing asbestos in the home.

The study shows that the environmental asbestos exposure typical of industrial areas can increase the risk of mesothelioma in non-occupationally exposed people. The authors suggest that low exposure to asbestos at home or in the general environment carries a measurable risk of mesothelioma.

Hodgson and Darnton (2000) also state in their review of the quantitative risks of mesothelioma, that short, intense exposures to crocidolite may carry a very low risk of causing mesothelioma. Iwatsubo et al. (1998) conducted a hospital-based case-control study and considered intensity, frequency and duration of exposure separately. Despite limitations in the exposure data, they observed that each parameter was significantly related to mesothelioma, and the relative risk increased along with each parameter. However, the dose–response relationship is best described by the cumulative exposure index. Their results suggest that intermittent exposure does not entail as high a risk of mesothelioma as continuous exposure.

In a review of dose–response at low levels of asbestos exposure, Iwatsubo et al. (1998) state that there were no cases of mesothelioma among the Wittenoom cohort exposed for less than three months, none among the North American insulators whose exposure lasted less than 15 months and only one, rather than 25 expected, among Rochdale textile workers exposed for less than 10 years.

In the study by Hansen et al. (1998), environmental exposure to crocidolite was examined in people living in Wittenoom for longer than one month. Exposure was estimated from static and personal monitoring carried out in the 1970s by the Department of Health Western Australia and divided into three groups: ≤7, 7.01–20 and ≥20 f/mL-years. Only one case of mesothelioma was diagnosed in a resident who first went to Wittenoom after the mining operations ceased. Mesothelioma cases stayed longer at Wittenoom, had a higher estimated level of exposure and a higher cumulative exposure to crocidolite. The Wittenoom residents aged 15 and over in this study experienced one of the highest population incidence rates in the world, i.e. a standardised incidence rate of mesothelioma of 260 per million person-years in comparison with the Western Australian rate of 50 (male) and 8 (female) per million person-years in 1988. In comparison, residents near an asbestos cement factory in Italy experienced age standardised incidence rates of 114 (males) and 73 (females) per million person-years.

This was the first study to show exposure–response relationships between incidence of mesothelioma and non-occupational exposure to asbestos. Cases of mesothelioma in this cohort of Wittenoom residents have occurred with crocidolite exposure as short as two months and estimated cumulative exposure as low as 0.53 f/mL-year.

The type of asbestos fibre seems to be important in the development of mesothelioma. Crocidolite and other amphiboles are most potent in the development of mesothelioma (Fubini, 2001; McDonald, 2001; Hodgson & Darnton, 2000; Berman & Crump, 1999; Hillerdal, 1999). A small number of mesothelioma cases have been reported following exposure to relatively high concentrations of chrysotile. However, this effect is now thought to have resulted from minor amounts of tremolite or other contaminants in the dust.

Mesothelioma cases have been observed to have a relatively lower fibre content in the lungs compared with lung cancer cases (IARC, 1987), suggesting a higher potency of the fibres in causing mesothelioma than lung cancer. Asbestos fibres can be found in most lungs during autopsy, even in people with no known occupational or environmental exposure. However mesothelioma in the general population is rare. Therefore, the presence of fibres in the lungs does not necessarily lead to the development of asbestos-related mesothelioma (Berry et al., 1989). Hillerdal (1999) states that even where heavy exposure to asbestos has occurred, most people will die from other causes.

Further research

It is unlikely that better ways of estimating past exposures will be developed to allow improved estimates of risks from past occupational studies. While these studies have provided extremely useful information in establishing asbestos as a cause of mesothelioma, lung cancer and asbestosis, their usefulness in risk assessment is limited because of the uncertainties in determining the exposures of those involved in the studies.

Future research should focus on establishing the incidence of asbestos-related diseases in situations where estimates of exposure are much improved over those of the past. This will require agreement on consistent reliable sampling and analytical techniques to measure levels of asbestos fibres in the non-occupational environment. If better estimates of exposure can be achieved, then research on the relationship between soil and air concentrations, for example, would be very important.

In addition, as Goldberg (2001) points out, to enable risk assessment in non-occupational environments better data is required on:

- fibre characteristics
- intensity of exposure associated with various exposure scenarios
- lifetime histories of duration and frequency of exposure in these exposure scenarios.

However, these would only be useful in prospective studies on the incidence of mesothelioma and lung cancer from environmental exposure. Knowing more precisely the exposure in these settings will contribute to more reliable assessments of risks.

Appendix II: Air sampling and analysis

Sampling should be appropriate to assess whether people have been or are being exposed, or to delineate the area of asbestos contamination.

Sampling strategies for non-occupational exposure to asbestos have been neglected in the past. Electron microscopic techniques are preferred for low-level exposure situations where the fibre size and identification are important. If the analytical method is not sufficiently sensitive and reliable it will not contribute significantly to the risk assessment.

Results obtained by air sampling in non-occupational environments are almost invariably below the detection limit of the membrane filter method, especially when samples are taken at times when the asbestos is not being disturbed.

Important considerations for designing an air sampling program include:

- purpose of the air sampling
- sampling strategy:
    - measurement instruments (sampler configuration and design)
    - flow rates and sampling times
    - use of personal versus area sampling
    - statistical design
- available methods and analytical techniques:
    - limits of detection
    - cost effectiveness
- record keeping and quality assurance.

Purpose

The purpose of any air sampling should be clearly identified. For example, there may be community concerns about airborne asbestos fibres in which case sampling would be appropriate to determine if there are elevated airborne fibre levels. Air sampling may also be undertaken where work is being completed to confirm that the risk management strategy implemented is appropriate.

Sampling strategy

A sampling strategy needs to be determined by someone experienced in sampling and exposure assessment. A suitable air-monitoring program for assessing health risks will include long-term sampling (one-week average). Considerations for assuring the validity of exposure estimates derived from measurements of airborne asbestos include:

- The samples must be representative of the exposure environment.
- The number of samples collected should be sufficient to characterise the site to the precision and accuracy desired and to ensure sufficient sample filters are obtained from all sampling locations that are not overloaded with dust.
- Where possible, sampling should be carried out in low-wind and low humidity conditions in outdoor environments.
- Weather conditions, wind speed and direction during the sampling period and any information concerning local topography and types and positions of sources should be recorded (International Organization for Standardization 1999). Any variation in airborne asbestos concentrations should be noted and causes identified.
- Airborne samples must be collected and analysed using validated procedures, e.g. membrane filter method, ISO indirect and direct methods.

Positioning of air samples collected inside buildings to determine whether asbestos-containing materials contribute to the asbestos fibre concentration in the indoor air should only be determined after a complete survey of the building to establish air movement patterns. Control samples should be taken away from areas with asbestos-containing materials (International Organization for Standardization 1999), preferably in the same building.

The principles for collecting samples in ambient air should be consistent with those used for sampling in occupational environments. The sampling strategy, including the location of sample collection points and duration of sampling, may need to be varied, depending on the circumstances and analytical techniques to be used.

The sampling rate and the period of sampling should be selected to provide as high a sampled volume as possible, which will minimise the influence of filter contamination.

In static sampling, the sampling strategy depends on topographical placement, standardisation of control sites, variability of meteorological conditions and variations in human activities. Static samples do not represent personal exposure.

Para-occupational sampling to assess effectiveness of control measures

Due to the sampling period required and the subsequent time needed for sample preparation and counting, air monitoring is not a useful tool for informing managers during the course of asbestos disturbance, control, or removal operations. In such circumstances more reliance should be placed upon management controls and frequent visual inspection of the containment area (NOHSC, 2005a).

Electron microscopy is costly and tedious and would probably not be sufficiently responsive to enable adequate control of dust emissions. When asbestos removal is in progress the para-occupational sampling method should be used. The method can also be used during contaminated site remediation as the detection limit achieved offers a consistent level of protection to the public, as currently is the case in removal of asbestos from buildings.

Para-occupational sampling can only serve as an indicator of the effectiveness of measures taken to control dispersion of contamination. For such purposes dust levels should remain sufficiently low for measured asbestos concentrations to be below the practical lower detection limit of 0.01 f/mL. It does not provide an adequate estimate, although at times the only one, of worker or community exposure under the specific circumstances. Thus comparing results of para-occupational sampling to exposure guidelines or limits is not valid as it does not necessarily provide an adequate estimate of whether or not people have been exposed to dangerous levels of fibres. A better estimate of exposure can be derived from personal samples taken within the breathing zone of the individual (NOHSC, 2005a).

During removal or remediation the samples should be:

- close to sources of emission in order to evaluate fibre concentrations, or the standard of any controls used
- at various places in the area to ascertain the distribution of asbestos dust
- in particular areas which may be taken to represent typical exposure (NOHSC, 2005a).

Sampling record

All data used for determining the fibre concentration must be recorded for quality control, comparison with other sampling data, recording conditions at time of sampling and for use as exposure estimates in any studies undertaken. The information collected for air sampling should include:

- the date and time of sampling
- the names of the people conducting the sampling and analyses
- sampling instrument used, its accessories and the method of analysis, e.g. flow rates, filters used and any deviation from standard protocol and reasons
- the location, nature, dimensions and other distinctive features of the site
- where static measurements were made
- the activities and location of any person wearing a sampling device

- the source or sources of airborne asbestos being released, their location and the activities being performed during sampling
- the composition and trade names (if known) of materials containing asbestos
- relevant information on the functioning of the process, engineering controls, ventilation and weather conditions in respect to emission of asbestos dust
- the duration of exposure, and other notes relating to the exposure evaluation.

Analytical methods

It is important that a NATA-accredited laboratory (see Appendix IX) performs the analysis and supplies a NATA-endorsed certificate. This will ensure a consistent and reliable use and application of methods and reporting and will allow a more meaningful comparison of results between circumstances and laboratories than has been or is currently the case. The aim is to ensure standardisation, reliability, reproducibility and comparability between samples, analyst and laboratories results.

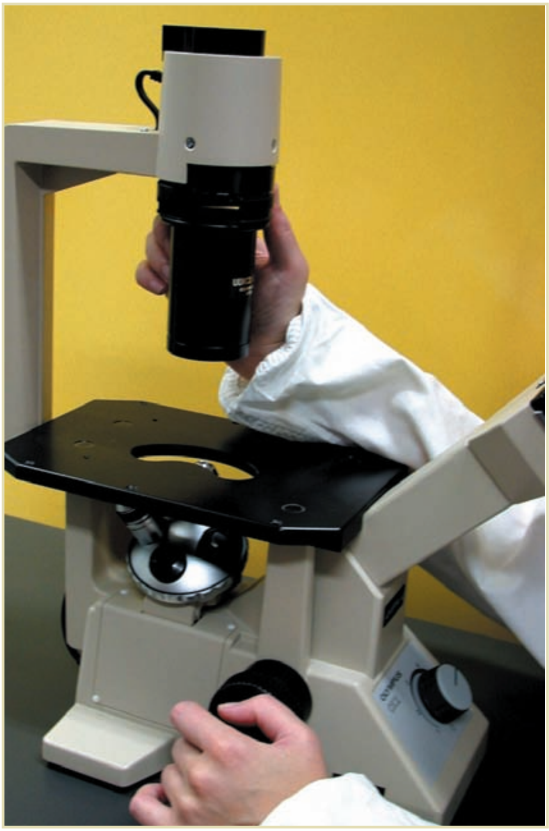
Occupational environments are characterised by asbestos fibres predominantly in the air, where employee exposure occurs to dust generated from work processes involving disturbance of asbestos fibres. Asbestos fibres may represent only a small fraction of the total number of particles/fibres in the general non-occupational environment, where wool, cotton, glass and other fibres would be present. In addition, the types of fibres and their fibre diameters may be smaller than found in the occupational setting. Given the importance of fibre properties in the toxicity of asbestos, it is necessary to characterise the sizes, shapes and mineralogy of the asbestos structures in each sample if measurements are to be used for risk assessment.

Currently used analytical techniques include:

- phase contrast microscopy (PCM)
- electron microscopic techniques:
  - scanning electron microscopy (SEM)
  - transmission electron microscopy (TEM).

Phase contrast microscopy

The membrane filter method is the only recognised and standardised measurement technique regularly employed across Australia for the determination of airborne asbestos fibre. The method is set out in the *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust* (NOHSC, 2005). It provides a useful estimate of personal exposure where the airborne fibres present are predominantly asbestos fibres. It does not require the use of expensive equipment, and is relatively quick and readily available.



Phase contrast microscope

Phase contrast microscopy can distinguish fibres down to a diameter of 0.25 μm. The method requires drawing an accurately measured volume of air through a specially prepared membrane filter, and then counting the number of fibres collected on this filter, using an optical microscope. The filter is transformed into a transparent, optically homogeneous specimen and the fibres are sized and counted using a phase contrast microscope. The result is calculated from the number of fibres on the filter and the measured volume of air sampled.

The weaknesses for asbestos assessment by phase contrast microscopy in non-occupational environments are that it cannot adequately distinguish between asbestos and non-asbestos fibres and it cannot detect fibres less than 0.2 μm in diameter (Corn, 1994). Cherrie et al. (1989) have shown that it is a poor indicator of the actual asbestos fibre concentration (concentration was greater in approximately 40 per cent of samples) and hence the risk.

Electron microscope techniques are preferred for low-level exposure situations where the fibre size and identification are important.

Electron microscopy

Both scanning and transmission electron microscopy can identify fibre types through energy disperse X-ray analysis. Transmission electron microscopy also uses selected area electron diffraction. Energy disperse X-ray analysis has limitations in identifying specific asbestos varieties, while the combination of energy disperse X-ray analysis and selected area electron diffraction allows for the most accurate fibre identification. For this reason and because of higher sensitivity, transmission electron microscopy is the method of choice for asbestos in non-occupational settings where more than one fibre type may be present (Corn, 1994) and where fibre sizes and concentrations are usually much lower than in occupational exposure (NICNAS, 1999).

ISO 10312:1991 and ISO 13794:1999 are validated transmission electron microscopy methods. These methods have a detection limit of 0.002 f/mL in ambient air. The ISO methods are preferable for risk assessment purposes in non-occupational environments because:

- electron microscopy will allow identification of fibre types in samples
- fibres of smaller diameter will be included
- the method is validated for a lower practical limit of detection
- results can be compared with levels measured in overseas non-occupational environments.

Transmission electron microscopy requires expensive equipment and qualified personnel and is therefore less available and more costly than the other two methods.

Scanning electron microscopy techniques have been used within Australian jurisdictions (WAACHS, 1990; Brown, 1997) to achieve detection limits of 0.002 f/mL. Transmission electron microscopy at 8000 magnification gives equivalent estimates of the number of asbestos fibres longer than 5 μm, although more of the shorter fibres can be detected by this method. Using transmission electron microscopy fibres can be chemically characterised to a diameter of 0.01 μm, if equipped with energy disperse X-ray analysis, whereas the smallest diameter fibre that can be detected with scanning electron microscopy is 0.03–0.04 μm.

Selecting an analytical technique

The current practice in Australia for occupational exposure is to report on the levels of regulated fibres, which are defined as any particles longer than 5 μm, diameter <3 μm with an aspect ratio of 3:1. While this is sometimes the basis for analysis of fibres from environmental monitoring, there is a need to apply consistent rules to the analysis of asbestos fibres. The methods chosen for sampling and analysis will depend on the intended purposes. Therefore, standardised and validated methods should be applied for each situation.

It may be possible to use phase contrast microscopy techniques to screen a large number of samples, thereby reducing costs. The membrane filter method is currently the most commonly used sampling and analytical method in Australia. The practical limit of detection for the occupational and para-occupational sampling methods are 0.05 f/mL and 0.01 f/mL respectively (NOHSC, 1988).

Para-occupational sampling using the membrane filter method can be used to assess dust control on sites being remediated as well as asbestos removal in buildings and has a practical detection limit of 0.01 f/mL.

ISO 10312:1995 Ambient Air – Determination of asbestos fibres – Direct-transfer transmission electron microscopy method and ISO 13794:1999 Ambient Air – Determination of asbestos fibres – Indirect-transfer transmission electron microscopy method are validated methods for sampling and analysis in non-occupational environments. However, transmission electron microscopy is not readily available in Australia.

The ISO 10312:1991 direct method is preferable due to the higher amount of chrysotile fibres in non-occupational environments, which are more susceptible to degradation. The indirect method (International Organization for Standardization, 1999) may be used because of problems with dust overload on filters. However, preparation of the samples in the indirect method alters the form of multi-fibre asbestos structures and increases the number of fibres from fibre degradation. Nicholson (1989) recommends that a sufficient number of paired samples are collected and analysed to establish a site-specific correlation, and correspondingly a conversion factor, between directly and indirectly prepared samples.

Any method used will need to provide results suitable for supporting risk assessment and will need to be reproducible within and between laboratories that may offer that method commercially. The use of optical microscopy would insure that a sufficient number of testing facilities would be available and would keep costs low. Electron microscopy may be used for analysis of difficult samples or to minimise the risk of false negatives.

Results

Results obtained by light microscopy can only be compared with those obtained by transmission or scanning electron microscopy if the same counting criteria are used (i.e. fibres greater in length than 5 μm with diameters 0.25–3 μm). Where comparison with light microscopy is not required fibres with diameters of <0.25 μm can be included.

The following items should be specified for inclusion in the report received from the analytical laboratory:

- the sample identification number
- the analytical method used
- detection limits
- a description of the sample appearance
- concentration and type of asbestos present
- comment on other materials detected
- number of dust overloads
- time spent looking at samples by analyst.

Appendix III: Soil sampling and analysis

There is currently no reliable method to determine the relationship between soil levels and air levels for asbestos-contaminated soil. As inhalation is the exposure route of concern, this makes exposure assessment from soil concentrations extremely difficult. While some methods have been proposed (Davies et al., 1996; Schneider et al., 1998; United States Environmental Protection Authority, 1997), and some show promise (Davies et al., 1996), they are yet to be validated for routine use. Much soil sampling is conducted using non-validated methods.

Soil sampling does not reflect exposures from activities that may disturb asbestos and may result in different levels of fibres in air. This limits the usefulness of soil sampling when assessing exposure. Given the difficulties in obtaining representative samples of soil contamination, detailed sampling may not add much to the risk assessment and consequent management of the problem.

The focus needs to be on implementation of management strategies that will prevent exposure to any material containing asbestos, and to avoid unnecessarily expensive analysis. This is not to say that sampling should not be undertaken. Sampling should be used to assess whether asbestos-containing material is present, determine the relative amount of contamination and to delineate the area of asbestos contamination.

The sample needs to be representative of the source material. Any variations in the appearance, texture or colour of the material will necessitate additional sampling.

Determining airborne levels from soil contamination

Addison et al. (1988) demonstrated that the asbestos concentration in air is unlikely to occur above 0.1 f/mL under controlled conditions where 5 mg/m^3 of respirable dust is generated from dry soil containing 0.001 per cent asbestos. This study was undertaken to determine a practical limit for the asbestos content of contaminated land below which no further decontamination would be necessary as soil 'free of asbestos' would be unattainable or impractical. The study found that unless considerable dust clouds are generated it would not be possible to measure airborne fibre levels at the levels required.

Addison et al. (1988) recommended a level of 0.001 per cent, below which no action would be required to decontaminate further or to protect workers specifically from asbestos dust.

High dust levels are unlikely to be generated in residential areas. Dust-suppression techniques used during disturbance of any soil (e.g. developments) to prevent nuisance dust would be sufficient to control worker exposure to asbestos.

Preliminary investigation and assessment

Generally, the preliminary investigation and assessment of a site will provide the most useful information in determining health risks from asbestos-containing materials present on the site. The site history, condition of the site and visual identification and assessment of contamination are the most important factors in hazard identification (Figure 4).

In some instances, where asbestos tailings or asbestos cement products have been dumped or used as infill, the area of contamination can be readily determined through the preliminary investigation. The areas where asbestos-containing material has been intentionally added can be subject to risk management without further assessment.

Difficulties arise where there has been erosion of the material or where the asbestos-containing material (such as fragments of broken asbestos cement) has been mixed through the soil and is present in small quantities. In these situations, a more detailed investigation may be required.

Detailed site investigation

It may not be viable to do detailed grid sampling, as it is unlikely to provide further, meaningful information on health risks. However, randomised stratified soil sampling and analyses can confirm the type of fibres and aid in the spatial delineation of the contamination, particularly where the contamination extends beyond the surface. Information on these sampling techniques is available in the National Environmental Protection Measure for assessment of site contamination (National Environmental Protection Council, 1999).

A more detailed site investigation, with soil samples representative of the surface area or volume of material from which asbestos is expected to be released and contribute to exposure, would only be required where:

- additional evidence is needed to determine the asbestos type, location and extent of the contamination
- information obtained in the site history or from visual inspection suggests asbestos may be present on or below the surface or in any filled areas.

Judgemental sampling would be most appropriate under these circumstances as it can be based on evidence from the preliminary investigation and take into account the heterogeneous nature of most sites contaminated with asbestos-containing material. Judgemental sampling is localised sampling based on knowledge of known or probable distribution or location of contamination at a site.

Stratified sampling would only be required where the preliminary investigation revealed very little information on the location, depth and type of asbestos-containing material on-site. Information on the sampling strategies is available from the National Environmental Protection Council's *National Environment Protection (Assessment of Site Contamination) Measure* (1999) and AS 4482.1 (Standards Australia, 1997). The extent and depth of sampling should take into account the information on the extent of contamination obtained from the preliminary investigation and the future land use and management of the site.

Where bulk asbestos material is present (e.g. asbestos cement fragments) test pits are preferable for collecting sample material. Test pits make it easier to observe any evidence of the presence of asbestos fragments.

Safety precautions

Protective footwear, which can be washed down before leaving the site, should be used for visual surface inspections. If disturbing the material (e.g. sampling, digging/raking for visual inspection), protective footwear, coveralls and respiratory protection should be worn (a class P1 or P2 half face disposable respirator should offer adequate protection). Any work on-site should comply with occupational health and safety requirements.

Analytical methods

The analytical method used to identify asbestos in bulk materials (including soils) is polarised light microscopy with dispersion staining. An Australian Standard method (AS4964-2004) for the qualitative identification of asbestos in bulk samples has been prepared from an existing draft NATA Guidance Note (1990) *Identification of Asbestos in Bulk Samples.* This qualitative method provides results[1] that are reported as no asbestos detected, trace asbestos detected, or asbestos detected. It can be used to classify contaminated sites. Where asbestos or trace asbestos is detected in a representative number of samples the site should be considered contaminated.

Davies et al. (1996) developed and tested a method for quantifying asbestos fibres that may be in low or trace concentrations in loose aggregates and soil (0.001%). This method uses wet sedimentation to allow the larger particles to settle out and a known quantity of the suspension is then passed through an appropriate filter and analysed by phase contrast optical microscopy and polarised light microscopy. Analysis by light microscopy may be sufficient for preliminary

[1] With a calculated practical detection limit of 0.01–0.1 per cent.

investigations and electron microscopy methods may be used where more detailed information is required. Fibres of asbestos are measured and counted. The volumes of the fibres are calculated from their measured dimensions and their masses calculated by the application of an appropriate specific gravity factor. The cumulated masses are then expressed as a proportion of the original mass in suspension. This method has been further developed and validated by Schneider et al. (1998), and provides reliable quantification down to 0.01 per cent for determining classification of carcinogens for the European Union at a level of 0.1 per cent.

The United States Environmental Protection Authority superfund method (United States Environmental Protection Authority, 1997) uses a dust generator to create respirable dust from a soil sample. This method eliminates the need for other preparation techniques (such as crushing or grinding) that potentially alter the distribution of respirable asbestos structure sizes and shapes found in the sample. The respirable dust is collected on a filter and the filter is prepared using the direct method (International Organization for Standardization, 1995) for analysis by transmission electron microscopy and hence has a detection limit of 0.002 asbestos structures/mL.

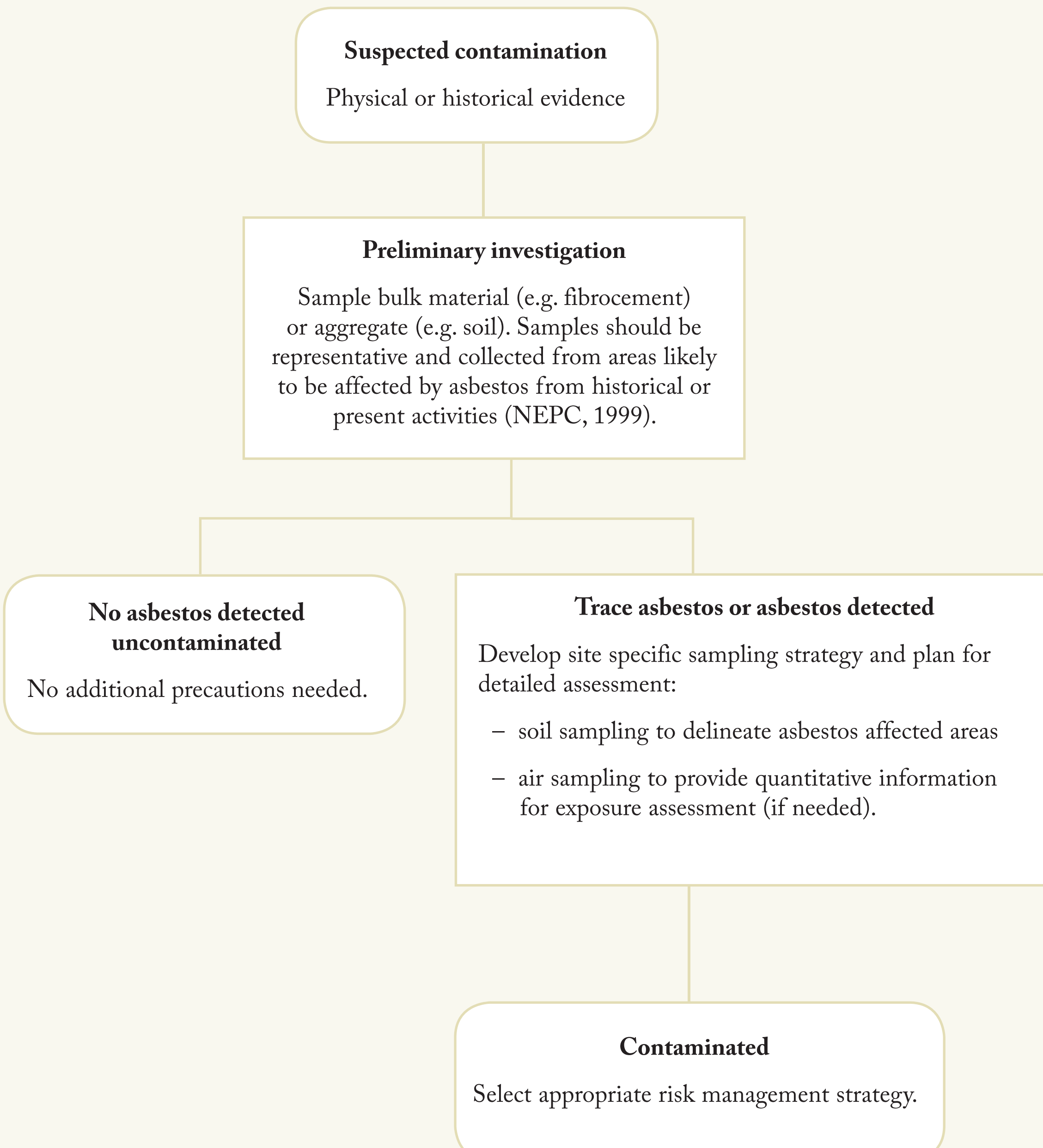
These methods are not considered appropriate as:

- The superfund method deals with the testing of release of fibres from soil, not their quantification (NATA, correspondence 24 May 2002). Also, if there are non-respirable asbestos clumps in the mixture they will not contribute to the risk assessment, but if the material were subjected to work, perhaps by crushing or by vehicular traffic then that non-respirable fraction could be made respirable.
  The estimated cost of analysis (US$900–1500 per sample) is prohibitive. The estimated precision of the method is ±50 per cent relative for tests in a single laboratory. The extensive use of riffles in sub-sampling could release fibres, thus not only confusing interpretation of the measurements but also presenting a hazard for analysts.
- The European methods are extensive and expensive. The Davies et al. (1996) method is considered to achieve a detection limit 10–100 times lower than the Draft Australian Standard Method for the Qualitative Identification of asbestos in bulk samples but is only suitable for fine, homogenous asbestos contamination, which is rarely found on contaminated sites (NATA, correspondence 24 May 2002).
- The methods introduce layers of complexity and there are insufficient competent operators and laboratories to meet the demands of such analysis.

Any method used will need to provide results suitable for supporting risk assessment and will need to facilitate reproducibility within and between laboratories that may offer the method commercially. To support risk assessment the method must achieve sufficient analytical sensitivity to adequately measure asbestos over the entire range of concentrations that might potentially pose an unacceptable risk.

Until an alternative analytical technique is developed and validated the Australian Standard *Method for the Qualitative Identification of asbestos in bulk samples* (AS4964–2004) is recommended for use.

Figure 4: Determination of sites as contaminated with asbestos fibres



Appendix IV: Trade names applied to asbestos cement products

The following list shows approximate dates when products ceased to be manufactured with asbestos fibre. Asbestos was slowly phased out and some products manufactured around these dates may contain from 3–5 per cent asbestos:

- Hardiflex 1981
- Hardiplank 1981
- Villaboard 1981
- Versilux 1982
- Harditherm 1984
- Compressed 1984
- Drain Pipe 1984
- Super Six 1985
- Highline 1985
- Shadowline 1985
- Coverline 1985
- Roofing Accessories 1985
- Pressure Pipe 1987

Appendix V: Sample inspection and investigation form

A 'walk through' survey will provide preliminary information. In assessing existing situations, it is important to talk to the owner/occupier regarding practical information about activities and history, e.g. they could describe what happens for maintenance, or in different weather conditions, or use activities that can affect exposure.

Inspection conducted by:	
Date:	Time:
Contact person:	
Address:	
	Postcode:
Telephone:	Facsimile:
Mobile:	Email:
Owner/occupier:	
Address:	
	Postcode:
Telephone:	Facsimile:
Mobile:	Email:

Contaminated land	Yes/No	Building/structure	Yes/No
Site/building/ location:			
Description: that is, type of building or structure e.g. dwelling, garage, fence and age,[1] building use, land use.			

Type of material containing asbestos present[2,3]	Quantity of the material	Exposed surface area	Date installed (if known)
Loose insulation material around boilers and pipes in flats or older house			
Decorative coating – textured plasters and paints			

[1] Older materials are likely to be made from asbestos. Asbestos is most likely to be present in buildings constructed or refurbished between 1950 and 1985.

[2] Check original building or site plans for any relevant information.

[3] Substitute materials can easily be mistaken for asbestos. Colour is not a reliable guide to the type of asbestos present.

Insulating fibreboard			
Asbestos cement guttering			
Asbestos cement pipe or tank – sewerage, rainwater, cold water and flues			
Asbestos backed linoleum			
Vinyl asbestos tiles			
Flat asbestos cement sheet – eaves, internal walls, external walls			
Corrugated asbestos cement sheet – fence, roof			
Older products such as heaters, oven gloves, simmering pads, ironing boards, fire blankets.			
Other:			
Photographs/video/sketch attached			Yes/No
Site/building plans attached			Yes/No
Material sampling results attached			Yes/No
Air sampling results attached			Yes/No

Condition of the material:		
Good	Minor damage or deterioration	Poor
Describe		
Has any material been emitted or released? How? (e.g. any visible evidence of contamination or visible dust that can be readily disturbed or become airborne?)		

Is the suspect material easily accessible to children? Note that accessibility is a measure of future damage, not exposure.	
What is the potential for future damage, disturbance, weathering or erosion of the suspect asbestos-containing material?	
High	Low
Describe actions or activities that may disturb asbestos-containing material.[4] Who is taking, proposing to take, or has taken the action? What is the nature of the action or disturbance affecting the suspected asbestos-containing material (e.g. redevelopment, weathering, erosion, drilling and cutting, removal, reuse, renovation, repair or redecoration, change in building or land use)? When is the action or disturbance of asbestos-containing material proposed?	

[4] See Labelling and warning signs and occupational health and safety (p. 37), Demolition control – prevention (p. 38) and Fires and natural disasters (p. 40).

	Who is potentially exposed? (number of people)	The exposure occurs intermittently? Yes/No	The exposure occurs continuously? Yes/No, (approx. hrs/day or hrs/week)
People who live or work within affected areas.			
People who perform maintenance.			
Visitors or people who work near or pass through affected areas			

Describe any steps taken to prevent or reduce exposure to the lowest level reasonably practicable (e.g. controls in place, such as isolation or enclosure of processes, management plan)	
Are any existing control measures effective, properly used and maintained?	Yes/No
If no, identify deficiencies:	
Can the asbestos-containing material be readily removed?	Yes/No

Risk rating	
High	There is exposure to airborne asbestos fibres. Remediation required urgently. Evacuate people and isolate affected area.
Medium	Material-containing asbestos is present. Activities at the site or disturbance of material may result in exposure to airborne fibres levels. A Management Plan is required to control exposure.

Low	Exposure to asbestos fibres is unlikely or effectively controlled. Risk is not significant now and is not likely to increase in the future. No further action is required beyond management plan to prevent further damage or deterioration
Unsure	There is uncertainty about the risks. Further information is required to determine the degree of potential exposure to asbestos fibres.
Action taken/recommended	

Appendix VI: Sampling of asbestos products in buildings

Sampling and analysis of suspect material is the only way to verify the presence of asbestos. Suspect material should be regarded as containing asbestos until the results of analysis are available (NOHSC, 2005a, 2005b). Sampling of air and soil as well as the suspect material may be involved.

The sampling methodology should include:

- isolating the area of concern
- wearing appropriate personal protection equipment, i.e. a class P1 or P2 half face disposable dust mask and coveralls
- dampening the material to minimise fibre release and using manual collection of a small sample – use hand tools if necessary but avoid the use of power tools
- placing samples in sealed containers/plastic bags labelled with:
    - the name and location of the site
    - the exact location of the sampled material
    - date of sampling
    - a sample identification number
    - the name of the person sampling
- using plastic sheeting to collect any fibres that may fall onto floor surfaces.

The sample should be representative of the source material. Any variations in the appearance, texture or colour of the material will necessitate additional sampling.

To ensure reliable and reproducible results it is important that the analysis is performed by a NATA-accredited laboratory and reported on a NATA-endorsed methodology (see Appendix IX). False positive or negative results could lead to expensive abatement actions or allow an existing hazard to remain uncontrolled.

Appendix VII: Safety precautions when working with asbestos cement

The following precautions are recommended when removing, repairing or otherwise handling asbestos cement products.

1. Isolate work area

Precautions should be taken to ensure that people in the vicinity of the work, who are not involved in the work activity, are not exposed to asbestos dust. All windows and doors on the building should be closed to protect people in the vicinity.

When removing or directly disturbing asbestos cement building products the surrounding area should have signs and barriers to warn of the potential danger and prevent other people from entering.

2. Wear personal protection equipment

All people who as a result of their activity may be exposed to airborne asbestos fibres or dust during the handling or removal of asbestos cement products should wear disposable coveralls and respiratory protection (for low level exposure either a class P1 or P2 half face disposable respirator should offer adequate protection), which are available from most hardware stores.

3. Dampen to minimise fibre release

The asbestos cement material should be gently sprayed with a PVA solution or kept wet if likely to be disturbed during building repair, renovation or removal. Do not use high-pressure water jets. The sheets should not be wet if this creates a high risk of slipping from a roof.

4. Where possible work outside

If there is no risk to people in the vicinity work should be conducted in the open air or in a well ventilated area.

5. Use hand tools

The use of power tools should be avoided. Only non-powered hand tools or approved portable power tools which incorporate approved dust suppression or dust extraction attachments should be used.

6. Avoid walking on asbestos cement roofs

Walking on an asbestos cement roof can be highly dangerous, particularly if the roof has undergone significant weathering. Many people have been injured falling through weathered asbestos cement roofs while attempting to treat or repair the roof surface. Another danger is that asbestos coatings can hide asbestos roofing nails which normally indicate where it is safe to walk. When asbestos roofs are coated, safe-walk areas should be clearly marked.

8. Avoid breakage

Asbestos cement should be handled and removed with minimal breakage and should be handled with care to avoid fibre release (e.g. lowered to the ground, not dropped).

9. Avoid abrasion of asbestos cement

When stacking removed asbestos cement materials care should be taken not to skid one sheet over the surface of another or otherwise abrade the materials as this action will result in scuffing and the release of fibres.

10. Clean gutters

Roof gutters should be cleaned or sealed prior to their removal.

11. Use an approved vacuum cleaner or wet cleaning

Any asbestos cement residue remaining in the roof space or the removal area should be cleaned up using an approved vacuum cleaner incorporating high efficiency particulate air filters or using wet cloths which can be disposed. Do not dry sweep dust.

12. Wrap waste in plastic

The removed asbestos cement products should be kept wet, stacked on polythene sheeting and wrapped and sealed in this sheeting prior to transportation and disposal. Alternatively they could be placed directly into disposal bins that have been lined with polythene sheeting and sealed for removal. Used disposable coveralls and masks should be placed in bags for removal with other asbestos waste.

13. Keep site tidy

Waste containing asbestos should be removed from the site as soon as practicable. It should not be left lying about the site where it could be broken or crushed.

14. Dispose of waste safely

All waste containing asbestos is to be disposed of at an approved site and in accordance with the appropriate state or territory legislation (see Appendix X).

Appendix VIII: Summary of mining history in Australia, 1880–1976

State	Location	Asbestos type
New South Wales	Baryulgil	Chrysotile
	Wood's Reef	Chrysotile
	Orange district	Tremolite
	Gundagai district	Actinolite
	Broken Hill district	Chrysotile
Tasmania	Beaconsfield district	Chrysotile 'amphibole'
	Zeehan district	Chrysotile
South Australia	Robertstown	Crocidolite
	Flinders Rangers (Oraparinna Station)	Crocidolite
	Truro district	Crocidolite, Tremolite
	Cowell	Chrysotile
Western Australia (Pilbara)	Lionel	Chrysotile
	Sloansville	Chrysotile
	Nunyeri	Chrysotile
	Wittenoom Gorges	Crocidolite
	Yampire Gorge	Crocidolite
	Colonial Gorge	Crocidolite
	Bindi Bindi	Anthophyllite

(Nevill, 1994; Imray & Neville, 1993)

Appendix IX: National Association of Testing Authorities approved laboratories for each state and territory

Contact your local NATA office for information including the benefits of using NATA-accredited laboratories or inspection facilities, how to interpret a NATA report, the differences between laboratory accreditation and ISO 9000 certification, the requirement for NATA accreditation for government contracts, and what to do if you are seeking NATA accreditation for your testing, calibration or inspection service.

National Association of Testing Authorities offices:

Sydney (Head Office)

7 Leeds Street, Rhodes NSW 2138	Ph: 61 2 9736 8222 Fax: 61 2 9743 5311

Melbourne

71–73 Flemington Road, North Melbourne, Vic. 3051	Ph: 61 3 9329 1633 Fax: 61 3 9326 5148

Brisbane

Ground floor, 80 Jephson Street, Toowong, Qld 4066	Ph: 61 7 3870 3844 Fax: 61 7 3870 4570

Adelaide

Unit 1, 13 King William Rd, Unley, SA 5061	Ph: 61 8 8179 3400 Fax: 61 8 8271 7061

Perth

Business Centre, 2A Brodie Hall Drive, Bentley WA 6102	Ph: 61 8 9451 0883 Fax: 61 8 9470 1323

A directory of NATA-accredited laboratories can be found at <http://www.nata.asn.au> go to Find a facility|Chemical testing|Asbestos or call 1800 621 666.

Appendix X: Acts, regulations and codes of practice that apply to regulation of asbestos

New South Wales

Protection of the Environment Operations (Waste) Regulation 1996

Regulation 1996 Asbestos Wastes Chemical Control Order 1989

Occupational Health and Safety (Asbestos Removal Work) Regulation 1996

Victoria

Occupational Health and Safety (Asbestos) Regulations 1992

Environmental Protection (Transport) Regulations 1987

Environmental Protection (Prescribed Waste) Regulations 1987

Health Act 1958 (Nuisance provisions)

Queensland

Code of Practice for Safe Treatment, Removal and Disposal of Asbestos Cement Sheeting and Asbestos Coated Metal Sheeting, 11 September 1992

Environmental Protection Act 1994

Workplace Health and Safety Regulations 1997

South Australia

Occupational Health and Safety Act 1986

Environmental Protection Act 1993

Occupational Health and Safety Regulations 1995

Code of Practice for the Safe Removal of Asbestos, November 1986

Code of Practice for Asbestos Work (Excluding Asbestos Removal) No. 7 1991

Western Australia

Health (Asbestos) Regulations 1992

Occupational Safety and Health Regulations 1996

Environmental Protection (Controlled Waste) Regulations 2001

Northern Territory

Work Health (Occupational health and Safety) Regulations 1996

Tasmania

Industrial Safety, Health and Welfare Regulations 1979

Dangerous Goods Act 1984

Occupational Safety and Health Act 1989

Australian Capital Territory

Building Act 1972

The Dangerous Substances (Asbestos) Amendment Act 2005 took effect April 2005

Bibliography

Addison, J 2001, *The mineralogy of asbestos*, Asbestos Health Effects Conference, Oakland, California.

Addison, J 1994, *Vermiculite is not asbestos*, Addison-Lynch, Edinburgh.

Addison, J, Davies, LST, Robertson, A & Wiley, RJ 1988, *The release of dispersed asbestos fibres from soil*, Report No. TM/88/14, Institute of Occupational Medicine, Edinburgh.

Agency for Toxic Substances and Disease Registry (ATSDR) 2001, *Toxicological profile for asbestos. Update*, United States Department of Health and Human Services, Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR) 1995, *Toxicological Profiles: Asbestos,* United States Department of Health and Human Services, Public Health Service, Atlanta, GA.

Albin, M, Magnani, C, Krstev, S, Rapiti E & Shefer I 1999, 'Asbestos and Cancer: An overview of current trends in Europe', *Environmental Health Perspectives* 107 (Suppl. 2):289–298.

Alste, J, Watson, D & Bagg, J 1976, 'Airborne asbestos in the vicinity of a freeway', *Atmospheric Environment*, 10:583–589.

Altree-Williams, S & Preston, JS 1985, 'Asbestos and other fibre levels in buildings', *Annals of Occupational Hygiene* 29 (3):357–363.

Australian and New Zealand Environment and Conservation Council (ANZECC) 1992, *Australian and New Zealand Guidelines for the Management of Contaminated Sites*, Australian and New Zealand Environment and Conservation Council, National Health and Medical Research Centre.

Australian Contaminated Land Consultants Association Inc. (NSW) 2001, *Asbestos in Soils: ACLCA Code of Practice*, Version 2, 25 February 2002.

Berry G & Newhouse ML 1983, 'Mortality of workers manufacturing friction materials using asbestos'. *British Journal of Industrial Medicine*, 40: 1-7.

Berry, G, Rogers, AJ & Pooley, FD 1989, 'Mesotheliomas: asbestos exposure and lung burden. In Non-occupational exposure to mineral fibres', edited by J Bignon, J Peto and R Saracci. Lyon: International Agency for Research on Cancer, p. 486-496.

Berman, DW & Crump, KS 1999, *Methodology for Conducting Risk Assessments at Asbestos Superfund Sites. Part 1: Protocol.* and *Part 2: Technical Background Document.* Prepared for: Kent Kitchingman, U.S. Environmental Protection Agency, Region 9, 75 Hawthorne, San Francisco, California 94105.

Berman, DW, Crump, KS, Chatfield, EJ, Davis, JMG & Jones, AD 1995, 'The sizes, shapes and mineralogy of asbestos structures that induce lung tumours or mesothelioma in AF/HAN rats following inhalation', *Risk Analysis,* 15 (2):181–95 (Berman, DW 1995, Errata, *Risk Analysis* 15 (4):541).

Bignon, J 1989, 'Mineral fibres in the non-occupational environment' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Brown DP, Dement JM, Okun A 1994, 'Mortality patterns among female and male chrysotile asbestos textile workers'. *J Occup Med*. 36(8):882-888.

Brown, SK 1997, *Indoor Air Quality*, *Australia: State of the Environment Technical Paper Series (Atmosphere)*, Department of the Environment, Sports and Territories, Canberra.

Camus, M, Siemiatycki, J & Meek B 1998, 'Non-occupational exposure to chyrsotile asbestos and the risk of lung cancer', *The New England Journal of Medicine,* 338(22):1565–1571.

Case, B 2001, *Lung-retained fibre as a marker of environmental dose*, Asbestos Health Effects Conference, Oakland, California.

Cherrie, J, Addison J & Dodgson J 1989, 'Comparative studies of airborne asbestos in occupational and non-occupational environments using optical and electron microscope techniques' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Churg, A 1988, 'Chrysotile, tremolite and malignant mesothelioma in man', *Chest* 33 (3):621–27.

Churg, A & Wright, JL 1989, 'Fibre content of lung in amphibole and chrysotile-induced mesothelioma: Implications for environmental exposure' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Commins, BT 1989, 'Estimations of risk from environmental asbestos in perspective' in J Bignon, J Peto & R Saracci, 1989, *Non-Occupational Exposure to Mineral Fibres,* International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Corn, M 1994, 'Airborne concentrations of asbestos in non-occupational environments', *Annals of Occupational Hygiene*, 38(4):495–502.

Council of the European Communities 1983, 'Special Provisions on the Labelling of Products Containing Asbestos, Council Directive 76/769/EEC Annex II', *Official Journal of the European Communities*, No. L 263/34, 24.9.83.

Daniel, R 2000, 'Ventilation and indoor air quality in schools', *Air Infiltration Review*, 21(4).

Davies, LST, Wetherill, GZ, McIntosh, C, McGonagle, C & Addison, J 1996, *Development and Validation of an Analytical Method to Determine the Amount of Asbestos in Soils and Loose Aggregates.* Edinburgh Institute of Occupational Medicine (Health and Safety Executive Contract Research Report No. 83/1996), Edinburgh.

Davis, JMG 1989, 'Mineral fibre carcinogenesis: Experimental data relating to the importance of fibre type, size, deposition, dissolution and migration' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Dement, J 2001, *Differences in carcinogenicity between asbestos types*, Asbestos Health Effects Conference, Oakland, California.

Dement JM, Brown DP & Okun A 1994, 'Mortality among chrysotile asbestos textile workers: cohort mortality and case-control analyses'. *Annals of Occupational Hygiene*, 38: 525-532.

Department for Environment, Food and Rural Affairs 1999, *Asbestos and man-made mineral fibres in buildings: Practical Guidance*. Department of the Environment, London, UK ISBN 0 7277 2835 0.

Doll, R and Peto, J 1985, *Effects on health of exposure to asbestos. A report to the Health and Safety Commission*. HMSO. London.

Driscoll, K 2001, *Introduction to toxicology, pathology and mechanisms,* Asbestos Health Effects Conference, Oakland, California.

enHealth Council 2002, *Environmental Health Risk Assessment Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra.

enHealth Council 2001, *Health-based Soil Investigation Levels*, Soil Series No. 1 (3rd ed.), Commonwealth of Australia, Canberra.

European Commission 2000, *Management of Construction and Demolition Waste*, Directorate General Environment, Directorate E – Industry and environment ENV E.3 – Waste Management, European Commission.

Ferguson, D 1990, 'Low-level asbestos–the priorities are wrong', *The Medical Journal of Australia*, 152:617–618.

Fubini, B 2001, *The physical and chemical properties of asbestos fibres which contribute to biological activity*, Asbestos Health Effects Conference, Oakland, California.

Gardner, MJ & Saracci, R 1989, 'Effects on health of non-occupational exposure to airborne mineral fibres' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Goldberg, M 2001, *Health effects of non occupational exposure to asbestos*, Asbestos Health Effects Conference, Oakland, California.

Hansen, J, de Klerk, NH, Musk, AW & Hobbs ST, 1998, 'Environmental exposure to crocidolite and mesothelioma', *American Journal of Respiratory Critical Care Medicine*, 157:69–75.

Hansen, J, de Klerk, NH, Musk, AW, Eccles, JL & Hobbs ST 1997, 'Mesothelioma after environmental crocidolite exposure', *Annals of Occupational* Hygiene, 41:189–193.

Harris RL Jr, Timbrell V 1975, 'The influence of fibre shape in lung deposition-mathematical estimates'. *Inhaled Part*. 4 Pt 1:75-89.

Health Effects Institute–Asbestos Research (HEI–AR) 1991, *Asbestos in Public and Commercial Buildings*, HEI–AR, Cambridge, MA.

Hillerdal, G 2001, *Radiological changes as markers of environmental exposure and environmental risk of lung cancer and mesothelioma*, Asbestos Health Effects Conference, Oakland, California.

Hillerdal, G 1999, 'Mesothelioma: cases associated with non-occupational and low dose exposures', *Occupational and Environmental Medicine*, 56:505–513.

Hodgson, JT & Darnton, A 2000, 'The quantitative risks of mesothelioma and lung cancer in relation to asbestos exposure', *Annals of Occupational Hygiene*, 44(8):565–601.

Hubbard, R 1997, 'The aetiology of mesothelioma: are risk factors other than asbestos exposure important?', *Thorax*, 52:496–497.

Hughes JM, Weill H & Hammad YY (1987) 'Mortality of workers employed in two asbestos cement manufacturing plants'. *British Journal of Industrial Medicine*, 44(3): 161-474.

Ilgren, EB & Browne, K 1991, 'Asbestos-related mesothelioma: Evidence for a threshold in animals and humans', *Regulatory Toxicology and Pharmacology*, 13:116–132.

Imray, P & Neville, G 1993, 'Approaches to the Assessment and Management of Asbestos Contaminated Soil', in A Langley & M Van Alplen, *The Health Risk Assessment and Management of Contaminated Sites*, Contaminated Sites Monograph Series No. 2.

Inter-departmental Committee on the Redevelopment of Contaminated Land 1990, *Guidance Note 64/85, Asbestos on Contaminates Sites*, 2nd edn, Inter-departmental Committee on the Redevelopment of Contaminated Land, London, UK.

International Agency for Research on Cancer (IARC) 1987, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Overall Evaluations of Carcinogenicity: An updating of IARC Monographs Volumes 1–42*, Supplement 7, 106–116, International Agency for Research on Cancer, Lyon.

International Agency for Research on Cancer (IARC) 1977, *Evaluation of the Carcinogenic Risk of Chemicals to Man: ASBESTOS*, 14, 81, International Agency for Research on Cancer, Lyon.

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

International Organization for Standardization 1995, 10312:1995, Ambient air – Determination of asbestos fibres – Direct-transfer transmission electron microscopy method, ISO, Geneva.

International Programme on Chemical Safety 1988, *Report of an IPCS Working Group Meeting on the Reduction of Asbestos in the Environment*, Internal Technical Report (12–16 December 1988 Rome).

International Programme on Chemical Safety 1999. Environmental Health Criteria 211 *Health effects of interactions between tobacco use and exposure to other agents*. World Health Organization, Geneva.Iwatsubo, Y, Pairon, JC, Boutin, C, Ménard, O, Massin, N, Caillaud, D, Orlowski, E, Galateau-Salle, F, Bignon, J & Brochard, P 1998, 'Pleural mesothelioma: Dose–response relation at low levels of asbestos exposure in a French population-based case-control study', *American Journal of Epidemiology*, 148(2):133–42.

Lange, JH & Thomulka, K 2000, 'Air sampling during asbestos abatement of floor tile and mastic', *Bulletin of Environmental Contamination and Toxicology*, 64:497–501.

Lippmann, K 2001, *Risk assessment of non occupational exposures to asbestos*, Asbestos Health Effects Conference, Oakland, California.

Magnani, C, Dalmasso, P, Biggeri, A, Ivaldi, C & Mirabelli, D 2001, 'Increased risk of malignant mesothelioma of the pleura after residential or domestic exposure to asbestos: A case control study in Casale Monferrato, Italy', *Environmental Health Perspectives,* 109:915–919.

Magnani, C, Agudo, A, Gonzalez, CA, Andrion, A, Calleja, A, Chellini, E, Dalmasso, P, Escolar, A, Hernandez, S, Ivaldi, C, Mirabelli, D, Ramirez, J, Turuguet, D, Usel, M & Terracini, B 2000, 'Multicentric study on malignant pleural mesothelioma and non-occupational exposure to asbestos', *British Journal of Cancer*, 83(1):104–111.

Magnani, C & Leporati, M 1998, 'Mortality from lung cancer and population risk attributable to asbestos in an asbestos cement manufacturing town in Italy', *Occupational and Environmental Medicine*, 55:111–114.

McDonald, C 2001, *Carcinogenicity of fibrous tremolite in workplace and general environments*, Asbestos Health Effects Conference, Oakland, California.

McDonald, JC, McDonald, AD & Hughes, JM 1999, 'Chrysotile, Tremolite and Fibrogenicity', *Annals of Occupational Hygiene*, 43(7):439–442.

McDonald, JC, Sébastien, P, McDonald, AD & Case, B 1989, 'Epidemiological observations on mesothelioma and their implications for non-occupational exposure' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

McDonald AD, Fry JS, Woolley AJ, McDonald JC 1983, Dust exposure and mortality in an American factory using chrysotile, amosite and crocidolite in mainly textile manufacture. *British Journal of Industrial Medicine*, 40:368-374.

McDonald JC, Liddell FD, Dufresne A, McDonald AD 1993, The 1891-1920 birth cohort of Quebec chrysotile miners and millers: mortality 1976-88. *British Journal of Industrial Medicine*, 50(12): 1073-1081.

McDonald AD, Fry JS, Woolley AJ, McDonald JC 1984, Dust exposure and mortality in an American chrysotile asbestos friction products plant. *British Journal of Industrial Medicine*, 41(2): 151-157.

McDonald JC, McDonald AD, Armstrong B, Sebastian P 1986, Cohort study of mortality of vermiculite miners exposed to tremolite. *British Journal of Industrial Medicine*, 43(7): 436-444.

Ministry of Health 1997, *Management of Asbestos in the Non-Occupational Environment*, Manukau, New Zealand.

Mossman, BT & Churg, A 1998, 'Mechanisms in the Pathogenesis of Asbestosis and Silicosis', *American Journal of Respiratory Critical Care Medicine,* 157:1666–1680.

Musk, AW, de Klerk, NH, Eccles, JL, Hansen, J & Shilkin, KB 1995, 'Malignant mesothelioma in Pilbara Aborigines', *Australian Journal of Public Health*, 19:5:520–522.

National Environmental Protection Council (NEPC) 1999, *National Environment Protection (Assessment of Site Contamination) Measure 1999*, Environment Australia, Canberra.

National Industrial Chemicals Notification and Assessment Scheme (NICNAS) 1999, *Chrysotile Asbestos, Priority Existing Chemical No. 9: Full Public Report*, Commonwealth of Australia, Canberra.

National Occupational Health and Safety Commission (NOHSC) 2001, *The incidence of mesothelioma in Australia 1996 to 1998: Australian Mesothelioma Register Report 2001*, Commonwealth of Australia, Canberra.

National Occupational Health and Safety Commission (NOHSC) 1999, *List of Designated Hazardous Substances*, Commonwealth of Australia, Canberra.

National Occupational Health and Safety Commission (NOHSC) 1995, *Guidelines for Health Surveillance,* Commonwealth of Australia, Canberra.

National Occupational Health and Safety Commission (NOHSC) 2005b, *Code of Practice for the the Management and Control of Asbestos in Workplaces*, Commonwealth of Australia, Canberra.

National Occupational Health and Safety Commission (NOHSC) 2005a, *Code of Practice for the Safe Removal of Asbestos,* 2nd Edition*,* Commonwealth of Australia, Canberra.

National Occupational Health and Safety Commission (NOHSC) 2005c, *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres* 2nd Edition, Commonwealth of Australia, Canberra.

Nevill, M 1994, *Report of the Select Committee Appointed to Inquire into Wittenoom*, Legislative Assembly, Perth.

New South Wales Department of Industrial Relations and Employment 1988, *Chrysotile (white asbestos and workplace health and safety)*, Division of Occupational Health, Department of Industrial Relations and Employment, Sydney.

Nicholson, WJ 1989, 'Airborne mineral fibre levels in the non-occupational environment' in J Bignon, J Peto & R Saracci, 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Noy, EA 1995, *Building Surveys and Reports* (2nd edn), Blackwell Science, Pty Ltd, Carlton.

Osinubi, OYO, Gochfeld, M & Kipen, HM 2000, 'Health effects of asbestos and non-asbestos fibres', *Environmental Health Perspectives*, 108(suppl 4):665–674.

Otness P, Feldwick M, Di Marco P 2003, Asbestos – Recent Developments and Implications for Health Policy. In: *Proceedings of the Fifth National Workshop on the Assessment of Site Contamination* Eds: Langley A, Gilbey M and Kennedy B. NEPC Service Corporation, Adelaide.

Paoletti, L, Eibenschutz, L, Cassano, AM, Falchi, M, Batisti, D, Ciallella, C & Donelli, G 1989, 'Mineral fibres and dust in the lung' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres*, International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Peronard, P & Weis, C 2000, *Sampling and Quality Assurance Project Plan, Revision 1 for Libby, Montana, Environmental Monitoring for Asbestos*, United States Environmental Protection Authority R8.

Peto J, Doll R, Hermon C, Binns W, Clayton R, Goffe T 1985. Relationship of mortality to measures of environmental asbestos pollution in an asbestos textile factory. *Ann Occup Hyg* 29(3):305-355.

Rajhans, GS & Sullivan, JL 1981, *Asbestos sampling and analysis*, Ann Arbor Science Publishers Inc., Michigan.

Rihn, B, Coulais, C, Kauffer, E, Bottin, M, Martin, P, Yvon, F, Vigneron, JC, Binet, S, Monhoven, N, Steiblen, G & Keith, G 2000, 'Inhaled crocidolite mutagenicity in lung DNA', *Environmental Health Perspectives*, 108:341–346.

Rosenthal, GJ, Corsini, E & Simeonova, P 1988, 'Selected new developments in asbestos immunotoxicity', *Environmental Health Perspective*, 106, Supp. 1:156–169.

Schneider T, Davies LS, Burdett G, Tempelman J, Puledda S, Jorgensen O, Buchanan D, Paoletti L 1998, Development of a method for the determination of low contents of asbestos fibres in bulk material. *Analyst*. Jun;123(6):1393-1400.

Scottish Centre for Infection and Environmental Health (SCIEH) 2001, Guidance Note Series GN15-06/2001 at <http://www.show.scot.nhs.uk/scieh/environmental/enviropdf/asbestos.pdf>.

Sébastien, P 2001, *Exposure assessment in environmental circumstances*, Asbestos Health Effects Conference, Oakland, California.

Sluis-Cremer, GK 1991, 'Asbestos disease at low exposures after long residence times', *Annals of New York Academy of Sciences*, 643:182–193.

Spurny, KR 1989, 'Asbestos fibre release by corroded and weathered asbestos cement products' in J Bignon, J Peto & R Saracci 1989, *Non-Occupational Exposure to Mineral Fibres,* International Agency for Research on Cancer Scientific Publications No. 90, Lyon.

Standards Australia 2002, Australian Standard DR 02125 Method for the qualitative identification of asbestos in bulk samples, Standards Australia, Sydney.

Standards Australia 1997, Australian Standard 4482.1 Guide to the sampling and investigation of potentially contaminated soil, Part 1: Non-volatile and semi-volatile compounds, Standards Australia, Sydney.

Standards Australia 1981, Australian Standard 1216 Classification, Hazard Identification and Information Systems for Dangerous Goods, Part 1 1981: Classification and Class Labels for Dangerous Goods, SAA, Standards Australia, Sydney.

Standards Australia 1979, Australian Standard 1319, Rules for the Design and Use of Safety Signs for the Occupational Environment, Standards Australia, Sydney.

Stanton, MF, Layard, M, Tegeris, A, Miller, E, May, M, Morgan, E & Smith A 1981, 'Relation of particle dimension to carcinogenicity in amphibole asbestoses and other fibrous minerals', *Journal of the National Cancer Institute*, 67(5):965–975.

Stayner LT, Dankovic DA & Lemen RA 1996, Occupational exposure to chrysotile asbestos and cancer risk: a review of the amphibole hypothesis. *American Journal of Public Health*, 86(2): 179-186.

Suzuki, Y & Yuen, SR 2001, 'Asbestos tissue burden study on human malignant mesothelioma', *Industrial Health,* 39(2):150–160.

United States Environmental Protection Authority 1997, *Superfund Method for the Determination of Releasable Asbestos in Soils and Bulk Materials*, Environmental Protection Authority 540-R-97-028.

Vacek, PM & McDonald, JC 1991, 'Risk assessment using exposure intensity: an application to vermiculite mining', *British Journal of Industrial Medicine,* 48:543–547.

Van Der Walt, IJ & De Villiers, AB 1996, 'A model to determine airborne environmental pollution from asbestos mine dumps', *Zeitschrift fuer Geomorphologie Neue Folge (Annals of Geomorphology)*, 30(3):339–347.

Western Australian Advisory Committee on Hazardous Substances, 1990, *Asbestos Cement Products*, WAACHS, Perth.

Wong, O 2001, 'Malignant Mesothelioma and Asbestos Exposure among auto mechanics: appraisal of scientific evidence', *Regulatory Toxicology and Pharmacology*, 34 (2):170–177.

World Health Organization (WHO) 1986, *Asbestos and Other Natural Mineral Fibres,* EHC 53, WHO, Geneva.

Youakim, S 2005, BC Medical Journal 47(2); 82-28.