Occupational Hygiene Training Association

STUDENT MANUAL

Asbestos and other fibres

March 2010

CONTENTS

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ABBREVIATIONS

μm	Micrometre (micron)
ACM	Asbestos containing material
AIB	Asbestos insulating board
AIMS	Asbestos in Materials Scheme (UK)
AIOH	Australian Institute of Occupational Hygienists
ARCA	Asbestos Removal Contractors Association (UK)
BA	Breathing apparatus
BOHS	British Occupational Hygiene Society
CAD	Computer aided design
CE	Conformite Europeene (European Conformity)
cm	centimetre
cm^2	Square centimetre
cm^3	Cubic centimetre
CV	Coefficient of Variation
DETR	Department of the Environment Transport and the Regions (UK)
DPC	Damp-proof course
HEPA	High efficiency particulate arrestor
HSE	Health and Safety Executive (UK)
HSG	Health and Safety Guidance Note (UK)
IARC	International Agency for Research on Cancer
ILO	International Labour Organisation
IOM	Institute of Occupational Medicine (UK)
ISO	International Standards Organisation
L	Litre
L/M	Litre per Minute
LOD	Limit of Detection

ABBREVIATIONS (Cont'd)

m^2	Square metre
m^3	Cubic Metre
MCE	Mixed Cellulose Ester
MDHS	Methods for the Determination of Hazardous Substances
mg/m^3	Milligrams per Cubic Metre
ml	millilitre
MMMF	Machine Made Mineral Fibre (or Man Made Mineral Fibre)
MMVF	Man Made Vitreous Fibre
Mins	Minutes
MSHA	Mine Safety and Health Administration (USA)
NATA	National Association of Testing Authorities (Australia)
NIOSH	National Institute of Occupational Safety & Health (USA)
N/A	Not Applicable
NOHSC	National Occupational Health & Safety Commission (Australia)
NPL	National Physical Laboratory (UK)
NPU	Negative pressure unit
OEL	Occupational Exposure Limits
OES	Occupational Exposure Standards
OSHA	Occupational Health & Safety Administration (USA)
PAT	Proficiency Analytical Testing Programme
PCM	Phase Contrast Microscopy
PF	Protection factor
PLM	Polarised Light Microscopy
PPE	Personal Protective Equipment
ppm	Parts Per Million
PTFE	Polytetrafluoroethylene (Teflon)

ABBREVIATIONS (Cont'd)

PVC	Poly-Vinyl Chloride
RCF	Refractory ceramic fibre
RI	Refractive index
RICS	Royal Institute of Chartered Surveyors (UK)
RICE	Regular Inter-laboratory Counting Exchange (UK)
RP	Respiratory protection
RPE	Respiratory Protective Equipment
SD	Standard Deviation
SAED	Selective area electron diffraction
SCBA	Self Contained Breathing Apparatus
SEM	Scanning Electron Microscopy
TEM	Transmission Electron Microscopy
TLV®	Threshold Limit Value
TWA	Time Weighted Average
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
µm	Micrometre (micron)
USA	United States of America
WEL	Workplace Exposure Limits
WHO	World Health Organisation
XRD	X-ray Diffraction Spectrometry

1. COURSE OVERVIEW

1.1 INTRODUCTION

This Course has been based in the most part on the international module syllabus W504 – Asbestos and other fibres published by the British Occupational Hygiene Society (BOHS), Faculty of Occupational Hygiene. The BOHS administers a number of such modules; further information on which can be obtained by visiting the BOHS website at www.bohs.org.

At the time of publication every care has been taken to ensure that the majority of topics covered in the BOHS syllabus for the subject (W504) have been included in this Student Manual. Providers of training courses should check the BOHS website for any changes in the course content.

The authors of this Student Manual take no responsibility for any material which appears in the current BOHS syllabus for Module W504 which is not covered in this manual.

1.2 AIM OF COURSE

To enhance the student's knowledge of industrial hygiene practice in relation to fibrous dusts. This module concentrates on asbestos, but other fibres, e.g. machine made mineral fibres (MMMF), aramids, carbon etc., which are increasingly finding uses in industry are also covered. Successful completion of this module will benefit those working in asbestos consultancy as well as in mainstream industrial hygiene, giving an understanding of the health risks associated with asbestos and other fibres as well as the means of evaluation and control.

1.3 LEARNING OUTCOMES

On successful completion of this module the student should be able to:

- describe the composition, nature and properties of asbestos, machine made mineral fibres and other fibres and their historical uses;
- describe the health effects of asbestos and other fibrous materials and apply appropriate exposure limits;

- describe the uses of asbestos in buildings and the public health risk that these may pose
- understand the principles of and requirements for asbestos surveys including taking samples and identifying bulk asbestos types by microscopic techniques including relevant safety requirements
- be thoroughly familiar with current good practice in the construction and use of enclosures for asbestos remediation and the use of decontamination units
- understand all the principles of clearance testing, the requirements for measurement and appropriate techniques for post remediation evaluation
- conduct air sampling to determine airborne concentrations of asbestos or other fibres in accordance with defined procedures including microscopic counting techniques
- have the ability to advise on all the various techniques for the management of asbestos in buildings in accordance with good practice

1.4 FORMAT OF MANUAL

This manual has been designed to follow for the most part the syllabus for this course as published by the BOHS. Similarly, the material provided in this manual has been aligned with the presentations for each topic so students can follow the discussion on each topic.

It should be recognised that the format presented in this manual represents the views of the editors and does not imply any mandatory process or format that must be rigidly observed. Presenters using this manual may well choose to alter the teaching sequence or course material to suit their requirements. .

In the final outcome, the aim of this manual is to transmit the principles of asbestos monitoring, management and control and an understanding of the effects of human exposure to asbestos.

2. ASBESTOS AND OTHER FIBRES

2.1 INTRODUCTION

2.1.1 Historical perspective

Asbestos is a generic term used to describe a group of naturally occurring fibrous silicate minerals that are widely distributed in rocks and deposits throughout the world. Asbestos fibres occur in veins in certain rock types, where these veins are present in significant quantities commercial extraction of the asbestos was practicable.

These fibrous minerals have been used for many years because of their range of useful properties such as high tensile strength, heat resistance, incombustibility and resistance to chemical attack. Chrysotile is the most common asbestos mineral. Approximately 90% of the asbestos that has been mined and used industrially has been chrysotile.

There are many examples through history where the properties of asbestos have been utilised. As far back as about 2500 – 3000 BC it was used to strengthen clay pots in Finland. At about the same time it was already being used as wicks in lamps and candles.

At the time of the Greek and Roman Empires it was also used for funeral shrouds where its properties of non-combustibility were of value in protecting the ashes of important people during cremation. Marco Polo returned from his travels to China with descriptions of asbestos mines that produced a material that could be made into a flame resistant cloth.

Asbestos was used in body armour in the 15th century, in asbestos paper and boards in Italy in the early 1700's and in the manufacture of textiles and purses in Russia in the early 18th century. By the early years of the 19th century asbestos deposits were documented in Russia, Italy, South Africa and Canada as well as several other countries.

Commercial asbestos production began in Italy about 1850, in the making of paper and cloth, followed by the United Kingdom and Germany in the 1860's.

Large scale asbestos mining commenced in Canada, South Africa and Russia in about 1880 when exploitation of the extensive deposits in these countries reduced costs and spurred the production of a wide range of products.

The development of asbestos as pipe insulation increased production and was followed shortly after by other uses including brake linings, cement pipes and protective clothing. Asbestos production in the United States increased from about 6,000 tons in 1900 to a peak of about 650,000 tons in 1975 dropping to about 33,000 tons in 1994.

Exploitation of deposits of crocidolite and amosite started in the early 1900's in South Africa, while crocidolite was mined in Western Australia between 1937 and 1966.

2.1.2 Groups at risk from asbestos exposure

As early as the first century, the health effects of asbestos were documented by Pliny the elder who noted that slaves working in asbestos mines died young of lung disease. Asbestos has been mined and used for a variety of applications throughout history. Large scale mining of asbestos began towards the end of the 19th Century. As the amount of asbestos products increased, more evidence began to accumulate with regard to the health effects of exposure to asbestos.

In 1906, the first fully documented death was reported in the United Kingdom when the autopsy of an asbestos worker revealed lung fibrosis. By the 1930's the potential for high levels of asbestos exposure to cause asbestosis was well known. By the mid 1930's physicians were beginning to notice that some patients who had asbestosis also were victims of lung cancer.

In 1955 Richard Doll published evidence that asbestos causes lung cancer. In 1960 Chris Wagner produced evidence of the link between asbestos and mesothelioma among South African miners and people living near the mines.

In countries such as the United Kingdom, United States of America, South Africa and Australia the groups of people most at risk historically were those who worked directly with asbestos such as asbestos miners, laggers (people who applied asbestos insulation), shipyard workers, manufacturers of asbestos products and asbestos textile workers. Asbestos use in products such as asbestos insulating building boards peaked in these countries in about the mid 1970's, after which use of asbestos was progressively reduced. The large amount of asbestos products used in building products meant that builders and allied trades were also exposed to high levels of asbestos fibres during construction works.

As the production and installation of asbestos products declined after the mid 1970's in these countries, the very high exposure levels previously encountered have largely ceased. However, vast amounts of asbestos products that have been used and installed in the past still remain in-situ in all types of buildings and industrial installations.

In these countries, the workers considered most at risk now are those who may disturb asbestos materials during repair, maintenance and refurbishment work on buildings. Indeed, in the United Kingdom, the Health and Safety Executive (HSE) regard electricians, plumbers, carpenters and building maintenance workers to be the occupational groups most at risk when working on those buildings which still contain asbestos.

In some countries, particularly in parts of Asia, asbestos is still being used, while in others use of asbestos has only recently stopped. In these countries, higher levels of exposure may still be common and the precautions in place to prevent inadvertent disturbance of asbestos may not be well developed.

Whatever the situation, it is important that a comprehensive management system should be in place to prevent or reduce exposure to asbestos.

2.2 ASBESTOS FIBRE TYPES

2.2.1 Six regulated forms

Silicate minerals in their natural state vary in chemical composition and physical structure. They may occur in fibrous or non-fibrous varieties, often within the same deposits. This makes it difficult to define exactly which minerals pose a risk to health. For regulatory purposes, six different fibrous mineral types that have been commercially exploited have been defined as being “asbestos”. These are actinolite, anthophyllite, chrysotile, amosite, tremolite and crocidolite.

You may sometimes come across the terms “grunerite” and “riebeckite”, which are the names of the parent minerals from which amosite and crocidolite respectively are extracted. They may be fibrous or non-fibrous.

(Source: Gully Howard Technical Ltd)

Figure 2.1 Asbestos fibres – chrysotile, amosite and crocidolite

It should also be noted that the three most commonly used forms of asbestos are often referred to by their colour as found in the pure material. Chrysotile is often termed ‘white asbestos’, amosite is often termed ‘brown asbestos’ and crocidolite is often termed ‘blue asbestos’.

The asbestos varieties share several properties:-

- They occur as bundles of fibres that can split along their length to produce finer fibres
- The fibres have high tensile strengths

- They have high length/diameter (aspect) ratios, typically between 20 and up to 1000
- They are sufficiently flexible to be spun

2.2.2 Classification of fibre types

The asbestos minerals can be sub-divided into two different classifications: amphiboles and serpentines. Chrysotile is the only asbestos mineral that is classified as a serpentine mineral. The other five fibre types are classified as amphibole minerals. Both amphibole asbestos and serpentine asbestos are fibrous, but they have very different forms.

2.2.3 Structure of asbestos fibre types

The amphiboles are based on a double chain of silicates. The basic structural unit is $(Si_4O_{11})^{-6}$ with side groups that are responsible for the overall amphibole structure. Amphiboles are distinguished from one another by the amount and positioning of metal atoms (cations) including: sodium, calcium, manganese, magnesium, iron(II), iron(III) and aluminium. These variations in cation composition not only define the amphibole types, but are also responsible for the observed differences in optical properties within each type as the exact chemical composition will vary between different sources of asbestos deposits. Nominal chemical compositions of asbestos minerals are given in Table 2.1.

Table 2.1 – Nominal chemical composition of asbestos minerals

Asbestos variety	Non-asbestos mineral analogue	Nominal composition
Serpentine group		
Chrysotile	Lizardite, antigorite	$Mg_3(Si_2O_5)(OH)_4$
Amphibole group		
Crocidolite	Riebeckite	$Na_2(Fe^{2+}Mg)_3Fe^{3+}(Si_8O_{22})(OH)_2$
Amosite	Grunerite	$(Fe^{2+})_2Fe^{2+},Mg)_5(Si_8O_{22})(OH)_2$
Fibrous anthophyllite	Anthophyllite	$Mg_7(Si_8O_{22})(OH)_2$
Fibrous actinolite	Actinolite	$Ca_2(Mg,Fe^{2+})_5(Si_8O_{22})(OH)_2$
Fibrous tremolite	Tremolite	$Ca_2Mg_5(Si_8O_{22})(OH)_2$

The serpentine group of minerals has the formula $Mg_3Si_2O_5(OH)_4$. The serpentine structure is in the form of a sheet silicate. At a molecular level, these sheets tend to roll into a ‘scroll-like’ structure to form continuous tubes.

Chrysotile is very flexible and less likely to be ‘friable’ (easily broken down into finer fibres) when compared to the amphiboles. Amphiboles fibres are generally more brittle and accommodate less structural deformation during mechanical treatment or abrasion.

2.2.4 Physico-chemical properties of asbestos fibres

Industrial applications of asbestos take advantage of a combination of properties. The performance of the fibre as a reinforcing material is largely dependent on the length of the fibres. Other fibre properties that render them useful include flexibility, high tensile strength, non-combustibility, resistance to heat, low electrical conductivity and resistance to chemical attack.

2.2.4.1 Flexibility

Due to differences in crystal structure chrysotile fibres tend to be much more flexible than the amphibole fibres that tend to be straighter and more brittle.

2.2.4.2 Tensile strength

Generally asbestos fibres have high values for tensile strength with no significant differences between chrysotile, amosite and crocidolite. However other amphiboles e.g. tremolite have lower tensile strength.

Tensile strength will vary with temperature. Chrysotile is largely unaffected up to 550°C when dehydroxylation occurs (see 2.2.4.6). Tensile strength drops rapidly as this degradation occurs at higher temperatures. Amphiboles exhibit a decreasing tensile strength beginning at about 200°C.

2.2.4.3 Combustibility

Asbestos fibres do not burn and although they will undergo chemical and physical changes at elevated temperatures (see 2.2.4.6) have found widespread use as a fire-proofing material.

2.2.4.4 Thermal conductivity

All forms of asbestos have very low thermal conductivities – that is they are all very resistant to transfer of heat. This coupled with their properties as a reinforcing fibre has led to widespread use in insulation and lagging products.

2.2.4.5 Resistance to chemical attack

Asbestos fibres are generally unaffected by water. However prolonged exposure of chrysotile particularly at high temperatures will lead to some slow leaching of some metals and silicates from the crystal matrix. This process will be greatly increased by contact with mineral or strong acids leading to a loss of mechanical strength.

Generally amphibole asbestos is much more acid resistant than chrysotile, with crocidolite being particularly resistant to acids. Conversely with exposure to alkalis, chrysotile is the most resistant to chemical attack with all the amphibole fibres being slightly less resistant.

Table 2.2 - Physical and chemical properties of asbestos fibres

	Chrysotile	Amosite	Crocidolite
Flexibility	High	Fair	Fair to good
Capability of being woven	Very good	Fair	Fair
Tensile strength	High	High	High
Resistance to acids	Weak, undergoes fairly rapid attack	Fair, slowly attacked	Good
Resistance to alkalies	Very good	Good	Good
Decomposition temperature, °C	600-850	600-900	400-900

2.2.4.6 Effects of thermal degradation

Asbestos fibres are hydrated silicates so a primary effect of subjecting asbestos to high temperature is to cause a dehydroxylation reaction (loss of water of crystallisation from the mineral).

Chrysotile is generally thermally stable up to about 550°C after which dehydroxlation occurs. This continues progressively up to about 750°C. The resulting magnesium silicate will undergo further degradation at about 800°C to 850°C recrystallising to form forsterite and silica.

Amphiboles undergo similar degradation processes at high temperatures. Dehydroxylation occurs at temperatures between 400°C and 600°C. Further heating can lead to the formation of pyroxenes, magnetite, haematite and silica.

Thermal decomposition of amphiboles in the presence of oxygen leads to oxidation of iron present within the material. This leads to changes in colour (e.g. amosite changes from a pale brown to a dark brown colour).

These colour changes and other changes in chemical composition may affect the optical properties of the fibre seen under polarised light microscopy and cause difficulties when analysing samples for the presence of asbestos (see 8.5).

2.3 USES OF ASBESTOS

The properties of asbestos have led to its use in a wide range of industrial applications. Of the six forms of asbestos described earlier, only three forms have been widely used – chrysotile, amosite and crocidolite. About 90% of the asbestos that has been mined and used historically was chrysotile.

While all forms of asbestos have a number of similar properties the differences between the types of asbestos have led to some asbestos types being used preferentially in some products.

A brief summary of the types of products that have contained asbestos is given below. A more detailed listing is given in Section 5.1

- Thermal and acoustic insulation
- Spray coating (as fire protection)
- Asbestos reinforced insulation board
- Asbestos reinforced cement products
- Plastic products (e.g. vinyl floor tiles)
- Textiles
- Friction materials (brake pads etc)
- Gaskets and packing materials
- Roofing felts etc

In many products any of the forms of asbestos may have been used. However for some products some forms of asbestos are more likely.

Chrysotile is more hydrophilic (easily wetted) than the amphiboles and this property together with its stability in an alkali environment has led to the vast majority of asbestos reinforced cement products containing chrysotile. Conversely, the high resistance to acids has led to the preferential use of crocidolite in gaskets in 'chemically aggressive' environments such as chemical and gas production plant.

The greater flexibility of chrysotile fibres where it is more suitable for weaving into a material has also led to its preferential use in textile and paper products.

Other types of asbestos (tremolite, actinolite and anthophyllite) have been used very occasionally. When these materials have been found in industrial products they are usually found as a minor component mixed with one of the three main types.

It is important to realise that asbestos is sometimes found as a contaminant in other minerals that are mined or extracted e.g. iron ore. Other examples of minerals where asbestos has been found as a contaminant are vermiculite and talc. Historically substances such as industrial talc may have been contaminated with asbestos (particularly tremolite). Also some deposits of chrysotile have been found to contain small quantities of amphibole minerals such as tremolite.

2.4 MAN MADE MINERAL FIBRES (MMMF) and OTHER FIBRES

2.4.1 Man-made mineral fibres (MMMF)

Man-made mineral fibres (MMMF) or man-made vitreous fibres (MMVF) is the name given to a large class of synthetic materials that includes glass wool or glass fibre, continuous filament glass, rock wool, slag wool and refractory ceramic fibres.

Glass wool fibres are made by blowing or spinning molten glass through small holes. Rock wool, slag wool and refractory ceramic fibres are made similarly to glass wool, except that the respective starting materials are rock, slag (i.e. a by-product of certain smelting operations), and clays.

Glass wool fibres, rock wool and slag wool fibres are widely used for thermal and acoustic insulation of buildings and process plant and in structural fire protection. It is often supplied as an insulating mat or blanket or as pre-formed shapes such as pipework insulation or insulation of process vessels. They are also widely used in items such as ceiling tiles.

Refractory ceramic fibres are used in insulating boards and blankets and where high temperature insulation properties are required (e.g. furnaces).

HSE Guidance Note EH46 (1990) states that:
Ceramic fibres are able to withstand temperatures of 1000 to 1600^{o}C without appreciable distortion or softening. Ceramic fibres based on glasses of

alumina and silica are used for relatively low temperature applications, and fibres based on pure alumina or zirconia at higher temperatures.

Continuous filament glass fibres are made by extruding molten glass through small holes. These long fibres are woven into cloth or used in the manufacture of electrical insulants and to reinforce plastics and other materials used in manufacture of boats, car body panels and other products.

Man-made mineral fibres typically have fibre diameters much larger than asbestos fibres. There is a range of fibre diameters found with each type of man-made mineral fibre. There is also some variation in the ranges of fibre diameters quoted between different information sources.

Mean fibre diameters of glass wool, rock wool and slag wool are typically in the range 4 – 9 micrometres. Continuous filament fibres are usually in the range 8 - 10 micrometres. Refractory ceramic fibres have fibre diameters around 2 to 3 micrometres. Mean fibre diameters of 'Special purpose fibres' usually lie in the range 0.1 to 3 micrometres.

Special purpose fibres may be made from ceramic materials or less heat resistant glasses depending on application. Their small diameter gives them useful properties for specialist applications. They are used for lightweight high temperature insulation, particularly in the aircraft or aerospace industries, high performance acoustic protection and high efficiency filtration.
(Source: HSE Guidance Note EH46 – Reproduced under the terms of the Click-Use Licence)

DETR Asbestos and MMMF in buildings (1999) states that:
The toxicity of fibres is determined by dose, dimension and durability. As for all toxic materials, the amount of material reaching the target tissue (the dose), is of primary importance. The dimension of the fibre is important with respect to both the likelihood of it reaching the deep lung and its biological activity at the target site. Fibre durability, or biopersistence, determines how long it will remain in the lung to exert any potential toxic effect. Fibres of similar size and shape can have quite different toxicities due to different

durability in the lung. This may explain some of the differences which are observed in the effects on health of asbestos and man-made mineral fibres.

(Source: DETR Asbestos and MMMF in buildings – British Crown Copyright, reproduced by kind permission of the Department for Environment Food and Rural Affairs)

Table 2.3 – Comparison of the properties of man-made mineral fibres and asbestos relevant to health effects

A comparison of the properties of man-made mineral fibres and asbestos relevant to health effects		
Characteristics	MMMF wools	Asbestos
Naturally occurring, resulting in background human exposure	No	Yes
Fibrous	Yes	Yes
Crystalline	No	Yes
Diameter can be controlled	Yes, to a degree during manufacture	No; diameter decreases with handling
Breakage	Transversely into shorter fragments, dissolution in the lung with subsequent breakage will therefore reduce activity	Longitudinally into finer fibres and fibrils; can split even in the lung, increasing the number of fibres
Biopersistence	Approximate half-life from days to months	Half-life of decades for amphibole asbestos, months for chrysotile
Solubility	Very much more soluble than all forms of asbestos	Amphilbole asbestos less soluble than chrysotile
Approximate diameter	1-10μm	<1μm
LWGM* diameters	1->6μm	<1 μm
*LWGM, length weighted geometric mean – a measure of diameter minimally biased by the method of preparing the sample for measurement; 50% of the total length of the fibre in a sample will be above (and 50% below) this diameter		

(Source: DETR Asbestos and MMMF in buildings – Reproduced under the terms of the Click-Use Licence)

Man-made mineral fibres are coarser than asbestos fibres and do not split longitudinally into fibrils. Most currently available products do not readily release airborne fibres. Some fibres are fine enough to be breathed in, but few will reach the deep lung and those that do will not persist as they are generally much more soluble than asbestos.

(Source: DETR Asbestos and MMMF in buildings – Reproduced under the terms of the Click-Use Licence)

2.4.2 Carbon fibres

Carbon fibres (or graphite fibres) are produced by high temperature processing of rayon, pitch or polyacrylonitrile. The fibres produced are typically between 5 and 15 micron in diameter. Carbon fibres are flexible, light, strong and corrosion resistant. They also have high abrasion and wear resistance. They are poor insulators as they are very good electrical and thermal conductors.

Carbon fibres are used mainly in advanced composite materials in aerospace, military and other industries to improve strength, durability or electrical conductivity.

2.4.3 Aramid fibres

Aramid fibres are produced by the reaction of aromatic diamines and aromatic diacid chlorides. Aramid fibres are generally between 12 and 15 microns in diameter. However, some aramid fibres can have fine, curled fibrils of respirable size (<1 micron diameter) attached to the surface of the main fibres. These fibrils may become detached and become airborne when abraded during manufacture or in use. Aramid fibres are very strong and flexible, and are resistant to heat, chemicals and abrasion.

Aramid fibres (e.g. Kevlar and Twaron) are used mainly in advanced composite materials in aerospace, military and other industries to improve strength and durability e.g. high temperature conveyor belts, protective clothing, gaskets, tyres and high strength cables.

2.4.4 Polyolefin fibres

Polyolefin fibres are long-chain polymers composed of ethylene, propylene or other olefin units. Polyethylene and polypropylene are widely produced and used commercially. Generally the diameters of polyolefin fibres are greater than 10 microns and as such fall outside the respirable size fraction. Polyolefin fibres are extremely hydrophobic and unreactive. However, their tensile strengths are much lower than those of carbon or aramid fibres and they melt at low temperatures (typically 100 – 200 ^{o}C)

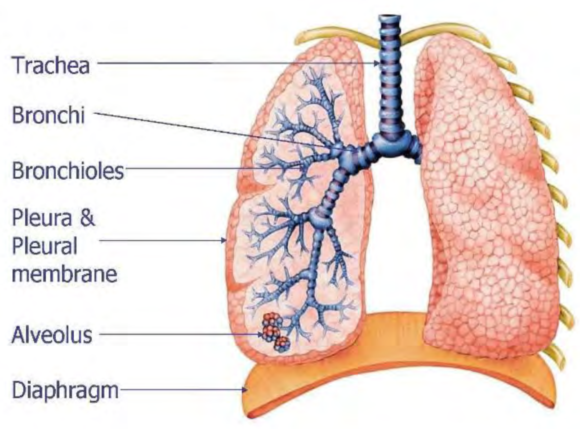
Polyolefin fibres are typically used in textile applications such as carpet backings, textiles and ropes.

3 HEALTH HAZARDS AND EXPOSURE LIMITS

3.1 HEALTH EFFECTS OF ASBESTOS

Recognised for their properties of flexibility, chemical resistance, and strength, asbestos fibres have been used worldwide in many types of industrial and commercial application. However, it is these characteristics, together with an ability to split into finer fibres, which make them a potentially deadly occupational hazard as, once inhaled, the same characteristics which make them useful to industry mean they are particularly resistant to the internal defence mechanisms of the body.

When disturbed, asbestos fibres split into increasingly finer fibres and are readily released into the air where they can remain airborne for long periods of time. During inhalation, asbestos fibres align with the air stream and can be carried directly into the various sections of the respiratory tract, depending on the fibre size.



(Source: Gully Howard Technical Ltd)

Figure 3.1 Structure of the lungs

According to Doll & Peto (1985), *"the hazard from airborne asbestos is greatest from fibres of between 5 and 100um in length (above which they cease to be respirable), with diameters less than 1.5 or 2um, and with aspect ratios (ratios of length to diameter) of more than 5 to one".*

"Fibre length seems to be the contributing factor in health issues and very short fibres may not be carcinogenic at all. There is no evidence however of a cut off point for width or diameter "

(Source: HSC Doll and Peto (1985) – Reproduced under the terms of the Click-Use Licence)

Large fibres (considered as greater than 3um in width), mainly deposit in the major airways of the respiratory system and are generally cleared by the cilia and mucous escalator mechanisms in the upper sections of the lungs. The smaller, respirable fibres are a greater cause for concern as they are capable of reaching the more sensitive sections of the 'deep lung' – the alveoli.

It is reported as far back as ancient times that asbestos fibres may cause health defects. The Greek geographer Strabo and the Roman naturalist Pliny the Elder both reported a 'sickness of the lungs' in the slaves that wove asbestos into cloth.

More information and knowledge surrounding the medical implications of asbestos exposure has accumulated slowly since the turn of the (20^{th}) century and it is now widely accepted that exposure to asbestos fibres can lead to a number of medical conditions and diseases.

The first documented case appeared in 1898, where a report was made by a factory inspector "on the adverse consequences of asbestos exposure" with reference to an individual who had been working for 12 years in a newly established textile factory in London, England.

Similar reports were subsequently undertaken over the next decade in other parts of the UK, Canada and Europe and the link between asbestos and lung disease was acknowledged by the British Medical Journal in a report published in the UK in 1927 which recognised the disease Pulmonary Asbestosis.

Exposure to dusty environments and fibrous materials, including glass wool and asbestos, has commonly led to skin irritation. Asbestos warts or corns are sometimes found on the skin of workers, caused when the fibres lodge in the skin and are overgrown causing benign callus-like growths. Any dusty environment can also lead to general eye, nose and throat irritation.

The three more serious, and better known diseases associated with asbestos exposure are Asbestosis, Lung Cancer and Mesothelioma.

3.1.1 Asbestosis

"The severity of asbestosis depends both on the amount of asbestos to which the individual has been exposed and the length of time since exposure first began" (Doll & Peto, 1985), commonly termed as a 'dose-response' or 'exposure-response relationship'. These relationships for asbestos were explored in the 1930's when both the United Kingdom and the United States of America conducted two major workforce based studies in textile workers. The findings of these reports went on to form the basis of the first 'Threshold Limit Values' and the first 'Control Regulations' in America and Great Britain.

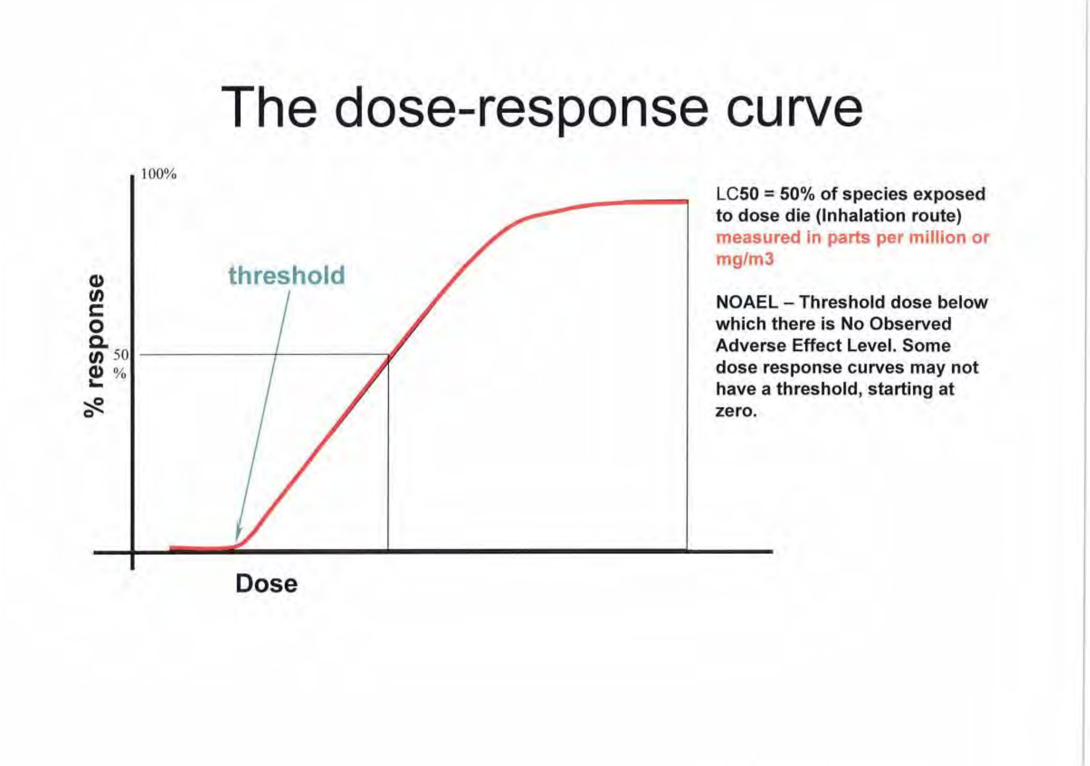
'Dose-response' and 'dose-response relationship' describe the effect on an organism caused by differing levels of exposure (or dose) to a stressor (usually a chemical). The dose-response curve is a crucial tool to understand the levels at which chemicals, drugs or pollutants begin to exert harmful effects and the degree of harm to be expected at various levels.

Data relating to the amount of drug or pollutant (in milligrams, micrograms or grams per kilo of body weight) can be plotted on a graph against the response of the organism in question. The resulting curve of the graph can then be used to show a number of points including:

- the 'no-effect range', where no effect is detectable because some biochemical or physiological mechanism, which may be considered a defence mechanism, handles the chemical in a manner that prevents an effect from occurring;

- the threshold-dose of the 'stressor', the point where the organism shows a response to the stressor (when the defense mechanism becomes saturated or overwhelmed);

- the points where the stressor will cause harmful or undesirable side effects.



(Source: BP International)

Figure 3.2 Typical dose-response curve

As the lungs become exposed to dust and debris through inhalation of contaminated air, the resident macrophages (a form of white blood cell) in the alveoli attempt to ingest or engulf these fine particles. Once the particle is ingested the macrophage aims to digest the debris by secreting enzymes and other chemicals.

This macrophage response is successful with the majority of debris particles but the unique size of hazardous asbestos fibres mean macrophages cannot ‘engulf’ and therefore digest the entire fibre. The damaged macrophage subsequently bursts and dies, releasing the partially digested particle along with the digestive enzymes and chemicals.

The chemicals released attract fibroblasts, the cells responsible for creating fibrous tissue and ‘wound healing’, and scar tissue is formed. The whole process is repeated as the body tries to remove the asbestos fibre from the lungs and results in permanent alteration and scarring of the alveoli.

As a result of the tissue scarring within the lungs, sufferers of asbestosis often experience shortness of breath, even during periods of rest depending on severity, persistent coughing, tiredness and nausea. The build up of scar tissue also interferes with oxygen uptake through the lungs and can lead to respiratory and heart failure.

Asbestosis can be caused by all forms of asbestos. It is however only associated with high levels of exposure for many years, unlike Lung Cancer and Mesothelioma.

3.1.2 Mesothelioma

'Mesothelium' is the term given to the membrane lining of several body cavities and internal organs. It is comprised of a single layer of 'mesothelial' cells whose main function is to produce lubricating fluids which facilitate movement of and provide protection for the organs and tissues.

Mesothelium is found lining the lungs and thoracic cavity (pleural mesothelium), the heart (pericardial mesothelium) and the abdomen (peritoneal mesothelium) as well as the reproductive organs.

Mesothelioma is a malignant tumour in which the mesothelial cells become abnormal and divide without control or order. These abnormal cells have the ability to migrate (metastasize) from the original tumour to other parts of the body. Epidemiological studies have frequently linked asbestos exposure to an excess incidence of mesothelioma.

Asbestos related mesothelioma most often first occurs in the pleural mesothelium and often spreads to the pericardium and peritoneum causing mesothelial tumours in these areas as well as spreading to other tissues.

Mesothelioma, (like asbestos related lung cancer) has a long latency period. Symptoms typically do not appear until between 20 and 30 years after exposure, extending up to 40 years in some cases.

Mesothelioma differs to asbestosis in that asbestosis appears to require a certain threshold of exposure before the ill-effect occurs. Studies to date have not been able to identify a level of asbestos exposure below which the mesothelioma risk is no greater than that of persons who have not been exposed to asbestos. Doll and Peto (1985) add that *"several studies have shown a qualitative relationship between risk and intensity of exposure".*

It has also been discovered that asbestos fibre type has an influence on mesothelioma development, as does the industry in which the asbestos material is being used.

Doll & Peto (1985) state that *"the four types of asbestos that have been used in industry to any material extent – all produce pulmonary fibrosis, cancer of the lung and mesotheliomas of the pleura and peritoneum in animal experiments".*

Further investigations, such as those by Hodgson and Darnton (The quantitative risks of mesothelioma and lung cancer in relation to asbestos exposure, 2000) have shown that the *"exposure specific risk of mesothelioma from the three principle commercial asbestos types is in a ratio of 1:100:500 for chrysotile, amosite and crocidolite respectively".*

Why crocidolite is more hazardous than chrysotile is not entirely clear. *It is probably because the curly fibres of chrysotile are more likely to become trapped in the upper airways of the respiratory tract and cleared by the body's initial defenses, not reaching the deep lung* (Doll & Peto (1985) and that the amphiboles are much more 'biopersistent' and resist the body's chemical attacks.

3.1.3 Lung cancer

Lung cancer, which can be considered as a malignant growth of abnormal cells in the lungs, is known to be triggered by a number of inhaled carcinogens, including asbestos.

As with mesothelioma, studies to date have not been able to identify a level of asbestos exposure below which the lung cancer risk is no greater than that of persons who have not been exposed to asbestos. Determining the risk of asbestos related lung cancer is further complicated by the much higher number of lung cancers attributable to smoking.

As with mesothelioma, there is a latent period after exposure before symptoms appear – this is typically at least 10 years and may be as much as 30 or 40 years. Similarly the chances of developing the disease are again increased with the intensity and duration of exposure.

One difference between mesothelioma and lung cancer is the ‘synergistic’ effect of asbestos exposure and tobacco smoking. Synergism is defined as when two factors are acting at the same time, the outcome is much greater than that which would be predicted by simply adding the effects of each factor acting alone.

The effect is shown in table 3.1 where in the absence of a synergistic effect the risk of developing lung cancer from asbestos and smoking might be expected to about 16 times higher (i.e. 11 + 5). In fact it is observed as 53 times higher (more than 3 times the expected effect if the two effects were acting independently).

Table 3.1 – Risks to health – Asbestos and lung cancer

Risk to Health			
Asbestos and lung cancer (Lung cancer and death rates per 100 000 person years)			
Asbestos Worker	Smoker	Death Rate	Mortality Rate
No	No	11.3	1
Yes	No	58.4	X5
No	Yes	122.8	X11
Yes	Yes	601.6	X53

(Source – HSE Asbestos Awareness Campaign – Reproduced under the terms of the Click-Use Licence)

Lee (2000) states that "*both asbestos and smoking act at different stages of the carcinogenic process"* and that the two combined can increase the chances of developing lung cancer.

3.1.4 Quantitative risks from asbestos exposure

3.1.4.1 Occupational exposure

It is difficult to quantify the risks from asbestos exposure and studies have shown considerable uncertainty. Hodgson and Darnton (2000) give the following best estimates of cancer risks from different levels of cumulative exposures together with highest and lowest arguable estimates:

For mesothelioma :

Cumulative exposures of 1 fibre / cm^3.years

Crocidolite 650 deaths per 100,000 exposed (highest 1500, lowest 250)

Amosite 90 deaths per 100,000 exposed (highest 300, lowest 15)

Chrysotile 5 deaths per 100,000 exposed (highest 20, lowest 1)

Cumulative exposures of 0.1 fibre / cm^3.years

Crocidolite 100 deaths per 100,000 exposed (highest 350, lowest 25)

Amosite 15 deaths per 100,000 exposed (highest 80, lowest 2)

Chrysotile Probably <1 death / 100,000 exposed (highest 4)

Cumulative exposures of 0.01 fibre / cm^3.years

Crocidolite	*20 deaths per 100,000 exposed (highest 100, lowest 2)*
Amosite	*3 deaths per 100,000 exposed (highest 20, lowest <1)*
Chrysotile	*Probably <1 death / 100,000 exposed (highest 1)*

Figures for lung cancer have also been produced – these generally are an order of magnitude lower than the figures (although the additional risk of the synergistic relationship with smoking should not be overlooked).

This study, together with several other studies, shows the wide range of estimates of possible risk. It is important to understand that currently it is not possible to accurately express the risk in quantitative terms.

There is also no information on the relative risk of high exposure over relatively short times versus mathematically equivalent exposures over longer times. Some regulatory systems impose a short term limit, but there is little scientific evidence to support one.

All these factors reinforce the principle that whatever exposure standard is used it does not represent a 'safe' level and exposure to any form of asbestos should be prevented or reduced to as low a level as is practicable.

3.1.4.2 Environmental exposure

Estimation of risk from environmental exposure in buildings is further complicated by the need for extrapolation to very low levels and the unreliability of measurement at these levels. Doll and Peto (1995) state that:

'Exposure to true asbestos fibres of regulated size within asbestos-containing buildings is seldom more than 0.0005 fibres/cm^3 above background. Exposure to this level for a working week in an office for 20 years in adult life or 10 years or so at school, or to lower average levels for more prolonged times at home is calculated to produce a life-time risk of death of one in 100,000. If 20% of the population experiences such exposure, this would imply that one death per year was caused by it in the whole country (the UK). This assumes that the exposure is to chrysotile. Exposure to crocidolite (and

possibly also to amosite) must be expected to produce effects that are appreciably greater.'

(Source: Doll and Peto (1985) – Reproduced under the terms of the Click-Use Licence)

3.1.5 Extent of asbestos related diseases

The extensive use of asbestos in the past, together with less stringent control procedures has led to a large number of people developing asbestos related diseases. The long latent period from exposure to asbestos to the development of a health effect means that in many countries deaths from asbestos related diseases are continuing to rise due to past exposures.

The US National Institute for Occupational Safety and Health estimates that approximately 8000 deaths per year in the United States are as a result of asbestos related diseases.

The UK Health and Safety Commission Health and Safety Statistics (2006) state that: '*In the UK the number of deaths from mesothelioma have increased from 153 in 1968, to 1969 deaths in 2004. Latest projections suggest that they will peak somewhere between current levels and 2450 deaths some time between 2011 and 2015*. *These mesothelioma deaths reflect industrial conditions of decades ago; deaths in men under 55 have been falling since the mid 1990's, suggesting better control more recently'.*

In the same publication it is also estimated that *'in 2004 approximately 2000 further deaths from lung cancer were attributable to asbestos, together with approximately 100 deaths from asbestosis'.*

(Source: HSC Health and Safety Statistics (2006) – Reproduced under the terms of the Click-Use Licence)

A similar pattern of numbers of mesothelioma deaths can be seen from Australia. The Australian Mesothelioma Register Report 2004 (NOHSC 2004) shows that the number of mesothelioma reports has risen from just over 200 per year in the mid to late 1980's to about 470 in 1999. The figures for the late 1990's appear to show a reasonably consistent number of new cases.

The report also states that there is no firm indication of when the incidence rates will start to decline in Australia.

3.2 CONTROL LIMITS ETC FOR ASBESTOS

3.2.1 Control Limits

Many countries have introduced permitted levels of exposure to airborne asbestos fibres. Since the available evidence does not allow any credible quantitative analysis of risk of asbestos exposure, especially at low levels, exposure limits do not represent a boundary between what is safe and unsafe. Regulatory limits represent a balance of scientific evidence and government policy as applied within the particular legal system applicable to each jurisdiction.

The US ACGIH Threshold Limit Value (TLV) for asbestos is 0.1 fibres per cm^3 averaged over an 8-hour reference period.

In the UK exposure must be kept below the asbestos control limit which is 0.1 asbestos fibres per cm^3 of air (averaged over 4 hours) for work with all types of asbestos including removal, repair or disturbance of asbestos and associated activities.

This replaces the previous distinction between the chrysotile (white asbestos) control limit of 0.3 fibres per cm^3 of air and the 0.2 fibres per cm^3 of air control limit for other forms of asbestos (including blue and brown asbestos). The reasoning behind this is that chrysotile asbestos (which is considered to be the less dangerous form) may be contaminated with other more dangerous forms of asbestos. There is also a peak exposure level of 0.6 fibres per cm^3 averaged over any 10-minute period.

The National Exposure Standard (NES) in force in Australia is also set at 0.1 fibres per cm^3 for all types of asbestos (averaged over an 8-hour) period.

3.2.2 Typical exposure levels for asbestos

Asbestos containing materials when disturbed can generate significant concentrations of airborne fibres. HSE Guidance Note HSG247 (2005) gives the following information on likely concentrations of fibres for various tasks.

Well controlled work with asbestos containing materials

	Fibre / cm^3
Controlled wet stripping of lagging using manual tools	*up to 1*
Careful removal of whole asbestos insulating board	*up to 3*
Drilling asbestos insulating board with shadow vacuuming	*up to 1*

Poorly controlled work with asbestos containing materials

	Fibre / cm^3
Stripping pipe/vessel lagging – partially wetted or dry areas	*up to 100*
Stripping spray coating – partially wetted or dry areas	*up to 1000*
Drilling asbestos insulating board without shadow vacuuming	*up to 10*
Power sawing asbestos insulating board	*up to 20*
Hand sawing asbestos insulating board	*5 – 10*

(Source: HSE Guidance Note HSG 247 (2005) – Reproduced under the terms of the Click-Use Licence)

These figures are only guides, but it should be noted that they are all much higher than the exposure limits in most countries. They show both the importance of good removal techniques to minimise fibre release and also the need to avoid disturbance of asbestos containing materials as even well controlled removal can generate significant fibre release.

As a comparison the following figures are taken from DETR Asbestos and MMMF in Buildings (1999).

Background (outdoor) concentrations	0.000001 – 0.0001 fibres/cm^3
Fibre levels in buildings where asbestos containing materials are in good condition	0.0005 fibres / cm^3
‘Clearance indicator’	0.01 fibres / cm^3

3.3 INHALATION STUDIES FOR OTHER FIBRES

As discussed at various points above, asbestos fibres can cause a wide variety of health effects, particularly centering on fibrosis and cancers of the lung and pleura. As replacements for asbestos have been sought and developed, concerns have been expressed with regard to possible health effects from these synthetic fibrous materials such as glass wool, rock wool, slag wool and refractory ceramic fibres.

It is a particular concern that the synthetic fibrous materials, which have been used as a replacement for asbestos, may produce similar effects to asbestos if of a comparable size. As a result, a large number of studies have been, and continue to be conducted to establish the health risks from these synthetic fibres.

Although synthetic vitreous fibres are not crystalline like asbestos and do not split longitudinally to form thinner fibres there is still a potential when disturbed for them to become airborne, inhaled and retained in the respiratory tract. It is a concern that this may cause them to *"produce similar effects to asbestos if of a comparable size"* (Davis, 1981)

A number of cross sectional studies have been carried out on populations working with fibrous glass materials *"through the administration of questionnaires, pulmonary function testing and chest x-ray examinations".* These studies however reported no consistent evidence for *"increased prevalence of adverse respiratory symptoms, abnormal pulmonary functions, or chest x-ray abnormalities"*.

(U.S Department of Health and Human Services, 2002)

A larger ongoing study in the United States between 1942 and 1992 which monitored 32,110 workers from 10 different fibreglass manufacturing plants also concurred that there was *"no consistent evidence of a relationship between synthetic vitreous fibre exposure and mortality from malignant or non-malignant respiratory disease but that a small overall excess risk for* *respiratory system cancer was found in both in both fibrous glass workers and rock wool/slag wool workers"* (U.S Department of Health and Human Services, 2002).

A similar European study supports this evidence with *"analysis of the lung cancer deaths of the workers in the European glass wool plants revealing that the risk was no different from that which would have been expected for other persons living in the same area"* (Lamm, 1994).

In addition to the studies carried out on humans, a number of animal experiments have also been conducted. The U.S Department of Health and Human Services (2002) explains that *"increased incidences of tissue scarring and tumours have been observed in studies of rodents exposed to glass wool, rock wool, or slag wool"* but only where glass fibres are directly implanted or injected into rodent tissues, and were *"not observed in studies of rodents exposed by inhalation"*

The U.S Department of Health and Human Services (2002) also explain that more recent studies on rodents report that some glass wool fibres, such as MMVF10a, dissolve more readily in the lungs and often cause only a mild form of reversible pulmonary inflammation without fibrosis whilst other, more biopersistent forms of synthetic fibre (e.g. MMVF33) are capable of causing mild pulmonary and pleural fibrosis and mesothelioma.

Hesterberg et al (1997) studied the effects on hamsters of inhalation of synthetic fibres and natural fibres averaging 15 – 20 μm in length and 0.5 - 1μm in diameter. The effects of exposure to one type of insulation glass caused non-specific pulmonary inflammation whilst the exposure to 'durable glass' and all asbestos doses were associated with lung fibrosis and possible mesotheliomas.

In conclusion, although the durable glass fibres caused lung changes, the associated pleural and pulmonary changes with the amosite asbestos were *"qualitatively and quantitatively more severe"* than those associated with glass fibre (Hesterberg et al, 1997).

Another investigation studied the effects of man-made vitreous fibres after chronic inhalation in rats. This study involved exposure of rats to respirable fibres of fibrous glass and refractory ceramic fibre. It was found that "*refractory ceramic fibre induced lung fibrosis and an elevation in lung tumours and pleural mesotheliomas"* whilst the fibrous glass resulted in *"no lung fibrosis, no statistically significant increase in the lung tumour incidence and no mesothelioma"* (Hesterberg et al, 1992).

Interestingly, following chemical analysis of the residual fibres, it was found that the fibrous glass had undergone changes in chemical composition, a possible indication of digestion by the body's defences, whilst the refractory ceramic fibre only showed slight changes indicating a greater biopersistence in the lung.

3.4 MAN-MADE MINERAL AND OTHER FIBRES

Synthetic vitreous fibres or 'Man-Made Mineral fibres' (MMMF) are a class of materials which include glass wool, continuous filament fibres, rock wool, slag wool and refractory ceramic fibres that have been used widely as thermal and sound insulation materials.

The U.S Department of Health and Human Services (USDHHS, 2002) describe how "*occupational exposure to synthetic vitreous fibres has been associated with acute irritation of the skin, eyes and upper respiratory tract*", particularly causing congestion of nasal passages, sore throat and coughing.

These symptoms are often only associated with very dusty workplaces such as removal of fibrous glass materials in enclosed spaces without respiratory protection. The symptoms generally disappear soon after ceasing exposure.

The International Agency for Research on Cancer (IARC) in 1988 had originally placed glass wool, rock wool, and slag wool into IARC Group 2B (possibly carcinogenic to humans) based on inadequate evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals. It also placed continuous filament glass into Group 3 (not classifiable as to carcinogenicity to humans based on inadequate carcinogenicity in human studies and experimental animals.

A review was conducted in 2001 however due to new research and evidence. This now places rock wool, insulation glass wool, slag wool and continuous filament glass into Group 3 “because of inadequate evidence of carcinogenicity in humans” along with their relatively low biopersistence, whereas refractory ceramic fibres and some special purpose glass wools (not used in insulation materials) have been placed in Group 2B due to their seemingly high biopersistence.

Carbon fibres are generally too large to reach the alveoli and they tend to deposit further up the respiratory system. There is limited information available on any fibrogenic or carcinogenic potential from carbon fibres.

Aramid fibrils have been shown to cause some fibrosis in inhalation studies on rats; however, the likelihood of causing cancer has not been confirmed.

3.5 EXPOSURE LIMITS FOR MAN MADE MINERAL FIBRES

Based on the above information from the International Agency for Research on Cancer and evidence from health studies, recommendations have subsequently been made to set occupational exposure limits for man made mineral fibres.

In the UK the HSE Guidance Note EH46 Man-made mineral fibres (HSE 1990) draws attention to the potential health risks of man-made mineral fibres and precautions which may be needed for anyone working or involved with them. The Workplace Exposure Limit (WEL), the level under which exposure to man-made mineral fibres should always be reduced is defined in HSE EH40 Workplace Exposure Limits (2005) in two ways, one as a gravimetric limit (total inhalable dust) and the other as an airborne fibre limit, both being 8-hour time weighted averages.

The limits are described in this way *"because different forms of man-made mineral fibres and different processes produce very different kinds of airborne dust. There is no fixed relationship between gravimetric and fibre count measurements. Some activities (and products) produce mostly coarse material and the concentration of fibres in the countable range will be relatively low. A gravimetric limit is appropriate in those cases. Others produce more respirable fibres with little coarse material and a fibre limit count becomes the appropriate one"*

The same publication also states that: *'For mineral wools it may normally be assumed that the gravimetric limit will be reached before the fibre count limit, and only gravimetric measurements will be needed; the same is true of almost all ceramic fibre processes. For special purpose or superfine fibres the fibre limit count will normally be reached first'.*

(Source: HSE Guidance Note EH46 (1990) – Reproduced under the terms of the Click-Use Licence)

The UK Workplace Exposure Limits are currently a gravimetric limit of 5mg / m^3 and an airborne fibre limit of 2 fibre / cm^3 whilst refractory ceramic fibres and special purpose fibres are 5mg / m^3 and 1 fibre/ cm^3 (HSE EH40 / 2005 Workplace Exposure limits)

In the U.S. the most recent recommendations (2007) come from the American Conference of Governmental Industrial Hygienists, who have adopted Threshold Limit Values – Time Weighted Averages. These stand at 1 fibre / cm^3 for continuous filament glass fibres, glass wool, rock wool slag wool and special purpose fibres whilst a TLV-TWA of 0.2 fibres / cm^3 has been assigned to refractory ceramic fibres

3.6 TYPICAL EXPOSURES TO MAN MADE MINERAL FIBRES

Man made mineral fibre products are used in a wide variety of applications, particularly as insulating materials in buildings. Airborne fibre concentrations during the installation of insulation vary depending on how confined the work area is, as well as the duration and type of work.

Exposure to airborne fibres is usually well controlled during the manufacture of man-made mineral fibre products. However, non-manufacturing activities such as insulation, construction and removal activities can generate fibre levels in excess of the exposure limits. Some examples of typical exposure levels are given below

Table 3.2 – Typical exposure levels to man-made mineral fibres

	Expressed as fibres/cm^3	Expressed as mg/m^3
Application of pre-formed mineral wool sections to piping	Less than 0.5	Less than 5
Application of pre-formed mineral wool slabs to boilers and ducting	Less than 0.5	Less than 5
Installation of ceramic fibre furnace lining and pipe lagging	1 – 5	5 – 20
Cutting mineral wool products without dust suppressants	2 – 4	10 – 20
Pre-formed sections removed intact	Less than 5	Less than 20
Furnace wrecking	0.5 – 10	5 – 10

(Source: HSE Guidance Note EH46 (1990) – Reproduced under the terms of the Click-Use Licence)

Furnace wrecking and demolition work involving man-made mineral fibres may present particular problems with some refractory ceramic fibre products where these products have been heated to temperatures in excess of about 1000^{o}C. At these temperatures these materials can undergo partial conversion to cristobalite (a crystalline form of silica that is hazardous by inhalation).

3.7 APPROACHES TO ELIMINATING ASBESTOS RELATED DISEASES

3.7.1 World Health Organisation

The World Health Assembly Resolution 58.22 in 2005 urged Member States to pay special attention to cancers for which avoidable exposure is a factor. It also recognised that special attention should be paid to the elimination of asbestos-related diseases.

The World Health Organisation – Environmental Health Criteria 203 (1998) states that: *"Exposure to asbestos occurs through inhalation of fibres primarily from contaminated air in the working environment, as well as from ambient air in the vicinity of point sources, or indoor air in housing and buildings containing friable asbestos materials. The highest levels of exposure occur during repackaging of asbestos containers, mixing with other raw materials and dry cutting of asbestos-containing products with abrasive tools. Exposure can also occur during installation and use of asbestos-containing products and maintenance of vehicles. Friable chrysotile and/or amphibole containing materials are still in place in many buildings and continue to give rise to exposure during maintenance, alteration, removal and demolition".*

(Source: WHO Environmental Health Criteria 203 (1998) – reproduced with permission)

The World Health Organisation – Elimination of asbestos related diseases document (2006) states that: *"Currently about 125 million people in the world are exposed to asbestos in the workplace. According to global estimates at least 90,000 people die each year from asbestos-related lung cancer, mesothelioma and asbestosis resulting from occupational exposures".*

It also states: *"Chrysotile asbestos is still widely used, with approximately 90% being employed in asbestos-cement building materials, the largest users of which are the developing countries. Other remaining uses of chrysotile are friction materials (7%), and textiles and other applications.*

To date, more than 40 countries, including all member states of the European Union, have banned the use of all forms of asbestos, including chrysotile. Other countries have introduced less stringent restrictions. However, some countries have maintained or even increased their production or use of asbestos in recent years. World production of asbestos in the period 2000-2005 has been relatively stable, at between 2,050,000 and 2,400,000 metric tonnes per annum".

(Source: WHO Elimination of asbestos related diseases 2006 – reproduced with permission)

The World Health Organisation has adopted a range of guidelines and recommendations on prevention of asbestos-related diseases. These are summarised below:

- The most efficient way to eliminate asbestos-related diseases is to stop using all types of asbestos
- Continued use of asbestos cement in the construction industry is a particular concern because
    - the workforce is large
    - it is difficult to control exposure
    - in-place materials can deteriorate and pose a risk to those undertaking alterations, maintenance and demolition
- Asbestos can be replaced by other fibre materials and by other products that pose less risk
- Materials containing asbestos should be encapsulated
- Generally, work should not be undertaken that is likely to disturb asbestos fibres
- If necessary such work should only be undertaken with strict precautions to avoid exposure to asbestos such as
    - Encapsulation
    - Wet processes
    - Local exhaust ventilation with filtration
    - Regular cleaning
    - Personal protective equipment
    - Decontamination facilities

3.7.2 Typical Legislative Approach (UK)

As the previous sections have documented, the health risks from inhalation of asbestos fibres have become clearer over the past few decades. It is now widely accepted that exposure to all forms of asbestos should be reduced or prevented.

As awareness of the risks increased many countries have introduced legislation to attempt to reduce or eliminate asbestos related diseases. In many cases this legislation has been introduced progressively with the higher risk materials and processes being banned or restricted first followed later by further legislation.

The history of asbestos legislation in the UK illustrates this principle.

1931	Asbestos Industry Regulations introduced addressing concerns that asbestos exposure particularly among textile workers led to lung damage
1969	Control of Asbestos at Work Regulations aimed to control levels of exposure to asbestos in some workplaces
1983	Asbestos (Licensing) Regulations required contractors working with asbestos insulation and spray coating to be licensed by the HSE
1985	Asbestos (Prohibition) Regulations banned import and use of crocidolite and amosite
1987	Control of Asbestos at Work Regulations introduced statutory requirements to control exposure to asbestos in the workplace
1992	Asbestos (Prohibition) Regulations banned some uses of chrysotile
1998	Asbestos (Licensing) Regulations amended to include work with asbestos insulation board
1999	Asbestos (Prohibition) Regulations banned import and use of chrysotile

2002	Control of Asbestos at Work Regulations introduced a duty to identify and manage all asbestos containing materials in the workplace
2006	Control of Asbestos Regulations introduced to combine all of the above into a single comprehensive document

As stated earlier the above approach progressively phased out the use of asbestos in the UK. However, large quantities of asbestos products remain in place and the emphasis is now on how these materials can be managed safely.

Groups at risk from exposure to asbestos include those working with asbestos containing materials, such as asbestos removal workers, and those who may inadvertently disturb asbestos containing materials.

Work with asbestos containing materials falls into two categories in the UK. The types of work more liable to produce high exposures (e.g. work with asbestos insulation, asbestos coatings and asbestos insulation boards) require the use of licensed asbestos removal contractors. It also requires more stringent controls such as use of enclosures, wet-stripping methods, air extraction systems, full decontamination facilities and independent inspection and verification of the work.

Work on lower risk materials such as asbestos cement and floor tiles etc still needs to be undertaken in such a way that fibre release is minimised but does not require the use of specialist licensed contractors.

In either case, the employer is responsible for ensuring that any work with asbestos is undertaken in such a way that risks to his employees and anybody else that may be affected by the work are reduced.

Another large group of people who may be affected by exposure to asbestos are maintenance and building workers such as plumbers, electricians, builders, demolition workers, telephone and computer cable installers etc. The UK Health and Safety Executive consider this group to be those most at risk from exposure to asbestos due to the possibility of inadvertent disturbance of existing asbestos containing materials.

To minimise the possibility of them disturbing the asbestos containing materials in the course of their work, systems must be in place to identify and document where asbestos containing materials are present in the workplace. As part of this a risk assessment must be undertaken to identify the potential of the asbestos containing materials to release fibres and the likelihood that the material will be disturbed. Depending on this a decision can be taken with regard to the most appropriate way of dealing with the asbestos i.e. removal, encapsulation, repair or manage.

Whatever the situation the over-riding requirement is to prevent or reduce the risk of exposure to asbestos to both workers and others who might be affected e.g. other workers, visitors, members of the public etc.

4. PERSONAL PROTECTIVE EQUIPMENT FOR WORKING WITH ASBESTOS

4.1 RESPIRATORY PROTECTION

4.1.1 Use of respiratory protection

Exposure to asbestos should be prevented or reduced as far as reasonably practicable. However processes, such as asbestos removal by their nature, can disturb and release asbestos fibres. Uncontrolled or poorly controlled asbestos removal can easily result in airborne asbestos fibre levels in excess of 10 fibres / cm^3 for removal of asbestos insulating board or even in excess of 100 fibres / cm^3 for removal of asbestos spray coating or lagging.

The level of asbestos fibre release should be controlled by good work practices and use of engineering controls such as enclosure and air extraction of the work area, wet removal, glove-bag and shadow vacuuming techniques. Emphasis must be put on work methods that prevent or reduce the potential for fibre release. However, for some work, the potential for significant fibre release remains and even if controls are in place airborne fibres levels may still exceed recognised standards. In these situations, effective respiratory protection should be provided and worn correctly.

The main reason for use of respiratory protection is as an additional layer of protection; either to provide additional assurance in the event another control fails or simply to further reduce exposure (and risk) even in the presence of all the other controls. It is important to re-emphasise that asbestos fibre concentrations should be reduced to a minimum before using respiratory protection as it can only reduce exposure, not stop it.

4.1.2 Types of respiratory protection

Whatever type of respiratory protection is chosen it should be:

- Adequate i.e. capable of providing the wearer with effective protection
- Suitable i.e. matched to the wearer, task and the environment
- Correctly used
- Properly stored, maintained, examined and tested

- Of appropriate standard e.g. 'CE' or 'NIOSH/MSHA' marked – i.e. meeting minimum standards of design and manufacture by conforming to a relevant standard

Figure 4.1a - Full face piece air purifying mask
(Source: Gully Howard Technical Ltd)

Figure 4.1b - Ori-nasal half mask
(Source: Gully Howard Technical Ltd)

Figure 4.1c - Filtering face piece
(Source: Gully Howard Technical Ltd)

Figure 4.1 – Examples of respiratory protection

The respiratory protection should be carefully chosen in consultation with the workers who are to use it. The type of respiratory protection chosen will need to take into account the type of work to be done, the expected airborne fibre concentrations, the working environment, the wearer and the need for any other personal protective equipment.

The expected exposure level is the start point in the selection process as this will determine the minimum protection required by the respiratory protection. It is often the case that it would not be known in advance what the actual airborne fibre level will be. An order of magnitude estimate is often made based on previous experience or air monitoring. The respiratory protection with the highest assigned protection factor should be considered first and then the other work and wearer related factors considered to determine the most suitable type.

The following table gives examples of assigned protection factors (the level of protection likely to be achieved when used and worn correctly) for a range of respiratory protection.

Table 4.1 - assigned protection factors for various types of respirators

Respirator type and class	HSE (UK)	OSHA (US)	NIOSH (US)
Air purifying			
Filtering facepiece	10 (P2 filter) 20 (P3 filter)	10	10
Half mask	20	10	10
Full facepiece mask	40	50	50
Powered air purifying			
Full facepiece mask	40	250	50
Hood / helmet	40	25	25
Supplied air (air line)			
Full facepiece demand	40	50	50
Full facepiece positive pressure	2,000	1,000	2,000
Self contained breathing apparatus			
Positive pressure	2,000	> 1,000	10,000

The above table shows the variation in assigned protection factors between different countries and organisations. This adds to the difficulty of ensuring adequate protection by use of respiratory protection and is another supporting reason for controlling exposure by preventing or reducing fibre release.

The uncertainty in the expected fibre levels mean that it is sometimes difficult to choose between respiratory protection that offers assigned protection factors of, for example, 10, 20 or 40. Air monitoring to determine actual exposure levels is useful to verify that the respiratory protection did indeed provide adequate protection. In addition, it provides more information for future assessments.

NOHSC Code of Practice for the safe removal of asbestos (2005) gives the following guidance on the minimum level of respiratory protection that should be selected for different tasks, assuming that correct work procedures are being followed.

Table 4.2 – Minimum level of respiratory protection

Work procedure	Required respirator	Filter type
Simple enclosure erection – no direct handling of undamaged asbestos materials, but disturbance possible	Disposable half-mask respirator or filtering half-mask respirator	P1 or P2
Sampling material for the purpose of identifying asbestos	Disposable half-mask respirator or filtering half-mask respirator	P1 or P2
Work with asbestos cement products	Disposable half-mask respirator or filtering half-mask respirator	P1 or P2
Extensive sample operations on friable asbestos	Full-face particulate filter respirator	P3
Removal of friable asbestos products that have been effectively wetted	Full-face powered respirator, or full-face positive pressure demand air-line respirator	P3
Dry stripping in confined areas	Full suit or hood, positive pressure demand continuous flow air-line respirator (NO LESSER RESPIRATOR WILL SUFFICE)	P3

(Source: NOHSC Code of practice for safe removal of asbestos (2005) - reproduced with permission)

4.1.3 Face mask fit testing

The performance of tight-fitting face masks depends on achieving a good seal between the wearer's skin and the face seal of the mask. As people's faces have a range of shapes and sizes no one particular type, or size of face mask will fit everyone. Inadequate fit will significantly reduce the protection provided to the wearer. To make sure that the selected face mask can provide adequate protection to the wearer, a fit test should be carried out. The fit test should be carried out as part of the initial selection of the respiratory protection

(Source: HSE Guidance Note HSG247 (2005) – Reproduced under the terms of the Click-Use Licence)

A qualitative fit test based on the wearer's subjective assessment of the leakage of a bitter or sweet tasting aerosol through the face seal can be used for disposable or half-mask respirators. This method is not suitable for fit testing full-face masks because it doesn’t provide sufficient sensitivity to measure the greater protection factors expected.

The method for fit testing full face masks (and the preferred method for fit testing half-masks) is a quantitative method that gives an objective measure of face fit. The most common method uses a particle counting device to measure the difference between the concentrations of particles within the mask relative to outside the mask under specified test conditions.

As with all tests, it is important that it is undertaken in accordance with documented and validated protocols. Similarly, the person undertaking the test must be competent to do so.

The fit test should be repeated whenever the wearer:

- Changes to a different model or size of respiratory protection
- Undergoes any substantial dental work or develops and facial changes (e.g. scars) around the face seal area
- Significantly gains or loses weight

Respirator users need to be aware of the above factors so that they will know when their fit test may no longer be valid. In addition the fit test should be repeated at suitable intervals. The frequency of these repeat tests should be determined by a risk based approach, with high risk materials such as asbestos, requiring repeat fit testing every year, with perhaps lower risk materials requiring repeat testing at two year intervals.

An additional benefit of quantitative fit testing is that it reinforces the need for correct fitting of the respiratory protection, as inadequate fitting is rapidly shown during the test. Annual repeat fit testing also has the benefit of being a ‘refresher training’ in the correct use and fitting of respiratory protection.

To obtain adequate performance during use, the selected respiratory protection should be worn correctly every time. Therefore the wearer should undertake a fit check before each use. Beards or even stubble will affect the face seal of masks that rely on a close contact between face and mask.

Therefore, people who wear respiratory protection relying on a tight face fit need to be clean shaven. In addition, other items that can affect the seal between the face and the respiratory protection and potentially compromise the protection includes hair, jewellery, eye glass frames etc.

A person's ability to wear respiratory protection not only depends on the adequacy of face-fit but also on other factors such as their health status. There are a number of medical conditions such as asthma, emphysema, chronic airways disease or skin sensitivity that prevent a worker from using respiratory protection. Some workers feel claustrophobic wearing a normal filter respirator; in these cases a powered air purifying respirator may be more acceptable.

Protection factors obtained on face-fit testing are sometimes much higher than the assigned protection factors for that type of respiratory protection. However, these higher values should not be used when selecting respiratory protection.

4.2 PERSONAL PROTECTIVE CLOTHING

Protective clothing should be made from materials which provide adequate protection against fibre penetration. Coveralls should be worn whenever a risk assessment indicates there is a possibility of contamination with asbestos fibres. Coveralls should not have external pockets or velcro fastenings because these are easily contaminated and difficult to decontaminate. Disposable coveralls are preferred. They should not be reused, and should be disposed of as asbestos waste.

(Source: Gully Howard Technical Ltd)

Figure 4.2 Disposable coveralls and full-face respiratory protection

The coveralls should have hoods and elasticated cuffs or be sealed with tape. The coverall should be worn over the footwear to prevent dust or debris entering the top of the boot. It is also important that the hood is worn over the straps of the respiratory protection.

Special attention should be paid to the risks of heat stress from working in hot environments. A competent person should determine the most suitable protective clothing and decontamination procedures for workers in these situations. It should be noted that there may be heat related concerns for those wearing protective clothing, even in moderate thermal environments, especially if the work is strenuous.

The use of protective gloves should be determined by risk assessment. If significant quantities of asbestos fibres may be present, disposable gloves should be worn. Protective gloves can be unsuitable, however, if dexterity is required. All gloves used for asbestos removal work should be disposed of as asbestos waste.

Appropriate safety footwear (i.e. steel-capped rubber-soled work shoes or boots) should be provided for all asbestos removal workers. This footwear should be laceless, because laces and eyelets are easily contaminated, and should remain inside the asbestos work area or dirty decontamination area for the duration of the asbestos removal work.

Safety footwear should be decontaminated at the end of the job and upon leaving the work area, or sealed in double bags for use on the next asbestos removal site (but not for any other type of work).

Whenever the use of protective clothing is required, it is important to consider where and how the workers will change and decontaminate themselves. If this is not undertaken correctly there is a possibility that asbestos contamination could be spread over a wide area.

5. ASBESTOS IN BUILDINGS AND SURVEYS

5.1 TYPES AND USES OF ASBESTOS IN BUILDINGS

5.1.1 Introduction

The properties of asbestos have led to its use in a wide range of industrial applications. Of the six forms of asbestos described earlier, only three forms have been widely used – chrysotile, amosite and crocidolite. About 90% of the asbestos that has been mined and used historically was chrysotile.

In the peak period of asbestos consumption in industrialized countries, over 3000 applications, or types of products, have been listed.

Due to the known health effects many countries have prohibited the continued use of asbestos in new products, with some exemptions for specialist uses. However, even in these countries, the widespread use of asbestos in the past has led to large quantities of asbestos products remaining in-situ in buildings, equipment and plant.

For example, *it is estimated that there are around 6 million tonnes of asbestos remaining in buildings throughout the UK, and that a large majority of all commercial and industrial buildings contain asbestos in one form or another.*
RICS. Asbestos and its implications for members and their clients (2003)

While many countries have banned new installation of asbestos containing products, this is by no means universal and asbestos containing materials are still being applied in many other countries. In these countries, the presence of asbestos containing materials in buildings, products and installations could be even more widespread and less predictable. Many asbestos containing products may be present without any indication (such as labelling etc) of asbestos being in place.

It should also be noted that even in countries where new installation of asbestos containing products has been banned; there is no general requirement to remove existing asbestos or asbestos containing materials. If asbestos containing materials are in good condition and unlikely to be disturbed they can be left in place and managed.

5.1.2 Applications of asbestos

As stated before it is the wide range of useful properties of asbestos fibres that have led to their exploitation in many industrial applications. These properties include their thermal, electrical and sound insulation; their non-flammability; their ability as a reinforcing material (cement, plastics and resins) and chemical inertness (except in acids).

The following table summarises those materials commonly found in buildings.

Table 5.1 – Asbestos containing materials commonly found in buildings

Product	**Use**	**Approximate % asbestos**
Spray coating	Structural fire protection, acoustic insulation, anti-condensation insulation	55 – 85%
Thermal insulation (lagging)	Thermal insulation of pipes, boilers, calorifiers etc	6 – 85%
Asbestos ‘millboard’	Fire, heat and electrical protection	40% and up
Asbestos insulating board	Fire protection, wall partitions, infill panels, ceiling tiles and panels	15 – 40%
Paper and felt	Electrical and heat protection of electrical equipment Reinforcement and lining of other products	100%
Ropes and cloth	Thermal insulation of pipes Jointing and packing materials Fire resisting blankets, curtains, clothing etc	100%
Gaskets and washers	Gaskets in boilers, pipework etc	90%
Friction products	Brake and clutch pads in machinery	30 – 70%
Cement products	Roofs, rain-water goods, wall cladding, ceiling panels, worktops, window sills, fascias, water tanks etc	10 – 15%
Textured coatings	Decorative surface coating to ceilings and walls	Up to 3%
Bitumen products	Roofing felt, damp-proof courses etc	8%
Flooring	Thermoplastic floor tiles	7 – 25%
Reinforced plastic and resin composites	Toilet cisterns, window sills, worktops	1 – 10%

A more detailed list is in HSG 264 “Asbestos: The Survey Guide” issued by the UK Health and Safety Executive. (This information is reproduced in Appendix 1). It contains information on product types, typical locations, uses, asbestos content and product names. It also gives information on dates when these materials were last used in the UK. While these dates are specific to the UK, they give an indication of how asbestos products have been progressively phased out over a number of years.

This is typical of the situation in many countries with the most hazardous types of asbestos and products being phased out first and lower risk materials being phased out at a later date. In the UK use of amphibole asbestos was prohibited in 1986 and with a few minor exemptions the use of chrysotile was prohibited in 1999. A similar approach was adopted in Australia with amphibole asbestos banned in 1994 and use of chrysotile prohibited in 2003. Currently (2007) while use of amphibole asbestos has been prohibited in the United States for many years, a ban on the use of chrysotile is still being debated in the legislature.

Banning has occurred mainly in developed countries where substitute materials or alternative products are readily available and it is economically feasible to use asbestos substitutes. In lesser-developed countries where economics and the level of industrial development is a factor, asbestos substitutes are not yet considered to be an option in many cases.

The following figures 5.1 - 5.10 are examples of asbestos containing materials.

(Source: Gully Howard Technical Ltd)

Figure 5.1 Spray coating to support girders and ceiling

(Source: Gully Howard Technical Ltd)

Figure 5.2 Insulation (lagging) to pipework and calorifiers

(Source: Gully Howard Technical Ltd)

Figure 5.3 Asbestos insulating board ceiling tiles

(Source: Gully Howard Technical Ltd)

Figure 5.4 Asbestos insulating board internal wall panels

(Source: Gully Howard Technical Ltd)

Figure 5.5 Asbestos insulating board wall lining panels

(Source: Gully Howard Technical Ltd)

Figure 5.6 Asbestos insulating board lining panels and asbestos cement flue pipe

(Source: Gully Howard Technical Ltd)

Figure 5.7 Asbestos cement external wall panels

(Source: Gully Howard Technical Ltd)

Figure 5.8 Asbestos cement corrugated roof panels

(Source: Gully Howard Technical Ltd)

Figure 5.9 Asbestos rope seal to oven door

(Source: Gully Howard Technical Ltd)

Figure 5.10 Asbestos based textured decorative coating to ceiling

5.2 SURVEYS OF ASBESTOS CONTAINING MATERIALS IN BUILDINGS

5.2.1 Introduction to surveys

Asbestos has been used in a wide variety of applications and products that have been installed extensively in industrial, commercial and residential premises.

Even in those countries where new installation of asbestos has been prohibited for a number of years large quantities of asbestos containing materials (ACMs) remain in-situ. In order to adequately control the risk from these materials it is important that an adequate management system is in place.

The risks from the asbestos containing materials will vary depending on the circumstances at the time. The risks during normal occupation of the building will be very different from the risks during major building works or demolition.

A fundamental part of the management of asbestos containing materials is that the presence and location of these materials needs to be known. In addition to identifying the locations of the asbestos containing materials it is important that information on the condition of the material is obtained together with an assessment of the accessibility of the material. In most cases this will mean that a survey of the whole site including plant, equipment and buildings will need to be undertaken.

HSE Guidance Note HSG 264 (2010) states that: *'in most cases the survey will have three main aims:*

- *it must as far as reasonably practicable locate and record the location, extent and product type of any presumed or known asbestos containing materials;*
- *it must inspect and record information on the accessibility, condition and surface treatment of any presumed or known asbestos containing materials;*

- *it should determine and record the asbestos type, either by collecting representative samples of suspect materials for laboratory identification, or by making a presumption based on the product type and its appearance etc.'*

(Source: HSE Guidance Note HSG 264 (2010) – Reproduced under the terms of the Click-Use Licence)

It is important that anyone undertaking these surveys should be appropriately qualified and trained. In the US asbestos surveyors are required to meet specific training requirements and typically have to be licensed. Recognised training schemes are also in place in the UK. Whoever undertakes the survey should also have in place documented procedures for undertaking and recording the survey together with suitable quality assurance procedures.

One way in which organisations undertaking the survey can demonstrate an adequate quality system is by ensuring that the survey is undertaken in accordance with the requirements of ISO 17020 – 'General criteria for the operation of various types of bodies performing inspection'. Accreditation to this standard is available in many countries through their National bodies (e.g. UKAS in the UK and NATA in Australia).

5.2.2 Types of asbestos surveys

Historically, there has not been an agreed protocol for conducting surveys for asbestos containing materials or for interpreting and reporting the findings. There is therefore often considerable variation in the level of survey and form of documentation provided by `asbestos inspectors'. This is particularly the case with surveys undertaken a number of years ago.

This was recognized in the UK and in 2001 the Health and Safety Executive (HSE) published guidance in the form of MDHS 100, entitled Surveying, sampling and assessment of asbestos-containing material. This attempted to clarify the different requirements and types of surveys that may be undertaken.

MDHS 100 Surveying, sampling and assessment of asbestos-containing materials referred to three types of `survey':

Type 1: Location and assessment survey ('Presumptive survey');

No samples taken - all materials that could be asbestos-based are presumed to contain asbestos and should be risk assessed and managed as such. It requires the lowest initial time and cost commitment and avoids the need to disturb the asbestos containing material. However, it may lead to non-asbestos products being managed as asbestos with consequent additional costs and disruption.

Type 2: Standard sampling, identification and assessment survey ('Sampling survey');

Representative samples taken and analysed to confirm the presence of asbestos in any suspect materials. This means that precautions need to be in place to prevent release of asbestos fibres during sampling, but it has the advantage that it enables only asbestos containing materials to be risk assessed and managed

In reality, both Type 1 and Type 2 surveys were undertaken to provide information to enable the continued safe management of asbestos on the site.

Type 3: Full access sampling and identification survey ('Pre-demolition/ major refurbishment survey').

The purpose of this survey is to locate all asbestos containing material in the plant, equipment and buildings and may involve destructive inspection of all areas. As the purpose is to enable a specification for removal work to be prepared, risk assessment of the asbestos containing material is not required.

The publication of MDHS 100 undoubtedly improved the overall quality and consistency of asbestos surveys undertaken in the UK. However, the Health and Safety Executive were still concerned about a number of areas including:

- Survey quality
- Report usability and suitability
- Surveyor competency
- What areas were considered reasonably accessible
- Extent of investigation in Type 3 surveys

As a result of these concerns HSG 264 (2010) Asbestos: The Survey Guide was produced. This publication replaced MDHS 100 and introduced two types of surveys – 'Management surveys' and 'Refurbishment and demolition surveys'. These terms were thought to be more descriptive of the purpose of these types of surveys.

Management survey (HSG 264)

The purpose of a management survey is to locate, as far as reasonably practicable, any materials suspected of containing asbestos, and to assess their condition. This usually involves sampling and analysis of materials to confirm the presence or absence of asbestos.

In general, management surveys should inspect all reasonably accessible areas, including ceiling voids, ducts, inside risers and lift shafts etc. It is very important to realise that with a Management Survey there is a limit to how intrusive the survey can be (e.g. it may not be practicable or acceptable for all ducts or ceiling voids to be fully accessed as this may cause considerable disruption and damage to the plant or building).

One of the major changes between MDHS 100 and HSG 264 is that the new publication includes much clearer guidance on areas that would normally be considered reasonably accessible. As a general principle, the expectation is that the onus is now very much on the surveyor to access as far as reasonably practicable all areas, and in those situations where this is not achieved, the reasons for this are documented.

Good survey planning and liaison with the building owner should ensure that the number of 'inaccessible' areas is minimised. Any areas / locations not accessed must be presumed to contain asbestos and clearly identified on the report.

Refurbishment and Demolition Surveys (HSG 264)

This type of survey is required where major refurbishment, replacement or demolition is contemplated, and it is therefore reasonable and essential to provide full access to all areas, involving destructive inspection as necessary.

As refurbishment and demolition surveys will usually require destructive inspection and this will normally require the area or building being investigated to be unoccupied. In some situations construction of temporary enclosures to access some areas may be required.

There is still the possibility that some asbestos may remain concealed within the structure, and will not be revealed until the works are under way. In such cases, the survey should be carried out in stages. In any event, emergency plans and arrangements should be in place to deal with any subsequent unexpected discovery of asbestos containing materials.

When surveying a site it is possible that the survey may include a mixture of the different types of survey described above. For example, in a hospital most areas could be inspected as a Management Survey with samples taken. However, materials in areas such as operating theatres and intensive care areas may not be sampled (and therefore are presumed to be asbestos) to minimize damage in these areas. Also if some areas are identified that are about to be demolished or undergo major refurbishment then a Refurbishment and Demolition Survey in these areas may be undertaken.

United States Environmental Protection Agency

The United States Environmental Protection Agency also has extensive guides covering all aspects of asbestos surveys such as ASTM E2356 – ‘Standard Practice for Comprehensive Building Asbestos Surveys. This document discusses two types of surveys: Baseline Surveys and Project

Design Surveys.

For each of these two types of survey the document discusses the following activities

- Planning the survey to meet defined objectives
- Obtaining and reviewing information on the building or facility including previous surveys and response actions
- Conducting the physical activities of inspecting the premises and collecting bulk samples of suspect materials
- Analyzing the bulk samples for asbestos type and content
- Assessing the current condition and potential for disturbance of asbestos-containing materials and
- Preparing a report that includes a narrative discussion of the findings, tabulations of inspection, sampling and analysis results, graphical depiction of the areas inspected, and the results of the assessment.

Whatever guidance is available in specific countries; there are a number of principles that are applicable in all situations. For example, the scope and nature of a survey will vary according to the purpose for which it is required. The information may be needed in connection with specific activities, such as a proposed refurbishment or demolition. It may apply to the whole or only part of a site, installation or building, or to the production of a plan to manage asbestos throughout the site.

As a general principle the aim of any asbestos survey is, as far as is reasonably practicable, to locate and report on all of the asbestos containing materials present, so that the risks can be assessed and managed.

Asbestos has been used extensively for many different purposes and in a variety of common products. In many cases the locations of these materials may not be immediately obvious and only a thorough, ‘intrusive’ search will reveal the presence of these materials. Locations that asbestos containing materials are likely to be found include plant rooms, ceiling and floor voids, within services ducts, behind panels or they may be beneath other non-asbestos materials such as cladding.

These hidden materials may not be detected during the survey unless fixed panels are removed, floor and ceiling tiles or panels are removed and access obtained into voids and ducts.

A comprehensive survey that would be able to access all these types of locations would often be disruptive and destructive, involving a degree of disturbance that may not be generally acceptable or reasonable. A compromise must often be found, and it must be understood that without virtual demolition, it may not be possible to find and identify all asbestos containing materials. There is therefore a risk of subsequently discovering additional asbestos containing materials.

5.2.3 Planning asbestos surveys

In those countries where installation of asbestos and asbestos products has been banned for a number of years, the `survey' of a new or recent installation or building may merely comprise a desk-top review of the available information such as a health and safety file, or other contract documents, for confirmation from the designers or builders that no asbestos containing materials were specified or used in the construction or installation. However, in unregulated or weakly regulated environments, the possibility that materials that are expected to be asbestos free may in fact contain asbestos.

In the majority of situations, however, a far more detailed investigation will be required. The age and type of an installation or building can give some initial pointers at the ‘desk-top’ stage as to the likelihood of the presence and locations of asbestos containing materials, but these cannot be relied upon. Asbestos containing materials may have been removed in the past, or indeed may have been installed subsequently. Even where asbestos containing materials have been removed in the past, the possibility of residues or debris remaining from this must be considered as the standards of asbestos removal may not have been so stringent.

What is of fundamental importance is that the client or person commissioning the survey understands the range of survey types and the potential limitations that apply. It is also important that prior to the survey being undertaken the survey parameters must be agreed and documented so that a clear and unambiguous brief for the survey can be prepared.

Areas that would need to be clarified would include the following:

- Buildings / plant / areas to be surveyed
- What type of survey
- What plans are available
- What areas are to be accessed / not accessed
- What voids / ducts etc are reasonably accessible
- Sampling protocol
- What risk assessment system is to be used
- Report format
- Type of marked-up plans required

5.2.4 Health and safety during asbestos surveys

An adequate risk assessment will need to be carried out before starting any asbestos surveys, or indeed any asbestos sampling. This is to ensure that neither the person undertaking the survey nor any other people in the area are put at risk. As well as assessing the potential risks created by the disturbance of asbestos, it is important that other hazards are taken into account. These risk assessments should be prepared prior to the work commencing and should be based on information gathered during an initial pre-meeting or site visit.

These hazards may be wide-ranging and would be site-specific. Examples of hazards that would need to be considered would include:

- Working at heights or in ceiling voids
- Working on or near operable machinery
- Any chemical, physical or biological hazards
- Electrical hazards

- Working in confined spaces
- Working in remote locations / lone working

To reduce risks, in most cases surveys would be undertaken by a team of at least two people.

Risks from exposure to asbestos fibres potentially released can be controlled by appropriate sampling procedures that may include pre-wetting / damping the material, minimising breakage, ‘shadow-vacuuming’. Further details on bulk sampling procedures are given in Section 5.3.2.

Areas where asbestos is being sampled should as far as possible be unoccupied. This may involve either undertaking the sampling out of normal working hours or by arranging for the normal occupants to vacate the area for a short period. In either case the arrangements for sampling should be considered and agreed as part of the survey planning.

In most cases appropriate personal protective equipment will be required. The level of personal protective equipment required will need to be assessed as part of the risk assessment and will vary according to the type of product being sampled and the environment in which the samples are being taken. In most cases a minimum requirement would be the use of the following:

- Disposable coveralls with hood
- Half-mask dust respirator with Type P3 filter
    - Head straps worn beneath hood
- Shoes that can easily wiped clean (or disposable overshoes)

A full face mask may be required when sampling high risk materials such as sprayed insulation.

On completion of the sampling the overalls should be carefully removed prior to removing the respiratory protection. The overalls and any other potentially contaminated items such as overshoes or wipes should be considered to be contaminated waste and disposed of in accordance with National legislation.

5.2.5 Undertaking asbestos surveys

5.2.5.1 There is wide variation in the size and complexity of an asbestos survey. This may range from a single sample of an possible asbestos containing material to a full survey of a whole site. As stated earlier, the quality and success of the survey can be optimized by careful planning and collecting as much information as possible about the types of buildings, their age and any existing knowledge of asbestos products in the properties.

The survey should be undertaken in accordance with documented procedures and only after adequate risk assessments have been prepared. It is also important that the survey is undertaken in a methodical and logical manner. This means that not only should the building be surveyed according to a standard protocol (e.g. external first, then start at the top of the building, work round each floor in a clockwise direction, finish on ground floor / basement) but each room should be surveyed in a consistent order (e.g. ceiling / ceiling void, then walls / riser ducts, floors / floor ducts, then plant and equipment). By adopting a set protocol this will help to ensure a consistent approach and minimize the possibility of missing an asbestos containing material.

Positive identification of asbestos can only be confirmed by analysis of a representative sample of the material, using a microscope. However, an experienced asbestos surveyor should be able to be able to make an informed presumption that a material may contain asbestos, or alternatively, that it does not. These presumptions are made on the basis of their knowledge and experience of likely asbestos products, together with other indications such as surface texture, appearance, hardness, sound when 'knocked' etc. In the absence of any analytical or other evidence to support a reasoned argument that they are highly unlikely to be an asbestos containing material, materials must be presumed to contain asbestos.

The presumption that a material contains asbestos can either be `strong', where there is good reason to believe that a material contains asbestos but this has not yet been confirmed by sampling, or as the ‘default' position, when there is insufficient evidence to be sure that a material does not contain asbestos.

5.2.5.2 It is important that the type and level of information recorded during the survey is sufficient to enable appropriate decisions to be taken in terms of the future management of any asbestos containing materials. The information that needs to be recorded relates not only to where the asbestos containing materials are but also relates to the condition of the material and its potential to release fibres. The use of photographs to record the location, extent and condition etc is strongly recommended

Location: The location of the asbestos containing material must be recorded unambiguously e.g. plant identifier, building identifier, floor, room number / identifier and position

Extent: The amount of the asbestos containing material must be documented e.g. area, length, volume or numbers as appropriate. This may be recorded as an estimate e.g. $24m^2$ or may be recorded in broad categories e.g. small, $< 10m^2$, $10\text{-}50m^2$, $50\text{-}500m^2$, $>500m^2$ etc.

Product type: e.g. Sprayed insulation, thermal insulation, insulating board, asbestos cement, gasket, floor tile etc

Level of identification: On what basis has the asbestos content of the material been identified e.g. identified by analysis, strongly presumed (by comparison with similar identified asbestos containing material or by professional judgement of appearance) or presumed (where there is insufficient evidence (analytical or appearance) to be confident that the material does not contain asbestos.

Asbestos type: Does the material contain crocidolite, amosite, chrysotile etc. This may not be confirmed without microscopic analysis

For surveys undertaken to develop a management plan, information also has to be recorded to enable a risk assessment of the potential of the material to release fibres to be prepared. This would include the following:

Accessibility: How easy is it for the material to be disturbed e.g. is it exposed, easily accessible, usually inaccessible, only reached with access equipment or special tools etc.

Condition: What is the extent of damage or deterioration? This is usually assessed using agreed criteria e.g. undamaged, isolated areas of minor damage, significant amount of material with damaged areas, extensive damage etc. While these descriptions are somewhat arbitrary and subjective they provide a relative means of assessing the condition.

Surface treatment / sealing: Is the surface unsealed, painted / sealed or encapsulated under another coating e.g. thermal insulation protected by fabric or bitumen based coverings

Where the purpose of the asbestos survey is to prepare specifications for the removal of asbestos containing materials rather than as part of the preparation of a management plan the last three categories are generally not relevant.

5.2.5.3 A large amount of information needs to be recorded in a clear and logical manner to facilitate the production of an asbestos register. A number of approaches have been developed to aid this including the use of pro-forma as well as the use of hand-held data logging systems using either commercial or in-house developed programmes.

An example of an asbestos survey form is shown below, together with a print-out of a commercial data recording system are shown in figures 5.11 - 5.13 on the following pages.

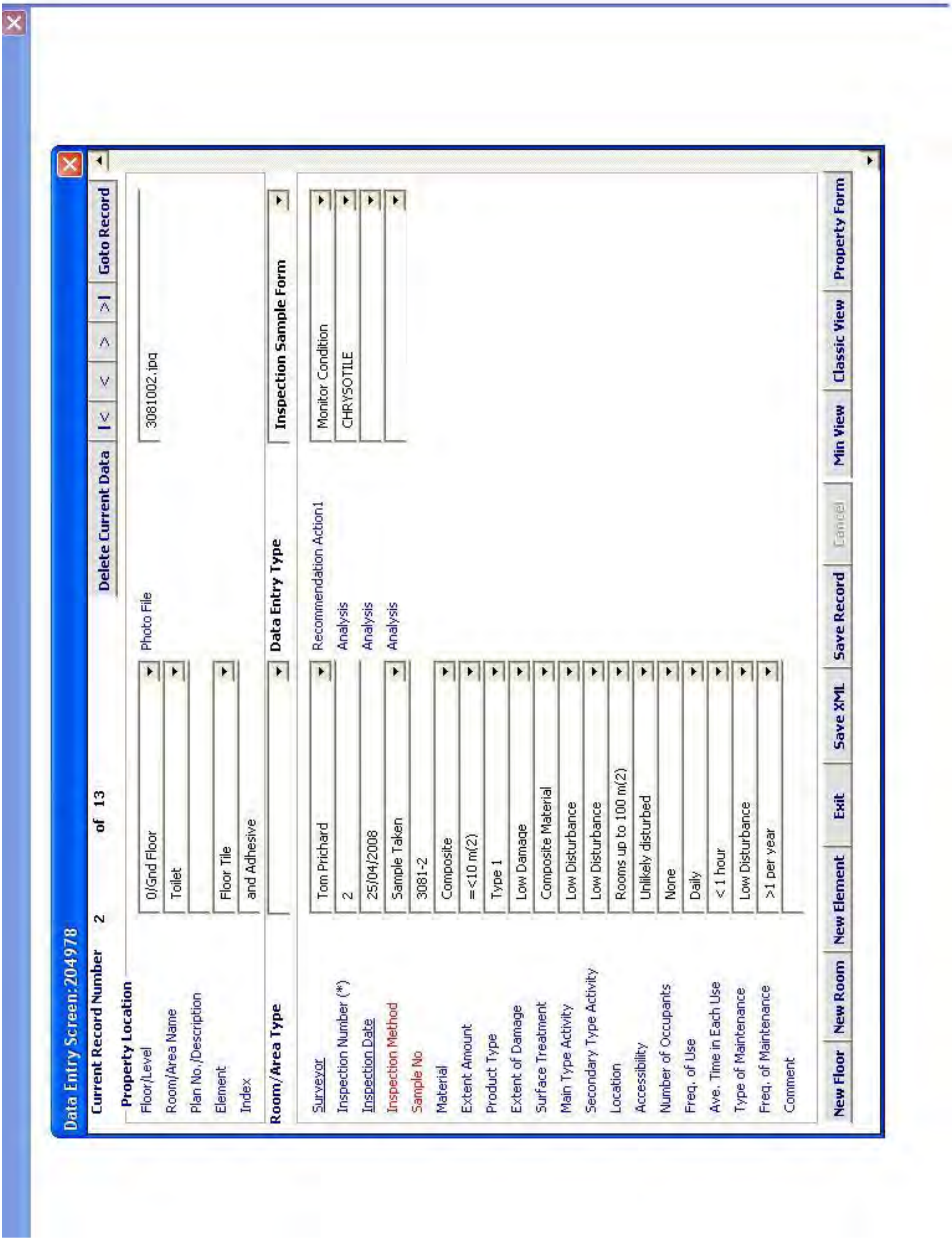
GULLY HOWARD TECHNICAL LTD ASBESTOS SURVEY FORM INTERNAL

PRN:		PROJECT NUMBER		Diagram (optional)
SITE				
ROOM TITLE				
PLAN NUMBER				
SURVEYOR		SURVEY DATE		

Report (Y/N)	Location & Materials															Asbestos Present?	Sample ID	Materials Assessment					Extent (m^2)
			No Access	Limited Access	Textured Coating	Insulating Board	Cement Sheet	Veg / MMMF	Plasterboard	Plaster /Render	Timber	Metal	Concrete	Brick/Block	Photo Ref			Product	Damage	Surface	Type	Total	
	Roof Void																						
	Ceiling Void																						
	Ceiling	Fixed / Suspended																					
	Skylight																						
	Walls																						
	Window Area																						
	Floor	Carpet / Lino / Vinyl Tile / Concrete / Timber / Other:																					
	Sanitary Fittings																						
	Other Items																						

(Source: Gully Howard Technical Ltd)

Figure 5.11 Example of asbestos survey data recording form



(Source: Gully Howard Technical Ltd)

Figure 5.12 Example of survey data collection system (entries chosen from drop down menus)

ASBESTOS REGISTER : LOCATION INFORMATION		**Floor / Position**	**0/Gnd Floor**
		Room /Area Name:	**Toilet**
		Plan No./Description:	**-**
		Location:	**Floor Tile/and Adhesive**
PRN NO: **204978**	Inspection Date: **25/04/2008**	Material Type: **Composite**	
Inspection Type: **Sample Taken**			
Quantity: **=<10 m(2)**		Inspection Result: **Asbestos Detected**	

A. Material Assessment		Surveyor(s): **Tom Prichard**	
Product Type:	**1**	Extent of damage:	**1**
Surface Treatment:	**0**	Asbestos Type:	**1**
Material Assessment Score	**A =**	**3**	

B. Priority Assessment				Main Activity	**1**	Secondary Activity	**1**
Location	**2**	Accessibility	**0**	Extent/amount	**1**	Number of Occupants	**0**
Frequency of use	**3**	Average time in use	**0**	Type of maintenance	**1**	Frequency of maintenance	**2**
Priority Assessment Score		**B =**	**5**	**Risk Assessment Score**		**A + B =**	**8**
Action Priority Rating from A+B: Low							
Recommendation: Monitor Condition							

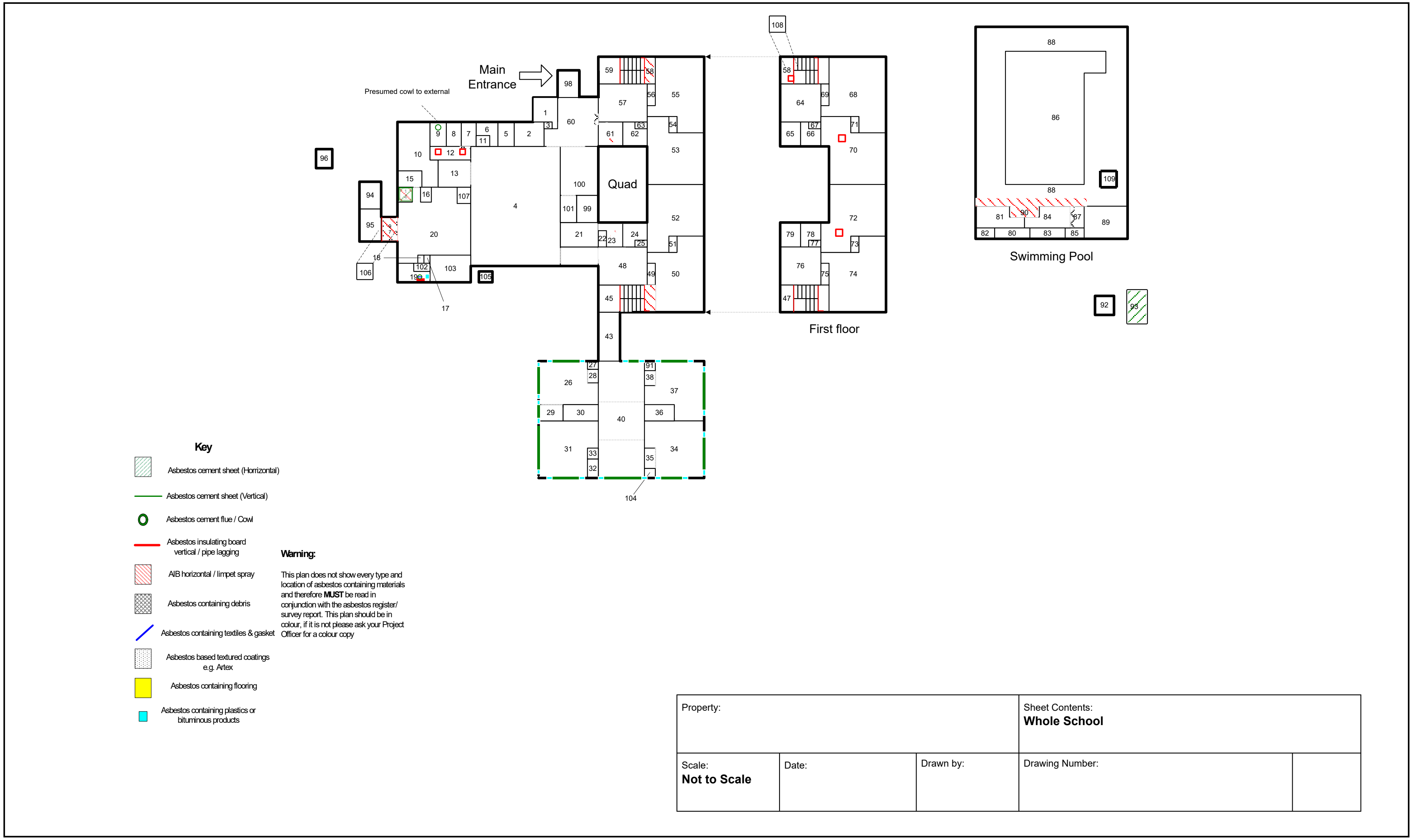
(Source: Gully Howard Technical Ltd)

Figure 5.13 Example report page generated by data collection system

Note: The material and priority risk assessment numbers given in the above examples are taken from United Kingdom Health and Safety Executive Guidance Notes HSG 264 and HSG 227 (see section 5.4.2)

In addition photographs of all identified or presumed asbestos containing materials are usually taken during the survey and incorporated into the final report or register.

In most situations plans need to be incorporated into the final report or register to provide a visual means of providing information to plant operators, building managers, building occupiers and contractors. The type and complexity of these plans will vary depending on the client requirements as well as the type of installation or building being surveyed. The plans may be schematic or to scale, simple line plans or multi-layer computer aided design (CAD) plans.



(Source – Gully Howard Technical Ltd)

Figure 5.14 Example plan with asbestos containing materials marked.

5.3 BULK SAMPLING

5.3.1 Sampling strategy

Air sampling is widely used to determine fibre concentrations in air. However, air sampling methods generally do not positively identify whether the collected fibres are asbestos or not. In order to confirm whether asbestos is present (and to characterise which type of asbestos it is), a 'bulk sample' is taken.

A 'bulk sample' is a term commonly used to describe material collected to establish whether or not asbestos is present in a material, location or area. The sample is usually analysed using polarised light microscopy as outlined in section 8. The amount of material collected will range from perhaps a small amount of dust or debris to samples of building materials several centimetres in size.

Bulk sampling may be undertaken for a variety of reasons ranging from the collection of a single sample through to a complete asbestos audit of a site to prepare an asbestos register to develop an asbestos management plan.

Guidance on sampling strategy and numbers of samples to be taken can be found in a number of publications including HSG248: The Analysts' Guide (Health and Safety Executive), Asbestos for Surveyors (Bill Sanderson) and Surveying Premises for Asbestos (Asbestos Control and Abatement Division). Full details for these publications are given in the references section. There are variations between the different publications, but all sampling methods require the following.

- Fibre release should be minimised
    - e.g. wetting, shadow vacuuming
- Samples should be representative of the material
    - e.g. full depth of insulation
- Samples should be of sufficient size to enable asbestos (including trace amounts) to be detected
- Sampling procedures should ensure that samples are not cross-contaminated

    - e.g. careful sampling procedures and cleaning of equipment between samples
- Where possible, samples taken from less conspicuous areas, or where it causes least additional damage
    - e.g. edges of boards or sheets that are already damaged
- Sample points should be repaired / sealed
- Sample locations should be accurately recorded and usually labelled
- Samples must be uniquely identified
- Appropriate respiratory protection and personal protective equipment should be worn (see 5.2.4) and used. It should also be decontaminated or disposed of as contaminated waste

The number of samples that need to be taken is one aspect of surveying for which it is impossible to be specific. It is always to some extent a matter of judgement. The need to take sufficient samples to be confident that asbestos products have been identified needs to be balanced against taking excessive samples with the associated additional costs and increased potential for fibre release and exposure during sampling.

Where large quantities of visually identical material is present in an installation or building e.g. many visually similar lengths of insulation or many rooms with identical ceiling tiles, a small number of samples may be sufficient to characterise the material by presuming that all are the same (particularly if the samples are found to contain asbestos). This approach should always be undertaken with caution to ensure that all the material is actually the same. If there is doubt additional samples will need to be taken.

5.3.2 Bulk sampling procedures

Pipe / thermal insulation

This material is often very variable in composition, particularly where it has been hand applied. It also may have been repaired or patched at some time. Initially sample locations should focus on areas that do not appear to have been modified. Where there are areas of insulation that are different colour, size or texture, this should alert the surveyor to examine these areas for additional samples.

Particular attention needs to be paid to the fact that insulation on pipe elbows, ‘tees’ and near valves may be different to that found on the main pipe lengths. This may be due to different material being used on installation, or the fact that these areas are more likely to have been disturbed and replaced at some point.

Due to the possible variation in asbestos content of pipe and thermal insulation, it is particularly important that the full depth of the material is sampled. The way that this is achieved is by use of a ‘core-cutter’ that obtains a full depth sample of about 2 or 3 cm diameter. Care must be taken to control any potential fibre release and precautions may include pre-wetting of the insulation, use of shadow-vacuuming, protecting surfaces below the sample point with plastic sheeting and filling / repair of the sample point. The core-cutter should be withdrawn from the insulation through a ‘wet-wipe’ to clean the surface of the core-cutter.

(Source: Gully Howard Technical Ltd)

Figure 5.15 - Core cutter

Where the pipe / thermal insulation is non-asbestos, and it is possible that it is a replacement material, the possibility of asbestos debris remaining on the underlying surfaces should be investigated, particularly if the original installation was constructed before asbestos insulation was banned.

(Source: Gully Howard Technical Ltd)

Figure 5.16 – Asbestos residues beneath mineral fibre insulation

Spray Coatings

This material is usually homogenous, so unless there are areas that appear different or the installation is very large, two samples (one at each end) of the installation would usually be sufficient.

Spray coatings have very asbestos content and are very friable. The potential for fibre release is therefore significant. The precautions for controlling fibre release outlined above should all be employed.

As the material is usually homogenous a small sample is usually sufficient. If the spray coating surface is sealed with paint, a small flap can be cut with a sharp knife and peeled back to reveal the spray coating. A sample can be obtained using either a core-cutter or a pair of tweezers.

Asbestos insulating boards

Asbestos insulating boards or tiles are usually homogenous but may have repaired or some boards may have been replaced on a piece-meal basis. If more than one type of board is noted, representative samples of each type should be taken.

One sample is usually sufficient for each room or small area (e.g. 25 m^2). Where there are extensive installations of identical boards a greatly reduced sampling rate would be appropriate.

A piece of board of a few square centimetres in size is more than sufficient as the material is usually homogeneous. In fact for common products such as 'asbestolux' a much smaller sample is usually sufficient as the amosite fibres are readily detected on analysis.

Samples can be taken from a damaged area or edge, or from a discreet location at an edge or corner of a board. A sample is usually obtained by levering off a small piece with a chisel or sharp knife. Alternatively a piece can be broken off with pair of flat-jawed pliers. In either case fibre release should be minimised by use of wetting. Shadow vacuuming may also be appropriate. Any broken edges should be sealed or painted after sampling to minimise further fibre release.

Asbestos cement products

Asbestos cement products are widely found as corrugated or flat sheeting and various moulded products such as guttering. These products are usually homogenous but some sheets or products may have been replaced on a piece-meal basis. If more than one type of sheet is noted, representative samples of each type should be taken.

In older buildings most exterior cement sheets and products contain asbestos and only limited sampling is required to establish the presence of asbestos. For each product type a piece of a few square centimetres in size is more than sufficient as the material is usually homogeneous.

Asbestos cement products are hard and samples are best taken from a damaged area or edge, or from a discreet location at an edge or corner. A sample is usually obtained by breaking off a small piece with a pair of flat-jawed pliers or by levering off with a chisel.

Asbestos cement roofs are fragile and care must be taken to prevent the risk of falls through the roof as well as falling from the roof. In situations where access is difficult it is common that the material is simply presumed to be asbestos-based. Similarly cement flues present problems for sampling as it is important not to damage the integrity of the flue. Again, often a presumption of asbestos content is made on the basis of its appearance.

Textured (decorative) coatings

Textured coatings pose particular problems for both sampling and analysis. It is impossible to tell from appearance or texture whether or not they are likely to contain asbestos. Also, if they do contain asbestos, it is only present in small quantities (typically about 1% or less) and it may not be evenly distributed within the matrix. The asbestos fibres are also difficult to extract from the matrix on analysis.

As a result it is necessary to sample a reasonable amount of material by scraping off with a chisel an area of about 10 – 20 cm^2. Some surveyors prefer to make a composite sample from about 4 or 5 smaller areas in a room.

Samples may need to be taken from each room or application or a decision taken as to what appropriate proportion of areas needs to be sampled.

Thermoplastic floor tiles / floor coverings

Samples can be obtained by cutting a small section or corner of the tile. Fibre release would be very low, unless asbestos paper backing or lining is present. One sample of each type or colour of tile is usually sufficient.

Other products (e.g. textiles, ropes, roofing felts etc)

Where there are distinct types of materials, one or two samples are usually sufficient. These can usually be obtained using a sharp knife or pair of scissors.

Debris and dust

Samples of debris and dust are usually taken by picking fragments that appear to be consistent with asbestos products or appear to contain visible fibres. Alternatively samples can be collected from areas where asbestos dust may have accumulated. Samples are usually obtained by use of tweezers.

Sample handling

To ensure traceability each sample should be given a unique reference number that is used at all stages of the process from sampling, through transport to the laboratory, analysis of the sample and inclusion in the final report and register.

All samples should be placed inside an impervious bag or container which can be sealed and this placed inside a second suitable bag or container i.e. 'double-bagged'. These bags or containers should be marked with the unique reference number. The final bulk container in which all samples are transported should be adequately marked with asbestos warning labels.

5.4 RISK ASSESSMENT OF ASBESTOS CONTAINING MATERIALS

When asbestos containing materials are identified (or presumed to be present) an assessment of the risk that they pose to users and occupants of the premises should be undertaken. The purpose of the assessment is to help decide what action is appropriate to deal with the asbestos containing materials and to make decisions on what materials should be dealt with first.

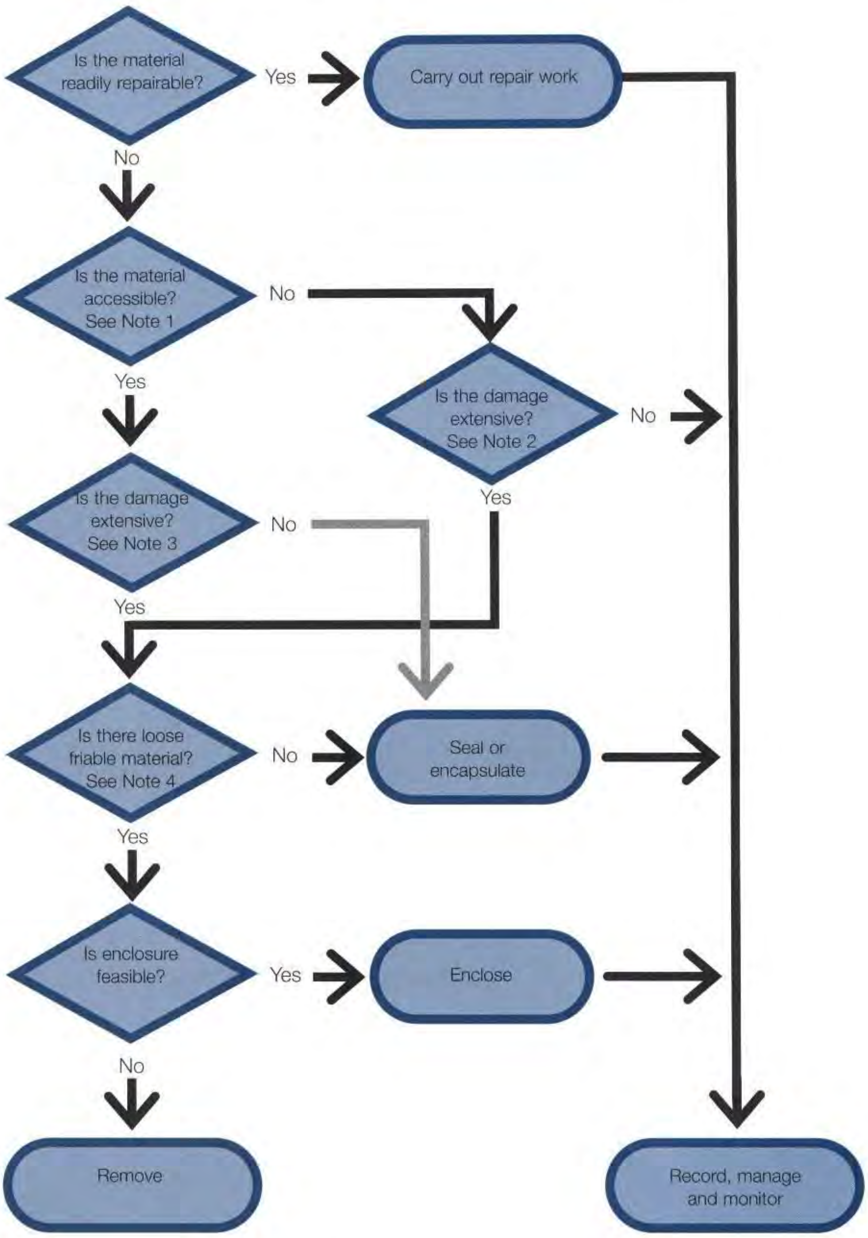
The risk to health is not simply dependent on how easily the asbestos containing material can release fibres, but also whether the material is likely to be disturbed and if disturbed whether people are likely to be exposed to the fibres. A number of different risk assessment systems have been developed that take into account these factors.

5.4.1 Flow charts

Some systems are based on a flow-chart or a decision tree format that lead to a conclusion or action that should be undertaken to deal with the asbestos containing material. These systems tend to lead to a consistent outcome but are not very good at prioritising which material should be dealt with first. In many respects flow-charts are more useful in developing a control strategy than as a risk assessment system. For instance if several asbestos containing materials in poor condition were found it is likely that the recommended action would be to remove the asbestos containing materials – however it may not be possible to tackle them all at once.

The following chart is an example, different charts are available for different types of asbestos products such as asbestos insulation board.

Appendix 1.2 Sprayed asbestos coatings and pipe and vessel insulation in poor condition



Notes

1 Is the material accessible and vulnerable to further accidental or deliberate damage from adjacent repair or maintenance, impact by people, vehicles, objects or vandalism?

2 If the damage is slight and the ACM is not easily accessible, remedial work is unlikely to be necessary. The damage should be monitored and your decision reviewed if circumstances change (eg the area becomes accessible).

3 If the damage is superficial, eg slight cracking to pipework insulation or deteriorated surface finish, then answer 'no' to this question. If, eg the insulation is starting to come away from the pipework or the spray coating appears to be loose in places, then answer 'yes' to this question. If there is debris on the floor or other surfaces then this will need removing following appropriate precautions.

4 The damage may be extensive, but if the material is generally sound without friable material or loose pieces, then sealing/encapsulation may be possible.

(Source: HSE Guidance Note 227 – Reproduced under the terms of the Click-Use Licence)

Figure 5.17 – Flow chart of management actions for sprayed asbestos coatings and pipe and vessel insulation in poor condition

5.4.2 Risk assessment systems

5.4.2.1 Australia

The NOHSC Code of practice for the management and control of asbestos in workplaces (2005) in Australia outlines the areas that need to be considered as part of the risk assessment as follows:

The risk assessment should take account of the identification information in the register of asbestos containing materials, including:

- *The condition of the asbestos containing materials (e.g. whether they are friable or bonded and stable, and whether they are liable to damage or deterioration;*
- *The likelihood of exposure;*
- *Whether the nature or location of any work to be carried out is likely to disturb the asbestos containing material; and*
- *the results from air monitoring from a competent person may assist in assessing the risks.*

(Source: NOHSC Code of practice for management and control of asbestos in workplaces (2005) – reproduced with permission)

5.4.2.2 United Kingdom

Many asbestos risk assessment systems use algorithms. An algorithm is a numerical way of taking into account several factors by giving each factor a score. These scores can then be added to give an overall score. The use of algorithms is not infallible, but the assessment process is transparent, so if discrepancies arise, it should be possible to re-examine the assessment process to find the root of any error.

The HSE Document HSG247 (2002) recommends that risk assessments are carried out in two stages – a material assessment and a priority assessment.

- Material assessment - an assessment of the condition of the material and the likelihood of it releasing fibres on disturbance. The material assessment gives an initial guide to the priority for management as it will identify materials that will most readily release fibres if disturbed. However, this may not always indicate high priority for remedial action. The four factors considered in HSE Document HSG 264 (2010) are:

- o Product type
- o Extent of damage
- o Surface treatment
- o Asbestos type

Table 5.2 – Material risk assessment scores

Sample variable	Score	Examples of scores
Product type (or debris from product	1	Asbestos-reinforced composites (plastics, resins, mastics, roofing felts, vinyl floor tiles, semi-rigid paints or decorative finishes, asbestos cement etc)
	2	Asbestos insulating board, mill boards, other low density insulation boards, asbestos textiles, gaskets, ropes and woven textiles, asbestos paper and felt
	3	Thermal insulation (e.g. pipe and boiler lagging), sprayed asbestos, loose asbestos, asbestos mattresses and packing
Extent of damage / deterioration	0	Good condition: no visible damage
	1	Low damage: a few scratches or surface marks; broken edges on boards, tiles etc.
	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres
	3	High damage or delamination of materials, sprays and thermal insulation. Visible asbestos debris
Surface treatment	0	Composite materials containing asbestos: reinforced plastics, resins, vinyl tiles
	1	Enclosed sprays and lagging, asbestos insulating board (with exposed face painted or encapsulated), asbestos cement sheets etc.
	2	Unsealed asbestos insulating board, or encapsulated lagging or sprays
	3	Unsealed lagging and sprays
Asbestos type	1	Chrysotile
	2	Amphibole asbestos excluding crocidolite
	3	Crocidolite

(Source: HSE Guidance Note HSG 264 (2010) – Reproduced under the terms of the Click-Use Licence)

Each of the parameters is scored and added together to give a total score between 2 and 12. Presumed or strongly presumed asbestos containing materials are scored as crocidolite unless analysis of similar materials from the building shows a different asbestos type, or if there is a reasoned argument that a certain type of asbestos was almost always used e.g. floor tiles contain chrysotile.

HSE Guidance Note HSG 264 (2010) states that:
Materials with assessment scores of 10 or more are regarded as having a high potential to release fibres if disturbed. Scores of between 7 and 9 are regarded as having a medium potential, and between 5 and 6 a low potential. Scores of 4 or less have a very low potential to release fibres. Non-asbestos fibres are not scored.

The material assessment should be carried out as part of the management survey. It identifies the 'high hazard' materials, i.e. those materials which will most readily release asbestos fibres if disturbed. It does not automatically follow that the materials with the highest score will be the highest priority for remedial action. Remember even an asbestos containing material in poor condition only presents a risk to health if the fibres are in the air we breathe.

Management priority must be determined by carrying out a risk assessment (priority assessment) which takes into account additional factors such as

- The occupancy of the area and activities carried out in the area
- The use to which the area is put
- The location and extent of the asbestos containing material
- The likelihood and frequency of maintenance activities

HSE Guidance Note HSG227 A comprehensive guide to managing asbestos in premises (2002) gives the following guidance on these factors:

Occupant activity
The activities carried out in an area will have an impact on the risk assessment. When carrying out a risk assessment the main type of use of an area and the activities taking place within it should be taken into account. For example a little used storeroom, or an attic, will rarely be accessed and so any asbestos is unlikely to be disturbed. At the other end

of the scale, in a warehouse lined with asbestos insulating board panels, with frequent vehicular movements, the potential for disturbance of asbestos containing materials is reasonably high and this would be a significant factor in the risk assessment. As well as the normal everyday activities taking place in an area, any secondary activities will need to be taken into account.

Likelihood of disturbance

The two factors that will determine the likelihood of disturbance are the extent or amount of the asbestos containing material and its accessibility / vulnerability. For example, asbestos soffits outdoors are generally inaccessible without the use of ladders or scaffolding, are unlikely to be disturbed. The asbestos cement roof of a hospital ward is also unlikely to be disturbed, but its extent would need to be taken into account in any risk assessment. However if the same ward had asbestos panels on the walls they would be much more likely to be disturbed by trolley/bed movements.

Human exposure potential

The human exposure potential depends on three factors: the number of occupants of an area, the frequency of use of the area, and the average time each area is in use. For example, a school boiler room is likely to be unoccupied, but may be visited daily for a few minutes. The potential for exposure is much less than say in a classroom lined with asbestos insulating board panelling, which is occupied daily for six hours by 30 pupils and a teacher.

Maintenance activity

The most important factor which must be taken into consideration is the level of maintenance activity likely to be taking place in an area. Maintenance trades such as plumbers and electricians are the group who the duty to manage is primarily trying to protect. There are two types of maintenance activity, planned and unplanned. Planned work can be assessed and carried out using procedures and controls to reduce exposure to asbestos. Unplanned work requires the situation to be dealt with as found and the controls that can be applied may be more limited.

The frequency of maintenance activities also needs to be taken into account in deciding what management action is appropriate.

(Source: HSE Guidance Note HSG227 (2002) – Reproduced under the terms of the Click-Use Licence)

As with the material assessment each of the four categories in the priority assessment can score a maximum of 3, giving each part of the assessment an overall maximum score of 12. Full details of the priority assessment scores are given in HSG227.

The overall risk assessment (maximum 24) takes into account the results of both the material assessment and the priority assessment and can then be used to develop the management action plan.

There is no official guidance as to the significance of the final number generated by the algorithm. Many organisations have developed their own guidance and indeed in many cases their own risk assessment systems that are more specific to their own requirements.

5.4.2.3 United States of America

The US Environmental Protection Agency (EPA) document EPA 560/5-85-024 (1985) gives guidance on assessing the need for abatement, determining its timing and choosing an abatement method.

It considers three types of material - surfacing materials, pipe and boiler insulation and other materials. It presumes that asbestos containing materials are included in a management program. The likelihood of fibre release determines the need for and timing of additional action. The nature and location of the material determines the abatement method.

The factors taken into account when assessing potential fibre release are divided into two categories:

- Current condition of the asbestos containing material
    - Evidence of deterioration or delamination
    - Evidence of physical damage

  - o Evidence of water damage
- Potential for future disturbance, damage or erosion
  - o Proximity to air plenum or direct airstream
  - o Visibility, accessibility and degree of activity
  - o Change in building use

More guidance is given on each of the categories and a simple ‘present’ or ‘absent’, ‘high’ or ‘low’ rating given for each factor. Numerical values are not given to each factor.

5.4.3 Reviewing risk assessments

Risk assessments should be reviewed regularly in accordance with any National legislative requirements. More specifically the risk assessments should be reviewed, together with any control measures, whenever:

- There is evidence that the risk assessment is no longer valid
- There is evidence that control measures are not effective
- There are significant changes to the workplace or work practices and procedures
- There is a change in condition of asbestos containing material; or
- The asbestos containing material has been removed, enclosed or sealed.

5.5 MANAGEMENT OF ASBESTOS CONTAINING MATERIALS

5.5.1 Introduction to management plans

It is worth restating that potential hazards of asbestos can only be realised if the fibres become airborne and are inhaled. Asbestos containing materials in good condition, well sealed and not likely to be disturbed should be left intact and managed.

This view is supported by the HSE Document L127 Management of asbestos in non-domestic premises (2006) which states that:

If asbestos containing materials are in good condition and are unlikely to be disturbed, then it is better to leave them in place and to introduce a system of management.

In general terms the control options available to deal with any asbestos containing materials fall into one of three categories;

- Manage the asbestos containing material asbestos containing material to prevent fibre release
- Repair / seal the asbestos containing material and then manage to prevent fibre release
- Remove the asbestos containing material

In order to make valid decisions on which course of action is most appropriate it is important that a comprehensive systematic management plan is developed and implemented. This means that persons with control of premises have a duty of care to:

- Determine whether asbestos containing materials are present on the site or premises
- Compile an asbestos register identifying the types of asbestos products on-site together with details of locations, accessibility and condition
- Prepare and implement an asbestos management plan that identifies the measures to be taken to either remove the asbestos containing material or to prevent or minimise the risks of exposure to asbestos
- Ensure the identified control measures are implemented
- Ensure that the management plan is regularly reviewed

If an asbestos abatement project is not urgent, it will be less costly if combined with building repair, renovation or scheduled plant or building maintenance. Other factors that may influence the timing of any asbestos abatement works include:

- The pattern of normal work operations
- Any legal liabilities

- Expected useful life of the plant or building
- Pressures from building occupants / users / public

Legislation in different countries sets out specific requirements concerning asbestos. Before commencing any work that may disturb asbestos containing materials in the workplace, the relevant legislation should be checked to ensure there will be full compliance with these legal obligations.

5.5.2 Awareness training for workers, contractors and others

Information and training should be provided to anybody who may come into contact with asbestos containing materials in a workplace, either directly or indirectly. The depth and extent of this training will depend on the particular circumstances but may include the following:

- The types of asbestos and the health risks associated with asbestos
- The types of products that may contain asbestos
- Typical locations and likely occurrence of asbestos containing materials in buildings and plant
- The procedures in place to prevent exposure including
    - The existence and location of the asbestos register and how it can be accessed
    - The control measures in place to minimise the risks from asbestos, including personal protective equipment
    - Standard operating procedures
    - Any requirements for use of a permit to work
- Any applicable exposure standards
- The purpose of any air monitoring or health surveillance

5.5.3 Development of an asbestos management plan

The purpose of an asbestos management plan is to ensure that persons with control of premises comply with any relevant asbestos legislation and prevent or reduce exposure to airborne asbestos fibres while asbestos containing materials remain in the workplace.

The following general principles should be applied in developing an asbestos management plan:

- The ultimate aim should be for all workplaces to be free of asbestos containing materials.
    - o This may not be practicable, particularly in the short-term
    - o Priority should be given to dealing with friable asbestos containing materials that are accessible
    - o Opportunities to remove asbestos containing materials during refurbishment and/or maintenance works should be considered in preference to other control measures such as enclosure, encapsulation or sealing
- Information on identified or presumed asbestos containing materials should be recorded in an asbestos register
    - o This information should be available for all workers and others who may be exposed to asbestos as a result of being on the site, together with details of control measures in place
    - o Use of labels or other measures to readily identify in-situ asbestos containing materials should be considered
- Risk assessments should be conducted for all identified or presumed asbestos containing materials. These risk assessments should identify:
    - o The potential of the material to release asbestos fibres
    - o The likelihood of the material being disturbed
    - o The controls to be implemented to prevent or reduce exposure to airborne asbestos
- There should be full consultation, involvement and information sharing during each step of the development of the asbestos management plan
- The identification of asbestos containing materials and associated risk assessments should only be undertaken by competent persons

The following figure (5.18) summarises how these general principles should be applied in the workplace

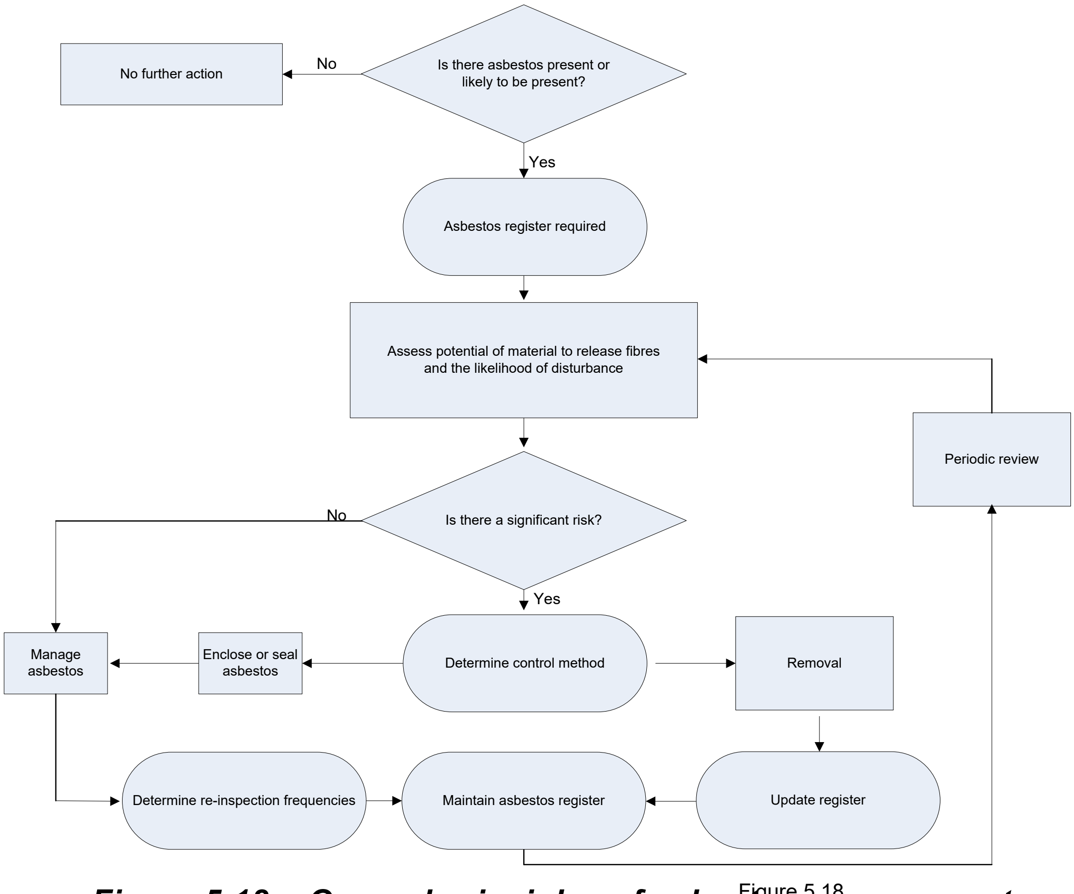


Figure 5.18 – General principles of asbestos management

5.5.4 Content of an asbestos management plan

The asbestos management plan should be comprehensive and include the following information:

- the asbestos register
- mechanisms for providing all relevant people with information about the location, type and condition of the asbestos containing materials, the risks they pose and the control measures adopted to eliminate or minimise these risks;
- decisions about management options (i.e. to maintain the asbestos containing materials or replace them with non-asbestos alternatives), including the reasons for these decisions
- a timetable for action, including priorities and dates

- arrangements for periodic inspections of all asbestos containing materials
- monitoring arrangements
- the responsibilities of all persons involved and the sections of the plan they are responsible for
- training arrangements for workers and contractors
- a procedure and timetable for review of the management plan, risk assessments and the asbestos register

The asbestos management plan should be clear and unambiguous. It should set out the aims of the plan, what is going to be done, when it's going to be done and how it is going to be done, and who is responsible for ensuring that each aspect of the plan is fully and correctly implemented.

There should be clear lines of responsibility, with each person involved understanding their roles and responsibilities. It is particularly important that the designation of the person who has overall responsibility for the implementation of the plan is identified.

Relevant local legislation should be checked for further information on individual obligations, training requirements, certification, licensing etc relevant to the management plan.

Some types of asbestos containing materials present little or no hazard (e.g. mastics). Other asbestos containing materials such as bitumen impregnated pipe-wrap or roofing felts can only release fibres under exceptional circumstances. These materials should still be included in the asbestos register and management plan, if only to document that they have been considered and found to be of minimal risk, with no specific actions required.

The register of asbestos containing materials should be kept up to date and be readily available to anybody who may come into contact with the asbestos containing materials. The procedures in place to ensure that asbestos is not disturbed inadvertently will vary from site to site but in many situations this may be best achieved through the use of a permit to work system.

As stated earlier, the options available for dealing with asbestos containing materials fall into one of three categories:

- Management of the asbestos containing material
- Repair, seal or encapsulate the asbestos containing material, then manage it
- Removal of the asbestos containing material (see Section 6)

To manage the asbestos containing material there are a range of actions that can be used to ensure that the risks of disturbance of the asbestos are minimised. These include:

- Isolate / restrict access
    - Restricted zones with controlled entry
    - Permit to work system
- Information / training
    - Suitable and sufficient labels / warning signs
    - Awareness training, including induction and periodic refresher training
- Monitor condition
    - Periodic inspection (e.g. every 6 months or annually)
    - System in place for reporting damage / deterioration
- Maintain register
    - Formal system in place to ensure alterations are recorded and that the register and management plan updated

There is also a range of options that can be used to repair, seal or encapsulate asbestos containing materials, these include:

- Repair of damaged asbestos containing materials
    - Use appropriate fillers and coatings

- Encapsulation of asbestos containing materials to prevent fibre release
    - Alkali resistant paint for cement products
    - High-solids emulsion paint for insulating boards (may need to be fire retardant paint)
    - Proprietary bituminous or semi-flexible polymeric coating
- Enclose or protect asbestos containing materials
    - Physical barriers or cover panels

5.5.5 Reviews of the asbestos management plan

The asbestos management plan should be reviewed (and formally re-approved by a senior manager) at suitable intervals. Many organisations undertake an annual review as a minimum, however, it should also review the plan if there have been significant changes or if there is reason to believe the plan is no longer valid. These reviews should critically examine the effectiveness in:

- preventing exposure to airborne asbestos fibres;
- controlling maintenance workers and contractors;
- identifying the need for action to maintain or remove asbestos containing material;
- raising awareness among all workers; and
- maintaining the accuracy of the register of asbestos containing material.

Issues that may affect the management plan include changes to the organisational structure, changes to staff, changes to company procedures or changes in building use / occupancy

A number of common problems relating to asbestos management are detailed below, together with the possible results and solutions.

Table 5.3 – Common problems relating to asbestos management

Problem	Possible result	Possible solutions
Asbestos containing materials not all identified	People may inadvertently disturb asbestos containing material leading to fibre release and potential exposure	Survey undertaken to identify all asbestos containing materials and identify areas not accessed
Maintenance staff or contractors inadvertently work on identified asbestos containing material	Asbestos containing material is disturbed possibly resulting in significant exposure	Asbestos register readily available Ensure labels sufficient and suitable Permit to work system Asbestos awareness training for staff
Maintenance staff or contractors may work on identified asbestos containing material but not follow correct procedures	Asbestos containing material is disturbed possibly resulting in significant exposure	Standard operating procedures Adequate training and instruction Good supervision
Assessment of potential fibre release from asbestos containing material overestimated	Unnecessary actions may be taken and costs incurred to prevent an insignificant risk	Ensure assessors are adequately trained and assessment criteria clear
Assessment of potential fibre release from asbestos containing material underestimated	Controls may not be sufficient to prevent significant exposure	Ensure assessors are adequately trained and assessment criteria clear
People become concerned because of the presence of an asbestos containing material even though it is in good condition	Unnecessary and costly action may be taken to prevent an insignificant risk People's concerns or worries may be raised unnecessarily	Ensure that people understand the risks from asbestos and how these risks can be controlled
Survey completed but no further action undertaken	Asbestos containing material is disturbed possibly resulting in significant exposure	Management plan developed identifying actions and controls to be implemented

6. ASBESTOS REMOVAL

6.1 PREPARATION

6.1.1 Responsibilities of the client / building owner

The decision to remove asbestos containing materials should be based on the application of the asbestos management plan that has been developed. As part of the process the asbestos removal contractors or workers will need to be provided with details of the asbestos removal requirements.

It is important that whoever engages an asbestos removal contractor should have enough knowledge to critically assess the contractor's competency and plan of work, or at least needs to engage a separate and independent third party to provide this review.

NOHSC Code of Practice for the safe removal of asbestos (2005) lists the issues that the work specification for the removal of asbestos containing materials should address as follows:

What:

- *Technical descriptions of the asbestos containing material to be removed, with details on the type and condition of asbestos containing material present, their quantity and any special or unusual materials, including any residual dust and debris*
- *Details on any section or materials to be left in place*
- *Cleaning/decontamination: the areas to be protected from airborne dust and the areas to be cleaned or decontaminated upon completion*
- *The dimensions of surfaces and fittings. (The provision of adequately detailed drawings should be sufficient).*
- *The types of fittings and supports, and whether or not these should be removed or disposed of with the waste*
- *The storage and disposal of asbestos waste*
- *The type of finish required*
- *Arrangements for clearance inspections and air monitoring.*

Where:

- *Location of the removal: - Indoors*
- *Outdoors but protected*
- *Outdoors and exposed to weather*
- *Enclosed in ducts (e.g. air-conditioning heater boxes) or trenches below ground level*
- *Difficult or unusual site conditions and access (such as working at heights), which will influence the selection or application of removal methods, particularly concerning transport, scaffolding and weather protection*
- *Areas that are difficult to access, such as wall and ceiling cavities. These could have hidden asbestos containing material, which would need to be further assessed for their risks*
- *Details on any areas that have not been assessed but could contain asbestos*
- *Safe work procedures for dealing with any unknown or unexpected asbestos found during removal work.*

Hazards:

- *Confirmation and details of residual heat in pipework, boilers, turbines or refinery equipment. Attention should be paid to the possibility of burns to workers*
- *Other temperature considerations:*
    - *Normal working temperature for each portion of the plant*
    - *Ambient temperature in the asbestos work area*
- *The location of electrical cables, switches and panels, which may pose an electrical hazard and need to be isolated or protected to prevent the electrocution of asbestos removal workers*
- *Any unusual or specific hazards associated with the removal work, such as brittle roofs or working at heights*
- *Site occupancy restrictions and conditions, including access and egress, work schedules and emergency management arrangements, including emergency communication and evacuation plans*

(Source: NOHSC Code of practice for the safe removal of asbestos (2005) – reproduced with permission)

Other issues not specifically identified in the NOHSC list above include:

- Confined spaces (often an issue in asbestos removal work)
- Any hazardous chemicals or materials other than asbestos that may be present
- What provisions and procedures will be implemented for communications with the site manager / owner

It is important that whoever undertakes the removal work is competent. In many countries asbestos removal contractors have to be registered or licensed by regulatory authorities for work with the higher risk asbestos containing materials.

In the UK the Health and Safety Executive issues licenses to contractors to work with asbestos coatings, asbestos insulation and asbestos insulating board. In Australia, asbestos removalists must hold a licence issued by the relevant State or Territory Occupational Health and Safety authority before being permitted to remove friable asbestos containing materials.

The fact that the removal contractor holds a licence should ensure that they meet certain minimum criteria. However, holding a licence does not necessarily mean that they are competent for all types of removal work or that they will undertake the work correctly. It is always important to critically review their plan of work and their competence as well as undertake audits of their work.

In many jurisdictions it is a requirement to notify work with asbestos to the relevant regulatory authorities. In some cases this notification duty is placed on the site owner or operator, while in others it is the responsibility of the asbestos removal contractor (or employer if their own workers are undertaking the work). It is important to establish who is accountable for any notifications. In some countries regional or local jurisdictions will often have additional requirements.

As examples, in the UK, for most work with asbestos insulation, asbestos spray coating and asbestos insulating board, the asbestos removal company must notify the enforcing authority before commencement of an asbestos removal job (usually 14 days notice is required – although in some emergency situations a waiver may be obtained). A similar approach is adopted in Australia where notification to the relevant authority is also required and some states also require notification and use of a licence holder for removal of larger quantities of asbestos containing materials even if they are not friable.

6.1.2 Risk assessment

The asbestos removal contractor will need to undertake a risk assessment to establish all the risks associated with the asbestos work and the precautions needed to prevent or minimise those risks. The risk assessment ensures that the scope of the proposed work is fully considered. This will help to identify appropriate work methods, so that exposure to asbestos can be adequately controlled and legal obligations satisfied.

The risk assessment should be carried out by a competent person and should describe the work, the expected exposures and the methods of control. The significant findings of the risk assessment should be recorded in writing and should form the basis of the plan of work (see 6.1.3). The risk assessment should also include non-asbestos risks such as falls from height, electrical safety, heat stress, or work in confined spaces.

6.1.3 Plan of work

Planning requirements for the removal of asbestos can differ greatly, depending on the specific asbestos removal task, the type, location, quantity and condition of the asbestos containing material to be removed, whether there are workers or other persons nearby and many other factors.

Asbestos removal work includes:

- *the removal of asbestos containing materials from buildings and structures, including demolition/excavation sites*
- *the removal of asbestos containing materials from plant and equipment, including friction products; and*
- *cleaning up asbestos dust or debris.*

Whatever the circumstances, it is essential for an asbestos removal control plan to be developed and implemented whenever any asbestos containing material is to be removed.

(Source: NOHSC Code of practice for the safe removal of asbestos (2005) – reproduced with permission)

The purpose of the plan of work (often called a method statement) is to provide a practical document, which details the specific work methods and control measures for a particular job at a particular location. The document directs the work and is a source of reference for the asbestos removal team. The plan of work is an active document and if any significant changes on site are necessary, it should be amended and the changes communicated to the employees. The changes (if significant) should also be notified in writing to the enforcing authorities.

Employers must make sure their employees follow the plan of work as far as it reasonably practicable to do so. If the work cannot be carried out in accordance with the plan, it must be stopped and the risks reassessed. Work should not start until a new plan of work is drawn up or until the existing plan is amended. (Source: HSE Guidance Note HSG247 (2005) – Reproduced under the terms of the Click-Use Licence)

It should be emphasised that the plan of work, however detailed, is not a substitute for well trained and experienced workers and supervisors.

It should also be noted that the requirement to notify the enforcing authorities of significant changes is part of the UK specific requirements. Other jurisdictions may or may not include this requirement. However, in any case it is good practice to ensure that any significant changes are documented and taken into account as part of an on-going risk assessment process and workers informed of any changes.

The asbestos removal control plan should include specifications and/or drawings addressing at least all of the items in the following table which are relevant to the particular removal job. Additional information should be included for each individual removal job as necessary. The asbestos removal control plan should be finalised in consultation with the client

Table 6.1 – Components of the asbestos removal plan

Information to be included	Friable ACM	Non-friable ACM
Identification		
Details of ACM to be removed (e.g. location, whether it is friable or non-friable, type, condition and quantity to be removed)	✓	✓
Preparation		
Assigned responsibilities for the removal	✓	✓
Program of commencement and completion dates	✓	✓
Emergency plans	✓	✓
Asbestos removal boundaries, including type and extent of isolation required and the location of any signs and barriers	✓	✓
Control of electrical and lighting installations	✓	✓
Personal protective equipment to be used (including RPE)	✓	✓
Details of air monitoring program	✓	-
Waste storage and disposal program	✓	✓
Removal		
Methods for removing the ACM (wet or dry methods)	✓	✓
Asbestos removal equipment (spray equipment, asbestos vacuum cleaners, cutting tools etc)	✓	✓
Details on required enclosures (size, shape, structure etc), and the location of negative pressure exhaust units	✓	-
Details on temporary buildings required (e.g. decontamination units), including details on water, lighting and power requirements, negative air pressure exhaust units and the locations of decontamination units.	✓	-
Other control measures to be used to contain asbestos within the asbestos work area	✓	✓
Decontamination		
Detailed procedures for workplace decontamination, decontamination of tools / equipment, personal decontamination and decontamination of non-disposable PPE and RPE	✓	✓
Waste disposal		
Methods of disposing of asbestos wastes including details on the disposal of		
• disposable protective clothing and equipment	✓	✓
• the structures used to enclose the removal area	✓	-

(Source: NOHSC Code of practice for safe removal of asbestos (2005) – reproduced with permission)

The above table details the areas that generally need to be included in the plan of work. The ✓ symbol means that the asbestos removal control plan should include this information and the – symbol means that this information may not be necessary for some asbestos removal tasks. Any decision to include this information must be made on a case-by-case basis.

There is considerable variation in legislative requirements in different countries. Care must be taken to ensure that any specific legislative requirements are met.

The plan of work should be kept on-site and be available to anyone involved in the removal work including any persons involved in the testing or monitoring of the asbestos removal work.

Throughout any asbestos removal work, the site owner or operator should have a competent representative checking the contractor to ensure that the work plan is being implemented and that any concurrent site operations that may potentially affect the contractor are properly communicated and planned for.

6.1.3.1 Emergency plan

As part of the plan of work an emergency plan, reflecting the risks involved, should be developed before any asbestos removal work commences. This emergency plan should be site-specific but should as far as possible be consistent between jobs so that people automatically react appropriately in an emergency situation. Workers should be regularly trained for emergency situations. Some decontamination procedures might need to be temporarily waived or modified in the event of an emergency.

Emergency planning should include provisions for fire or other emergency evacuation, including exit arrangements and emergency communications including visual and audible alarms. Routine ‘safety talks’ should frequently review emergency procedures. However, alarm testing or drills requiring actual evacuation should not be conducted during asbestos removal work.

Emergency procedures should also address procedures to be followed if a person in the restricted area is injured or becomes ill.

6.1.3.2 Planning for asbestos removal from hot surfaces

If possible, the removal of asbestos from hot metal or machinery should be scheduled and planned around shutdowns, with sufficient time being allowed for the metal/machinery to cool.

Machinery should be cool before removal is attempted. Removal of friable asbestos containing material from hot metal presents one of the worst conditions for removal, because wetting the material will not be effective and airborne asbestos fibres can readily spread on convection currents in the air. Hot removal should be used only in emergency situations.

Heat stress must be considered when preparing the asbestos removal control plan, particularly in the selection of personal protective equipment and the design of the work programme. The potential for problems related to heat stress is increased whenever the work area is contained within an enclosure.

6.2 ENCLOSURES

6.2.1 Definition and use

An enclosure is often used as part of the range of control measures to prevent the spread of asbestos during work with asbestos. The need for, and the type of enclosure required, depends on the type and quantity of materials being removed, the location of the materials and the removal methods. These and other factors, including any regulatory requirements, are taken into account in the risk assessment when developing the plan of work.

An enclosure is a physical barrier through surrounds or encloses the work area to contain asbestos dust and waste arising from the work and which will also prevent the spread of asbestos materials to the surrounding environment.

Access to the enclosure is through entrance and exit openings (known as airlocks). These allow the movement of personnel, waste and equipment in and out of the work area to be controlled and also enable the decontamination of personnel, equipment and waste items on exiting. The enclosure and airlocks should be designed and constructed so that the size and number of openings (and leaks) are minimised. The enclosure should be under mechanical extract ventilation.

Anybody entering or working inside an enclosure should wear suitable protective clothing and respiratory protection and thoroughly decontaminate themselves on leaving the enclosure.

(Source: Gully Howard Technical Ltd)

Figure 6.1 - Enclosure (inside)

(Source: Gully Howard Technical Ltd)

Figure 6.2 – Enclosure (outside)

Regulations frequently require an enclosure when working on the most hazardous forms of asbestos. In Australia this is defined as 'friable asbestos containing materials' and in the UK as those materials that require a licence to work with them (asbestos insulation, asbestos coating and asbestos insulating board).

Depending on the particular circumstances of the asbestos work, the risk assessment may determine that an enclosure is required for work with non-friable material such as asbestos cement if the amount of breakage required is extensive or the removal is in a particularly sensitive area. Conversely, an enclosure may not be practicable in some instances such as working on high level pipework in the open-air, or if the scale of the work is very small and the risk of asbestos fibre release is low.

Whether an enclosure is present or not, other measures need to be in place such as restriction of access by barriers, warning signs and decontamination arrangements. Particular emphasis should be placed on work methods which minimise dust generation and prevent the spread of contamination.

6.2.2 Enclosure design and main features

The enclosure should be of a suitable size that takes into account the working requirements and the need for any plant or equipment to be used. However, it should not be oversized as this will increase the potential for spread of asbestos contamination, and the ventilation requirements. An oversized enclosure will also add to the cost of its construction.

The enclosure could make use of part of the existing building structure e.g. parts of walls, floors or ceilings or can be a purpose-built free standing structure around the work area. In either case the surfaces of the enclosure should be smooth and impervious. In most cases this is achieved by using a lining material such as polyethylene sheeting.

The enclosure should be sealed as far as possible. All joints, windows, doors, grilles, inlets etc should be sealed. Particular attention is required to ensure a good seal around pipes, ducts, conduits or other items that pass through to adjoining rooms or floors. Openings can be sealed with materials such as sheeting, tape or sealing compounds such as expanding foam.

(Source: Gully Howard Technical Ltd)

Figure 6.3 – Enclosure (service duct under floor)

There should be sufficient negative pressure (i.e. mechanical extract ventilation) within the enclosure to ensure that all 'leakage' is into the enclosure. Its function is to provide additional control if there are any small or accidental leaks from the enclosure and to control air movement during personnel and waste transfers to and from the enclosure.

The provision of sufficient ventilation of the enclosure needs to be planned to avoid creating a confined space. An additional benefit of sufficient ventilation is that it will also help to reduce the potential exposure of those working in the enclosure by reducing the concentration of airborne asbestos fibres (and other contaminants) which would otherwise build up as the work progressed. In some cases, provision of adequate make-up air may be critical.

Depending on the size and shape of the work area, it may be better to sub-divide the work area in a number of smaller enclosures. It may also be required to use more than one air extraction unit to provide sufficient ventilation or good air flow through all areas of the enclosure.

Access to the enclosures should be through openings constructed in a manner that prevents asbestos escaping into the general environment. Ideally workers should enter the enclosure from the hygiene facility which should be attached via a short space or tunnel to the enclosure. However in many cases it is not practicable to position the hygiene facility close to the enclosure and is this case a 'transiting' arrangement is used, where workers enter the enclosure via a temporary airlock system.

(Source: Gully Howard Technical Ltd)

Figure 6.4 – Enclosure (airlock entry)

Ideally, for large enclosures, separate arrangements for the removal of asbestos waste from the enclosure should be in place. Another set of airlocks that are similar to the transit airlocks can be used where space permits to enable the waste to be removed. Whatever system is used the waste asbestos should not be taken through the hygiene facility as this would increase the risk of the hygiene facility becoming contaminated. Again, these arrangements should be documented in the plan of work and be based on the risk assessment of the particular job.

Whenever practicable, sufficient and suitable clear 'viewing panels' should be included in the walls of the enclosure to allow activities to be observed by supervisory personnel without the need to necessarily enter the enclosure. If it is not practicable to install sufficient viewing panels e.g. multiple floor buildings, underground locations etc use of camera (e.g. CCTV) or webcam systems should be considered.

6.2.3 Construction of enclosures

Prior to the construction of an enclosure, the area should be inspected to determine if there is a need for a pre-clean (e.g. remove minor ACM debris or dust or any non-asbestos dust and debris), prepare the site for work (e.g. sheeting over items or removing movable items) and to deal with matters that may cause difficulties for final clearance certification (e.g. wet floors).

The construction of the enclosure will depend on a number of factors including the extent of use of the existing building structure, the duration of the job and the location of the work. In most cases some or all of the enclosure will consist of a temporary frame or structure to which impervious sheeting material is securely fixed. Other factors that need to be considered include whether it will be subject to wind and weather or will be over permeable surfaces such as gravel or soil.

Polyethylene sheeting is the most widely used material. It needs to be thick enough to withstand the wear and tear of the job. The HSE Guidance Note HSG247 (2005) suggests that for most jobs sheeting of 1000 gauge (250 micron) thickness is suitable. The NOHSC Code of practice for the safe removal of asbestos (2005) states that heavy duty plastic sheeting of minimum thickness 200 micron is required.

While experience has shown that sheeting of 200 or 250 micron is generally suitable, heavier materials may be desirable for floors. In exposed locations stronger materials such as poly vinyl chloride (PVC) sheeting reinforced with nylon mesh may be required. Where there are fire hazards, flame retardant polyethylene sheeting should be used.

A common method of supporting the sheeting is by timber framework. This should be of such dimensions to provide adequate support. HSE document HSG247 (2005) suggests timber width of 50 mm x 50 mm is sufficient for most internal work). Suitable scaffold frameworks may also be used.

Airlocks should be as big as possible to allow necessary changing, cleaning and transfer activities. HSE document HSG247 (2005) states that they should be a minimum of 1m x 1m x 2m (height). Airlocks should be constructed with access openings that prevent asbestos dust passing from one compartment to another. This is usually achieved by cutting vertical slits in the dividing sheet between compartments, then placing another plastic sheet (fixed at the top to form a flap) on the inside to cover the slit. The flap is usually weighted at the base to improve control of airflow through the airlock.

(Source: Gully Howard Technical Ltd)

Figure 6.5 – Enclosure (temporary airlock system)

The floor of the enclosure should be covered by an impervious material, unless the existing floor is impervious and can be thoroughly cleaned. Polyethylene sheeting can be used for this but may present a slip hazard, an alternative is polyethylene sheeting covered by a layer of hardboard or similar material.

6.2.4 Air extraction equipment

Whatever the type of enclosure, there will always potentially be some degree of leakage, so extract ventilation should be applied to maintain the enclosure at negative pressure relative to the surrounding areas. The object is to ensure that any leaks will be inwards into the enclosure rather than outwards.

Make-up air is usually mainly achieved by air flowing inwards through the airlocks.

(Source: Gully Howard Technical Ltd)

Figure 6.6 Enclosure (air extraction units)

The location of the air extraction unit should be chosen so that there is effective airflow management through the enclosure. Ideally the extraction inlet should be furthest from the airlocks so that air is purged through all of the enclosure. In large or complex shaped enclosures, effective air management may be achieved by using more than one air extraction unit or by use of additional ducting within the enclosure to allow the inlet to be positioned in the most suitable position. The air extraction unit should normally be located outside the enclosure with just the pre-filter inlet within the enclosure.

The main characteristics of the extract ventilation system are:

- Adequate filtration – must be fitted with a high-efficiency (HEPA) filter of at least 99.997% efficiency when tested in accordance with standard procedures.
- Incorporates coarse pre-filters to minimise dust build-up on the main filter – these pre-filters should be changed regularly.
- Adequate fan performance
- Robust construction
- Incorporate a flow indicator (ideally with audible low-flow alarm)

- Should be of sufficient capacity for the enclosure being ventilated. HSE document HSG247 (2005) recommends that for small to medium size enclosures a flow rate that achieves a minimum of 8 air changes per air is usually satisfactory
    - Note: It is important to achieve a balance between achieving a suitable airflow (number of air changes per hour) and sealing the enclosure as far as possible. The rated capacity of the extraction unit is the start point when calculating the extraction equipment required, however, in an enclosure that is sealed 'tightly' air flow may be restricted. It is important that the actual flow achieved is sufficient.
- Incorporate discharge ducting to vent the extracted air to a safe location in the outside atmosphere

In some circumstances, it may be necessary to consider whether the make-up air needs heating (or more likely) cooling or conditioning to minimise potential thermal stress issues.

6.2.5 Decontamination procedures

Anybody who enters enclosures or designated work areas may become contaminated with asbestos and will need to decontaminate on exiting. The purpose of decontamination is to ensure that personal protective equipment and respiratory protection as well as the person are cleaned to reduce potential exposure and to prevent further spread of contamination. All workers should be properly trained in decontamination procedures, including practical training.

6.2.5.1 Full decontamination

In most situations, e.g. for workers involved in removal work full contamination would normally be required. Full decontamination requires the use of a hygiene facility.

There are two different forms of the full decontamination process:

- where the hygiene facility is directly connected via an intervening space or tunnel to the enclosure;
- the use of transit facilities where the hygiene facility is physically separated from the enclosure.

Hygiene facility connected to enclosure - Hygiene facilities should, where practicable, be positioned close to the work area with an intervening space or tunnel and a one-stage air lock constructed of polyethylene sheeting, connecting the hygiene facility with the stripping enclosure.

(Source: Gully Howard Technical Ltd)

Figure 6.7 – Mobile hygiene facility

Linking up the hygiene facility to the enclosure should be normal practice unless, as is often the case, it is impracticable (eg due to limited space, restricted access and multi-storey work), to site the hygiene facility close to the work area, or if it is impracticable to provide services to it such as water and drainage for showers.

Where it is not possible to connect a hygiene facility directly to the work area then transit facilities will have to be provided to enable workers to carry out preliminary decontamination before travelling to the main hygiene facility for full decontamination.

Transit facilities usually consist of a three-stage airlock system. The system is attached to the stripping enclosure and comprises three compartments separated by weighted sheets to minimise the spread of dust between the compartments. These compartments should be of sufficient size to allow the worker to undertake the preliminary decontamination tasks.

The object of the procedure is to remove as much of the asbestos fibre and/or debris acquired in the enclosure as possible. To minimise spread while on the transit route, people should put on transit footwear and a set of transit coveralls, in place of their enclosure coveralls and footwear.

All transit routes should be delineated to ensure that other workers or members of the public keep away from this route, where practicable. Once the worker has reached the main hygiene facility, they should decontaminate as normal.

The following summarises the procedures that should be undertaken:

- Hygiene unit attached to the enclosure – entering enclosure
    - Enter hygiene unit via clean end door
    - Inspect and check respirator, undress. Put on clean personal protective equipment and respirator. Carry out fit check on respirator
    - Pass through shower area into ‘dirty’ end
    - Leave hygiene unit. Go through intervening airlock and enter enclosure.

- Hygiene unit attached to the enclosure – leaving enclosure
    - Vacuum all visible dust from personal protective equipment and respiratory protection at edge of enclosure
    - Leave enclosure and enter intervening airlock
    - Enter dirty end of hygiene unit. Remove all footwear, clothing and underwear and place in storage or disposal bags. Do not remove respirator.

- Enter shower area with respirator on, shower and use a sponge to clean respirator.
- Remove respirator and dispose of filters if necessary, finish showering
- Move into clean area carrying respirator, dry off and dress
- Exit hygiene facility via clean end external door.

- Transiting procedure – entering enclosure
    - Enter hygiene unit via clean end door
    - Inspect and check respirator, undress. Put on transit coveralls and footwear and respirator. Carry out fit check on respirator
    - Pass through shower area (without showering) into ‘dirty’ end
    - Leave hygiene unit. Walk to transit facilities via designated transit route
    - Enter outer stage of transit airlock. Remove transit coveralls and footwear, put on working clothing and footwear
    - Pass through intervening airlock and enter enclosure.

- Transiting procedure – leaving enclosure
    - Vacuum all visible dust from personal protective equipment and respiratory protection at edge of enclosure
    - Leave enclosure and enter inner stage of transit airlock
    - Clean footwear with water, sponge down or wipe respirator
    - Enter middle stage of airlock. Remove coveralls and footwear worn in enclosure and place in waste bag (or store if re-entry required). Do not remove respirator.
    - Enter outer stage of airlock. Put on transit overalls and transit footwear. Walk to hygiene facility via designated transit route.
    - Enter ‘dirty’ end of hygiene unit. Remove all footwear and clothing. Do not remove respirator.
    - Enter shower area with respirator on, shower and use a sponge to clean respirator.
    - Remove respirator and dispose of filters if necessary, finish showering
    - Move into clean area carrying respirator, dry off and dress
    - Exit hygiene facility via clean end external door.

6.2.5.2 Preliminary decontamination

In some situations full decontamination procedures may not be necessary. The type of decontamination will depend on the activity undertaken and the potential or extent of contamination that occurs during the activity. The required decontamination level should be considered as part of the risk assessment for the work. In many cases, it will be sufficient for analysts carrying out routine site work (e.g. clearance certification after asbestos removal or building surveys) to undertake only the 'preliminary' decontamination procedure.

On exiting the enclosure as part of the clearance procedure, the analyst should follow the normal decontamination procedures required for exiting this environment. Although removal work is complete, the enclosure is still active and should have a vacuum cleaner fitted with a high-efficiency particulate filter in place along with buckets of water, brushes and sponges or wipes. These will be located at the edge of the enclosure or in the inner stage of the airlock system. The vacuum cleaner should be used to clean respiratory protection and personal protective equipment including footwear. The respiratory protection should then be wiped or dampened down using a wet sponge or wipe. Footwear should also be cleaned.

Sampling equipment should also be wiped down. Coveralls should be removed in the middle stage of the airlock and placed in a waste bag. The analyst should exit the airlock system and remove the respiratory protection and place in a bag.

However, if analysts are entering enclosures or areas where it is foreseeable that contamination is liable to be more significant; the analyst should undergo full decontamination on exit from the enclosure or area. Examples where full decontamination is appropriate would include:

- when entry into a ‘live’ enclosure is required as part of any supervisory duties, or when;

- there is greater potential for contamination to occur during clearance inspection and sampling (e.g. crawling through restricted areas to inspect, survey or collect sampling pumps).

For building surveys, decontamination of footwear is likely to be the most frequent activity. This will be necessary in areas where there is asbestos dust and debris on the floor. If disposable overshoes are worn these can be taken off, bagged and replaced with new ones. Otherwise it may be necessary to wipe down the soles with wet wipes to avoid the spread of asbestos-containing dust and debris. In general the coverall and respirator should be removed on completion of the survey (or at a break) in a safe area, e.g. in the open air.

6.3 REMOVAL PROCEDURES

6.3.1 Wet and dry methods for removing asbestos containing materials

There are a number of techniques that can be used to minimise the generation of airborne asbestos fibres. The chosen stripping method (or combination of methods) will depend on a number of factors including:

- *the type of asbestos product, e.g. lagging, sprayed coating, board, cement*
- *the thickness of the asbestos containing materials*
- *the presence and nature of any coating on the asbestos containing materials*
- *the type and nature of any fixing e.g. nailed, screwed*
- *other factors, e.g. whether pipework is redundant, the asbestos containing material is damaged, accessibility etc*

(Source: HSE Guidance Note HSG247 (2005) – Reproduced under the terms of the Click-Use Licence)

In all situations generation of airborne asbestos fibres should be minimised. Techniques that minimise disturbance or breakage should be employed e.g. careful unscrewing and removal of complete panels rather than breaking out, regular cleaning up and bagging of asbestos waste products, use of vacuum cleaners fitted with high efficiency filters.

For large sites, it may be possible to remove whole sections of plant (and asbestos) intact and transport them to a 'centralised' asbestos removal site. This minimises the need for extensive enclosures on process or manufacturing areas and consolidates major asbestos removal work in a controlled area. This principle would apply to demolition work as well as 'normal' removal work where the cleaned plant can then be returned to service.

Wherever possible, dry asbestos containing materials should not be worked on. This is particularly important for work with friable asbestos containing materials such as spray coatings and insulation. Removal of dry, or poorly wetted asbestos insulation can result in exposure levels of 100 fibres / cm^3 or higher. Good wetting of the insulation should enable exposure levels during removal to be controlled to less than 1 fibre / cm^3 (or much lower).

To achieve effective controlled wetting that wets the material all the way through requires attention to the following:

- The wetting agent should be applied at a rate at which it can be absorbed by the asbestos containing materials.
- Wetting is not instantaneous. Sufficient time must be allowed for the wetting agent to thoroughly penetrate the material. This will vary; porous materials such as sprayed coatings will become saturated much more quickly than dense materials such as some pipe lagging. Soaking times may vary from a few hours up to about 24 hours.
- Avoid over-wetting which may cause the wetting agent to create slurry which may be difficult to deal with.
- The degree of penetration and wetting should be checked visually before attempting removal; sometimes a dye is used in the wetting agent to aid this examination.

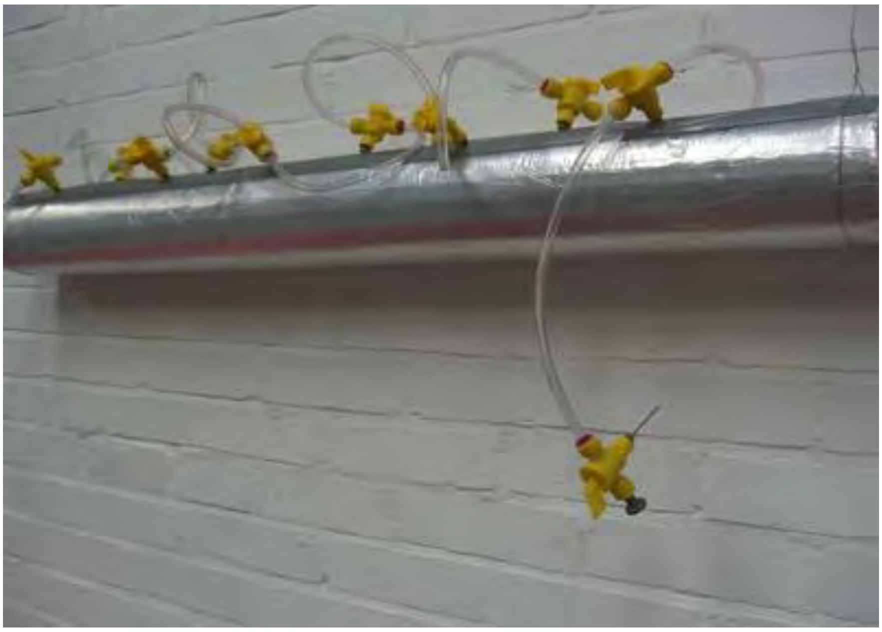
Wetting may be less applicable for harder, denser materials such as brake pads, cement pipes and panels or for those materials that have been treated with an encapsulating agent or waterproofing compound. In these cases wetting of the surfaces is still of benefit in reducing potential fibre release, but more emphasis needs to be placed on minimising breakage and disturbance.

6.3.2 Controlled wetting by injection method

Where appropriate, the asbestos containing material should be saturated through its full depth and maintained in a wet condition. Water alone may not be very effective at wetting and in most cases a wetting agent (surfactant), is added to the water, as this facilitates more rapid wetting of the material.

Injection techniques can be very effective in reducing fibre release from asbestos spray coatings and insulation during removal work, particularly when the outer surface of the asbestos containing material is sealed, covered or coated and the skin will prevent loss of fluid.

Multi-point systems have a number of needles connected together to a common injection pump. The most common and versatile arrangement is as a ‘string’ of needles about 10 – 15 cm apart. The needles are available in a range of sizes and designs depending on the type and depth of the asbestos containing material.



(Source: Gully Howard Technical Ltd)

Figure 6.8 – Wet injection equipment (last needle removed for clarity)

Correct positioning of needles and allowing sufficient time for penetration of the wetting fluid are crucial to the success of the injection method:

- Injection should be carried out in a methodical manner with needles not placed too far apart
- Where practicable, the wetting agent should be applied from the top so gravity aids the movement of the fluid through the asbestos containing materials
- Wet injection must be carried out at low pressure to ensure controlled and uniform wetting by capillary action. If higher pressures are used, intermittent wetting may occur and there is also an increased risk of the insulation being disturbed and breaking off.

6.3.3 Controlled wetting by spray method

HSE Document HSG247 (2005) states that: *This technique can be used for applications where injection is inappropriate, due to the physical nature of the material (e.g. too hard, unsealed etc). Spraying will generally wet the outer surface and penetrate only thin porous materials. However, penetration and wetting can be extended by increasing the number of sprayings and allowing sufficient 'soak-time'. Spraying can also be used to prepare surfaces before injection or removal. In summary spray wetting can be used in the following applications:*

- *where the material is unsealed and porous, e.g. thin sprayed coatings*
- *where the material is thin (less than 1 cm thick)*
- *the preparation of asbestos containing materials for removal, e.g. before the injection of damaged pipe lagging*
- *the removal of asbestos insulation board*
- *asbestos textiles, including blankets and rope seals*
- *in conjunction with glove bags*
- *the removal of asbestos debris*
- *work on asbestos cement*

(Source: HSE Guidance Note HSG247 (2005) – Reproduced under the terms of the Click-Use Licence)

Water alone may not be very effective at wetting the asbestos containing material and in most cases a wetting agent (surfactant), is added to the water, as this facilitates more rapid wetting.

For relatively small applications hand pressurised spraying equipment can be used. For more extensive applications, a low pressure spraying machine would be more appropriate.

The water spray should be applied in a manner that ensures the entire surface of the asbestos containing material is saturated; but minimises runoff. While the water spray should be copious, it should not be so forceful that the water droplets generate dust when they hit the surface of the asbestos containing material.

(Source: Gully Howard Technical Ltd)

Figure 6.9 – Wetting of asbestos textile insulation

(Source: Gully Howard Technical Ltd)

Figure 6.10 – Wetting of asbestos cement

When cutting equipment is being used to remove an asbestos containing material that is friable, the water spray should be directed at the site of the cut and the wetted material should be removed as the cut progresses. The wetted asbestos containing material should be removed in sections, immediately placed in suitably labelled asbestos waste containers and properly sealed. Any small sections that might be dislodged should be collected and properly disposed of as asbestos waste.

Although airborne asbestos fibres are significantly suppressed when the wet spray method is used, they are not entirely eliminated, so effective respiratory protection is also essential.

6.3.4 Dry removal method

Dry removal is the least preferred removal method, particularly for friable products, and should only be used if the injection or wet spray methods are not suitable (e.g. if there are live electrical conductors that cannot be isolated or effectively sealed). There is a much greater potential for airborne asbestos fibres to be generated with the dry removal method than with the wet spray method.

If the dry removal method has to be used the following factors should be considered and employed, as determined by a risk assessment:

- The work area should be fully enclosed with plastic sheeting and maintained at a negative pressure
- All personnel involved in the removal operation should wear respiratory protection provides a high assigned protection factor
- The asbestos containing material should be removed in small sections with minimal disturbance, so as to minimise the generation of airborne asbestos fibres
- Waste material placed immediately placed in appropriate containers and wetted
- Vacuum cleaners used to minimise airborne asbestos fibres by techniques such as shadow vacuuming

6.3.5 Wrap and cut removal method

There are a number of situations where this method can be used. The wrap and cut technique involves wrapping lagged pipework or assemblies with polyethylene sheeting before cutting out or disconnecting sections. These wrapped sections or assemblies can be taken to a central location where asbestos removal can be undertaken under more effectively controlled conditions. After removal of the asbestos, some or all of the underlying structure can be returned to service or disposed of as ordinary scrap once cleaned.

This method may also be suitable for the removal of redundant pipework and vessels. It is effective as it eliminates major disturbance of the lagging reducing the potential for fibre release. It is particularly suitable for small (less than 150 mm) diameter pipework. In these cases the section or assembly together with the asbestos insulation are all disposed as asbestos waste.

Wrap and cut is suitable when

- The items are manageable in size – handling large or awkward items can result in injury to personnel or tearing of the polyethylene wrapping. The pipework or plant should be divided into manageable sections.

- The items have been emptied and cleaned where necessary to remove residual hazardous materials
- The location of the item is such that building an enclosure is not practicable e.g. high level external pipework or remote locations

The need for any additional precautions such as enclosures should be considered in the planning stage.

6.3.6 Glove-bag removal method

Glove-bags are single use bags, constructed from transparent heavy-duty plastic. They are designed to allow stripping activities inside the bag by external operators using integral plastic arms and gloves, together with access ports. Glove bags are available in a range of sizes but generally they are approximately 1 metre wide and 1.5 metres deep.

Glove bags are designed to isolate small removal jobs from the general working environment. As such, they provide a flexible, easily installed and quickly dismantled temporary enclosure for small asbestos removal jobs.

(Source: Gully Howard Technical Ltd)

Figure 6.11 – Glove bag

The glove bag removal method is especially suited to the removal of asbestos lagging from individual valves, joints, piping, etc. Another use for glove bags is to remove small sections from larger assemblies to enable it to be broken down into sub-assemblies for moving to a central location for stripping the remaining asbestos. This has many advantages when working on major process units.

An advantage of glove bags is that they contain all waste and contamination within the bag, thereby reducing the need for extensive personal protective equipment and decontamination. A significant limitation on the use of glove bags is the volume of waste material they are able to contain. Care needs to be exercised to prevent overfilling of the bag with water or waste.

When using glove bags there is the potential that the bag could split or the seals fail. As part of the risk assessment the possibility that other people may become exposed if the bag splits or fails should be considered and if necessary an additional enclosure should be constructed.

Typically, if the work is in an area remote from other workers, e.g. sections of external pipework, building and maintaining an additional enclosure would not be practicable. In situations such as these, it is likely that it would be sufficient to restrict access to the area by use of suitable barriers and signs.

6.3.7 Hot stripping of asbestos

As discussed earlier, If possible, the removal of asbestos from hot metal or machinery should be scheduled and planned around shutdowns, with sufficient time being allowed for the metal/machinery to cool.

The removal of friable asbestos containing material from hot metal presents one of the worst conditions for removal, because airborne asbestos fibres can readily spread on convection currents in the air. In the limited circumstances where the dry removal of asbestos from hot surfaces is the only option (i.e. emergency situations), particular care should be taken in the selection of dust extraction equipment to cope with the convection currents involved, and the selection of appropriate personal protective equipment also becomes much more important.

The additional potential for heat stress must be considered when preparing the asbestos removal control plan. This would require particular attention with regard to the selection of personal protective equipment and the design of the work programme in terms of work / rest schedules to allow adequate recovery time from heat stress. Other factors to take into account would be the state of health of the workers, their level of fitness and whether or not they are acclimatised to the heat. It is also important that there is an adequate provision of drinking water and that the workers are trained to recognise the symptoms of heat stress.

6.4 WASTE REMOVAL

6.4.1 Waste removal procedures

Procedures for waste removal need to be developed taking into account:

- The location for temporary waste storage on the site
- The transport of wastes within the site and off-site
- The location of the waste disposal site
- Any local disposal authority requirements that apply

Loose asbestos waste should not be allowed to accumulate within the asbestos work area but should be regularly cleaned up and placed in suitable bags or containers as work progresses.

6.4.2 Waste bags and containers

In many cases asbestos waste should be collected in heavy-duty polyethylene bags. The bags should be labelled with an appropriate warning, clearly stating that they contain asbestos and that inhalation should be avoided. It is good practice to ‘double-bag’ the waste, the external surface of the first bag being cleaned to remove any adhering dust prior to placing inside a second bag. The outer bag should be clear to show that the waste has been ‘double-bagged’.

(Source: Gully Howard Technical Ltd)

Figure 6.12 – Asbestos waste bags (double bagged)

Controlled wetting of the waste should be employed to reduce asbestos dust emissions during bag sealing or any subsequent rupture of a bag. To minimise the risk of a bag tearing or splitting, and to assist in manual handling, asbestos waste bags should not be overfilled and sharp pieces of waste may need covering to minimise the risk of damage to the bag.

Large pieces of asbestos board should not be broken to enable them to fit in the bag but should be double-wrapped whole. Another option is to collect the asbestos in drums that can be sealed.

Whatever method is used to collect the asbestos waste, the routes for removing waste from the asbestos work area should be designated in the asbestos removal control plan before commencement of each removal. In occupied buildings, all movements of waste bags should be outside normal working hours.

Once the waste bags or containers have been removed from the asbestos work area, they should be placed in a lockable skip or container until removed from site for final disposal.

6.4.3 Disposal of asbestos waste

All asbestos waste should be removed from the workplace by a competent person and transported and disposed of in accordance with all relevant National or local legislation and guidelines. In some countries a licence from environmental and/or waste disposal authorities is required for the transport and disposal of asbestos waste.

6.5 TESTING, MONITORING AND MAINTENANCE OF ENCLOSURES

6.5.1 Testing and monitoring

The enclosure should be constructed correctly and adequately sealed. It is also important that it remains in good condition and that its effectiveness is maintained. A number of checks and tests may need to be undertaken to verify this, the outcome of these tests should be recorded.

6.5.1.1 Visual inspection of the enclosure prior to start of removal work

A thorough visual inspection of the enclosure should be undertaken to check that it has been constructed correctly and that it is effectively sealed. Particular attention should be paid to seals, airlocks, joints and the sealing of sheeting around pipes and conduits etc.

6.5.1.2 Smoke testing

The integrity of the enclosure should be tested by releasing smoke from a smoke generator inside the enclosure. Once the enclosure is full of smoke, all external areas should be checked for any escape of the smoke from the enclosure. Any defects in the enclosure should be rectified. An effective way of checking for minor leaks of smoke is to shine a beam of light from a torch or flashlight along the area being checked.

(Source: Gully Howard Technical Ltd)

Figure 6.13 - Start of smoke test inside enclosure

Note: The procedure in the UK is that the smoke test is undertaken with any air extraction units switched off, after successful smoke testing, the enclosure is tested with the extraction unit operating. The sheeting and airlock flaps should bow inwards slightly indicating negative pressure within the enclosure ensuring that any small residual leaks are inwards. Additional, small amounts of smoke can be released outside the enclosure around particular seals and joins to ensure they are effective. In the USA the smoke test is undertaken with the extraction units running.

Only when the integrity of the enclosure has been verified should asbestos removal commence. In some circumstances, e.g. large enclosures in remote or exposed conditions, the use and practicability of smoke testing may be limited.

6.5.1.3 Differential pressure monitors

These can be used to provide a continuous indication of the 'negative pressure' (relative to atmospheric pressure) within the enclosure. Considerable care is required when using these monitors as misleading results can be obtained. Particular problems are caused when the enclosure is subject to outside wind pressure (from strong winds). Monitoring results should always be used in conjunction with other indicators of the correct functioning of air extraction units.

6.5.1.4 Checks and inspections during removal work

A thorough visual inspection of the enclosure should also be carried out at the start of each working shift to check for any defects and to check that the negative pressure within the enclosure is being maintained (e.g. sides of the enclosure are drawn in). The air extraction unit pressure gauge should also be checked to confirm that it is operating within normal operating parameters.

6.5.1.5 Air monitoring

Air monitoring should be carried out periodically to confirm that the enclosure, airlocks and air extraction equipment are working effectively and no asbestos has spread outside. Monitoring should be performed once work starts and then periodically to demonstrate continued effectiveness of the system. Air monitoring in the vicinity of the air extraction unit discharge outlet(s) is necessary where it vents inside the building. Daily monitoring should be performed where the enclosure is located in an occupied building. However, monitoring should never be seen as a substitute for frequent thorough visual inspection of the enclosure. The requirement for monitoring and its extent will depend on the nature of the work and the location. More attention needs to be given to occupied or sensitive areas and less to unoccupied or remote locations

(Source: HSE Guidance Note HSG247 (2005) – Reproduced under the terms of the Click-Use Licence)

In addition to the air monitoring described above to confirm that the spread of asbestos is being controlled, air monitoring should also be undertaken within the enclosure to ensure that the respiratory protection is adequate for the airborne concentrations present during the work.

6.5.2 Testing and maintenance of air extraction equipment

Air extraction units should be switched on prior to removal work starting and as far as practicable left running continuously during the removal work including times when removal personnel are not on site.

The work plans should include a schedule for regularly checking air extraction equipment. It is recommended that it be checked at least once per shift for proper operation. The primary objectives of the check are to ensure that the unit is moving the expected air flow and that the filters are still functioning within designated limits. The air extraction equipment should also to be thoroughly tested and examined at suitable intervals. (In the UK this is required every 6 months).

7.0 AIR SAMPLING

7.1 PRINCIPLES AND TYPES OF AIR SAMPLING

Air sampling involves drawing air through a filter by means of a sampling pump operating at a known flow rate for a measured period of time. Airborne particles, including asbestos fibres and other fibres are collected on the filter.

In the most commonly used analytical method, the filter is 'cleared' (rendered transparent) before examination using a phase-contrast optical microscope. A proportion of the filter is examined and particles that conform to certain size criteria (see section 9.3) are counted. The number of fibres on the whole filter can be calculated and by dividing this number by the volume of air sampled the fibre concentration of fibres per cubic centimetre of air can be determined. Other analytical techniques are sometimes used, such as scanning or transmission electron microscopy. These techniques and when they are used are outlined in section 9.5.

Depending on the purpose of the monitoring the sample may be taken as a personal sample or as a static sample. Personal sampling is undertaken from within the breathing zone of the worker. This is defined in HSG248 (2005) as being 'as close to the mouth and nose as practicable, and preferably within 200 mm'. In most situations the filter holder will be fixed to the upper lapel or shoulder of the worker's clothing. It is important to ensure that the entry to the filter holder is not obstructed by the workers clothing or protective clothing.
Static monitoring (also known as area sampling or area monitoring) is usually undertaken with the filter holder positioned between 1 and 2 metres above the floor.

Air sampling for (asbestos) fibres may be undertaken for a variety of reasons. The main types of sampling are as follows:

- Personal sampling
    - To assess suitability of respiratory protective equipment
    - To check effectiveness of controls in place
    - To assess compliance with relevant exposure limits

- Static sampling
    - o Background sampling to assess fibre concentrations prior to any activity liable to generate asbestos fibres is commenced. (Note: this is generally of limited use, as in most cases the background levels are below the limit of quantification, and the fibre count may also be predominantly non-asbestos fibres)
    - o Leak monitoring outside a work enclosure to demonstrate that the controls in place are sufficient to prevent the spread of asbestos fibres and that the integrity of the enclosure is being maintained
    - o Clearance sampling as part of a clearance certification procedure to verify an area is suitable for re-occupation
    - o Reassurance sampling that may be undertaken to confirm residual airborne fibre levels (e.g. after removal of an enclosure in a building or enclosed area)

More detail on the sampling strategies adopted when undertaking air monitoring is given in Sections 7.2.3 and 7.3.

7.2 AIR SAMPLING EQUIPMENT AND PROCEDURES

7.2.1 Introduction

As stated earlier the most widely used method is examination of ‘cleared’ membrane filters by phase contrast optical microscopy. In order to obtain reliable and consistent results is it important that the sampling and analysis is undertaken by suitably trained persons who participate regularly in inter-laboratory quality control programs.

Historically, fibre counting by optical microscopy has produced very unreliable results; this can potentially still be a significant problem if the analysis is undertaken by non-accredited laboratories or by using non-standard methods.

The WHO Determination of asbestos fibre number concentrations (1997) recognises these potential problems when it states that:

'Experience has shown that this method does not always produce comparable results when used by different laboratories and different analysts. In fact, its precision is among the poorest of any occupational hygiene assessment method. Differences in results can arise through variations in sampling method, sample preparation, optical microscopy, the calculation of results and other factors, but particularly as a result of subjective effects associated with the visual counting of fibres. Such differences have both systematic and random components. The application of standard procedures and the establishment of a reproducible routine is the only way of controlling most of the sources of error inherent in the membrane filter method, which despite its limitations is the only method suitable for widespread international use in developed and developing countries'.

(Source: WHO Determination of asbestos fibre number concentrations 1997 – reproduced with permission)

Various specifications for the membrane filter method have been published by international, regional and national organisations. There is now a much greater harmonisation of specifications now than in the past (e.g. the UK adopted the WHO counting rules in 2006). Apart from harmonisation of methods comparability of results between different microscopists and laboratories can be improved by proper training and quality control systems.

WHO (1997) also states that: *'Reliable results depend on participation in a suitable quality assurance programme. The general requirements for the technical competence of testing laboratories published by the International Organisation for Standardisation (ISO 17025:2000) should therefore be followed. Microscopists should participate in intra-laboratory counting checks and laboratories should participate in a proficiency testing scheme'.*

(Source: WHO Determination of asbestos fibre number concentrations 1997 – reproduced with permission)

Many organisations demonstrate compliance with the requirements of ISO 17025 by accreditation by their National accreditation bodies e.g. United Kingdom Accreditation Service (UKAS) in the United Kingdom and the National Association of Testing Authorities (NATA) in Australia and the American Industrial Hygiene Association (AIHA) in the US.

Apart from the issues identified above, other problems associated with the method arise if

- substantial amounts of respirable fibres other than asbestos are present, which will also be 'counted' as asbestos fibres, or
- if the work will generate a large amount of non-asbestos particulate that could overload the sampling filters, making the microscopical examination of the filter difficult or impossible

7.2.2 Air sampling equipment

7.2.2.1 Air sampling pumps

Air sampling pumps should be capable of providing a smooth airflow (to avoid loss of material collected on the filter due to flow pulsation). It should also be capable of providing a flow that can be set to +/- 5% (+/- 10% for flow rates of 2 litres per minute and lower) and maintaining this flow during the sampling period. Most modern air sampling pumps have built-in flow sensors that should ensure steady flow rates throughout the sampling period. The size and type of sampling pump depends on the sampling application.

For personal monitoring, it should be light and portable enabling it to be worn by the worker on a belt or in a pocket. Due to these size limitations most personal sampling pumps operate between 1 and (up to) 4 litres per minute.

(Source: Gully Howard Technical Ltd)

Figure 7.1 – Low flow pump and sampling head

For static monitoring, these size restrictions are removed and pumps that are capable of 8 litres per minute are widely used, with the use of pumps that operate at up to 16 litres per minute becoming more common. These high flow pumps have the advantage that sampling periods can be reduced enabling results to be obtained more quickly – this is particularly useful for clearance monitoring.

With static sampling pumps a means whereby the sampling head can be positioned at a height of between 1 and 2 metres from the ground should be incorporated.

(Source: Gully Howard Technical Ltd)

Figure 7.2 – High flow pump and sampling head

7.2.2.2 Sampling heads

To comply with the WHO standard method sampling heads must be of an open-faced type filter holder fitted with an electrically conducting cylindrical cowl. This should expose a circular area of filter at least 20 millimetres in diameter. The actual diameter of exposed filter for a particular sampling head and O-ring assembly should be determined.

The cowl is designed to protect the filter from direct contact and to aid the uniform deposition of particulates on the filter by providing a laminar flow of air through the cowl. Flexible tubing is used to connect the pump to the filter holder. The cowl should point downwards during sampling to prevent dust or debris falling onto the filter. A cap or bung is needed for the cowl opening to protect the filter from contamination during transport.

If filter holders and cowls are being re-used, they need to carefully cleaned and dried prior to loading of new filters. Filters should be loaded, unloaded and analysed in areas known to be free from fibre contamination. The filter should be handled with clean flat-tipped tweezers.

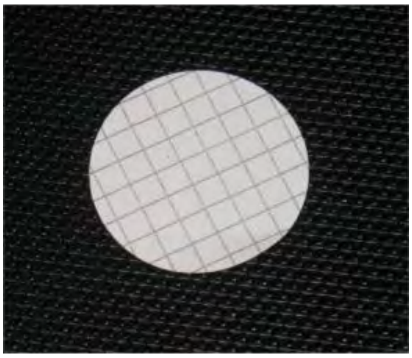
Figure 7.3a – Sampling head
Source: Gully Howard Technical Ltd)

Figure 7.3b – Sampling head (exploded view)
(Source: Gully Howard Technical Ltd)

Figure 7.3 – Asbestos sampling head (examples)

7.2.2.3 Filters

The internationally recognised sampling method specifies that the membrane filter must be of mixed esters of cellulose or cellulose nitrate, of pore size 0.8 to 1.2 micrometres. It should be 25 millimetres in diameter with a printed grid. The printed grid is on the sampling side of the filter and will be in the same plane as the particles collected on the filter and therefore provide a useful focussing aid during microscopical analysis.



(Source: Gully Howard Technical Ltd)

Figure 7.4 – 'Gridded' membrane filter

7.2.2.4 Flow measurement

The airflow should be measured by a flow meter, sufficiently sensitive to be capable of measuring the appropriate flow rate to within +/- 5 %. (Flow meters incorporated in the sampling pumps are generally not sufficiently accurate so a separate external 'working' flow meter is used). This 'working' flow meter should be calibrated against a 'master' or reference flow meter that has been calibrated against a primary standard.

For convenience of operation on-site, the working flow meter is often a float type (see below). The master flowmeter is sometimes also a float type flow meter or more often a bubble flow meter.

Figure 7.5a – Float type flow meter
(Source: Gully Howard Technical Ltd)

Figure 7.5b – Bubble flow meter
(Source: Gully Howard Technical Ltd)

Figure 7.5 – Typical flow meters

With float type flow meters it is important that it is held vertically when in use. It is also important that the length of the scale is sufficiently long and that there are a sufficient number of divisions to enable accurate readings. The indicated flow rate on a float type flow meter is affected by changes in temperature and pressure. While in most situations this is not significant, if the ambient conditions are more extreme (e.g. pressure more than 40 millibar from and temperatures more than 20 degrees from calibration conditions, correction factors may be needed).

Bubble flow meters measure the volume of air displaced by the pump directly and do not need correction for changes in temperature and pressure. The accuracy of flow measurement is generally better with bubble flow meters than with float type flow meters.

Other flow measurement devices are available such as electronic flow meters, dry gas meters and 'dri-cal' flow meters. Whatever type of flow meter is used it is important that when measuring the flow rate through the sampling train the flow meter is the first item – with the inlet to the flowmeter open to the ambient atmosphere. The external flow meter is used before sampling to set the flow rate and then disconnected. It is reconnected after sampling to verify that the flow rate has been correctly maintained.

7.2.2.5 Sampling procedures

At the start of the sampling period, the entire protective cap or bung is removed from the cowl, the pump started and the time recorded. The flow rate is measured at the start and end of the sampling period and the time at the end of the sampling recorded. The pump is stopped and the cap or bung replaced.

The flow variation between the start and end of the sampling should be maintained within +/- 10 %. If the flow has changed by more than this the sample should be rejected. Assuming that the flow has been maintained adequately the average flow rate should be used to calculate the sample volume. The sampling time should be measured to within +/- 2.5%. The filter should preferably be transported for analysis in the sealed sampling head.

7.2.2.6 Blank filters

Blank filters should be analysed to determine if there is any contamination from fibres. HSE Document HSG248 (2005) identifies three types of blanks.

- *Sampling media blanks are generated when filters are extracted from a box of unused filters. They are mounted and counted before sampling to check that the batch of filters is satisfactory. At least 1% of the filters should be checked (subject to a minimum of 4 blank filters) that are selected from each batch. Individual blank filter counts should not normally exceed 3 fibres per mm^2 (2½ fibres per 100 fields).*

(Note: filters are commercially available which have already been subjected to media blank analysis)

- *Field blanks are generated when filters are taken from satisfactory batches to the sampling area and subjected to the same treatment as filters used for sampling, the cap or bung is removed from the loaded filter holder and replaced after a few seconds. A field blank should normally be prepared for each job and sent with the field samples to the laboratory.*

(Note: the laboratory should not know which sample is the field blank. This serves as an additional quality assurance in the sampling process).

- *Laboratory blanks are generated when filters, extracted from satisfactory filter batches, are mounted and counted to check for laboratory contamination, if a field blank has indicated a need for investigation.*

(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

The WHO (1997) method specifies that 4% of the filters are analysed as sampling media blanks, together with field blanks equivalent to at least 2% of samples. Laboratory blanks are deemed to be optional.

Note: The WHO method calls for subtraction of the blank count; however this is not universally adopted. The method used in the UK does not allow subtraction of blank counts unless contamination on the blanks has been found. Also it could be considered that if the count on the blank is high enough to consider correcting for the background this may indicate that unacceptable contamination has occurred or that the laboratory may have a quality control problem.

7.2.3 Sampling strategies

The most widely used method for determining fibre in air concentration is the WHO method (WHO 1997). This method is valid for determining fibre in air concentrations ranging from the usual quantification limit of 0.01 fibres/cm^3 up to concentrations of about 100 fibres/cm^3 depending on sample volume.

To achieve maximum accuracy the sampling strategy should aim to achieve the optimum density on the filter of between 100 and 650 fibres / mm^2 of the filter. This means that in general, smaller volumes of air may be required for personal or compliance monitoring when working with asbestos materials where airborne fibre concentrations are potentially higher than those likely to be found during background, leak or clearance monitoring.

Similarly, flow rates used for personal monitoring are likely to be lower than those used for static monitoring as the size and weight of the pumps capable of higher flow rates are greater. Typically flow rates for personal monitoring range from 1 to 4 litres per minute, whereas flow rates for static samples range from 2 to 16 litres per minute.

In general, the larger the volume of air sampled, the lower the concentration of asbestos fibres in air that can be reported. However, there is a practical limit to this approach as too dense deposits of dust on the filter render examination of the filter difficult, if not impossible.

The accuracy and precision of the fibre counting method is discussed further in Section 9.3. However, the following examples illustrate typical flow rates, sample volumes and graticule areas examined, together with the expected limit of quantification for sampling onto 25 mm filters.

Table 7.1 – Typical flow rates, volumes and limits of quantification

Application	Sampling flow rate (litres/min)	Sample volume (litres)	Graticule areas examined	Limit of quantification (fibres/cm^3)
Compliance sampling	1 – 4	240	100	0.04
Assessment of respiratory protection	1 – 4	240	100	0.04
Clearance sampling	2 – 16	480	200	0.01
Background, leak and reassurance	2 – 16	480	200	0.01

In some situations these values may be varied e.g. it may be desired that a leak sample is obtained more quickly and a sample volume of 240 litres is taken. In this case if 200 graticules are examined the limit of quantification would be 0.02 fibres per millilitre. Similarly if a lower limit of quantification is required for compliance sampling a larger sample volume may be taken. Details of the calculations used are given in Section 9.4.

Personal sampling – the filter holder is positioned within the breathing zone of the worker (preferably within 200 mm of the noise and mouth). It is important that the person being monitored is identified and relevant details such as the type of work being undertaken at the time of sampling and any environmental factors that might affect the results. In addition the type of personal protective equipment (particularly the type of respiratory protection) being used should be recorded.

Background and reassurance sampling – the number and position of sampling points should cover likely sources of fibre release and areas where people are likely to be.

Leak testing – this is used to show that fibre release from a work area is adequately controlled. Sample positions to consider would include: near the entry / exit airlocks, near exhausts of air extraction equipment and near areas that may be difficult to seal completely.

7.2.4 Recording calibration and sampling information

To ensure that results are traceable and the purpose and the outcome of the sampling are clear it is important that sufficient information on the sampling and subsequent analysis is recorded. Sampling and analytical records should contain relevant site information and other information to establish the traceability of any calibrations, to calculate the results and to assure the quality of the sampling and analysis.

Details of the sampling that should be documented include:

- Date of sampling
- Type of sampling carried out (personal, leak, clearance etc)
- Location of sampling
- Any relevant environmental conditions and relevant activities taking place during the sampling period
- Identification numbers of equipment used including sampling pumps, flow measurement devices, filters and sampling heads
- For each sample
  - Unique identifier
  - Specific sample position
  - Start and finish time for each sample
  - Flow checks at start of, (during) and finish of sampling

Details of the analysis that should be documented include:

- Method of analysis
- The limit of quantification or limit of detection
- Details of the microscopical analysis including
  - the measured diameter of the graticule
  - sets of lines visible on test slide
  - number of graticule areas examined

  - o number of fibres counted, and
  - o measured diameter of exposed area of filter
- Identification numbers of equipment used including microscopes and associated test slides and micrometers

An example of a laboratory report is shown on the next three pages (Figures 7.6a - 7.6c)

UKAS TESTING 2735

the science of the built environment

GULLY HOWARD
TECHNICAL LIMITED
CHARTERED SURVEYORS

F.A.O
HAMPSHIRE COUNTY COUNCIL
Air Test Ref: 1834 – A1
Enquiries to: MISS H. ORMES

Type of testing conducted: Delete as appropriate	**REASSURANCE SAMPLING/~~BACKGROUND SAMPLING/LEAK (ENCLOSURE CHECK) SAMPLING~~ – TEST REPORT**

Please refer to reverse for descriptions of testing types and methods of assessment.

On site copy ☐
Client copy ☑

SITE NAME: ——— SCHOOL, ODIHAM, HANTS.	**Plan Date:** NOV 06
LOCATION: BOILER ROOM (210)	
Type of asbestos: INSULATING BOARD (DEBRIS)	**Tested by:** H ORMES
Removal Contractor (if applicable): N/A	**Date tested:** 25/5/07
Reason for sampling: DEBRIS DISCOVERED ON FLOOR ADJACENT SMALL PUMP.	
Comments	

In my opinion, the airborne fibre concentration at the time of sampling was SATISFACTORY.
Visual inspection at the time of sampling was…——…

Signed. H Ormes ……on behalf of Gully Howard Technical Ltd Date 25/5/07

Received on site by……——…… on behalf of ……——…… Date ……——……

To be read in conjunction with asbestos air test form QMF 89 Page 1 of 3

Opinions and interpretations expressed herein are professional observations outside the scope of UKAS accreditation.

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QMF 90 Issue Date 11/06/07 Issue no 3

Source Gully Howard Technical Ltd

Figure 7.6a an example of laboratory air test report (page 1 of 3)

TYPES OF AIR MONITORING

1. **CLEARANCE INDICATOR SAMPLING (CLEARANCE TESTING):**

   This requires air monitoring in a cleaned and visually examined enclosure from which asbestos has been removed or encapsulated.

2. **REASSURANCE SAMPLING:**

   This is monitoring which may be conducted in certain circumstances (such as when an enclosure has been removed) to confirm that the residual asbestos fibre concentrations are <0.01 f/cm3.

3. **BACKGROUND SAMPLING:**

   This is conducted to establish fibre levels prior to any activity that may lead to airborne asbestos contamination.

4. **LEAK (ENCLOSURE CHECK) SAMPLING:**

   This is performed outside the enclosure while asbestos removal work is in progress to check that the environmental controls systems are adequate.

METHOD OF ASSESSMENT:

All sampling and analysis was carried out in accordance with in-house work instructions 06.00 and 07.00 based on HSE Guidance Note Asbestos Analysts Guide, using phase contrast microscopy with a limit of detection of 0.01 fibres/cm3 (assuming that a measurement of 480 litres is made and 200 graticule areas are counted).

Source Gully Howard Technical Ltd

Figure 7.6b an example of laboratory air test report (page 2 of 3)

2735

ASBESTOS AIR TEST RECORD

the science of the built environment

GULLY HOWARD
TECHNICAL LIMITED
CHARTERED SURVEYORS

Date 25/5/07 | Air Test Refs 1834 - A1 | Site SCHOOL, ODIHAM, HAMPSHIRE | Area BOILER ROOM (210)

Microscope no 2 | Graticule diameter (µm) 100 | Blocks visible on HSE test slide: 5 | Analyst H ORMES

Filter clearing method: Acetone/triacetin. **Air test abbreviation: L–Leak, R-Reassurance, C-Clearance, P-Personal, F-Field blank, M-Microscope area**

Air test ref no.	Even Dist. Y/N	Air Test Type	Location	Pump No	Filter Head No	Time On	Time Off	Sample time	Start Flow Rate (l/min)	End Flow Rate (l/min)	Mean Flow (l/min)	Volume (litres)	Fibres	Fields	Fibre Concentration (f/cm3)
1834-A1	Y	R	BOILER RM (210)	014	3	14.10	15.10	60	8.5	8.4	8.45	507	3	200	<0.010

All filters have been counted in accordance with the Health and Safety Executives Asbestos: Analysts guide. This states that the fibre concentration should not exceed 0.01 fibres per cubic centimetre (f/cm3) of air for a 480 litre sample volume.

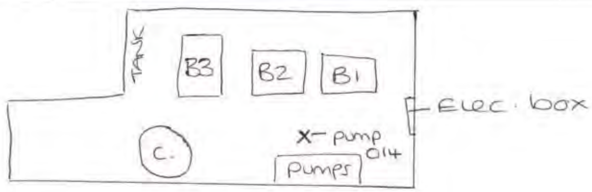
The airborne concentration is calculated by:

$$\text{Concentration} = \frac{D^2 \times N \times 1000}{d^2 \times n \times V} \text{ fibres per cm3}$$

Where

N is the number of fibres counted
n is the number of graticule areas examined
D (mm) is the diameter of the exposed area of the filter
d (µm) is the diameter of the Walton Beckett graticule
V (litres) is the volume of air sampled

Diagram of sampling positions (showing NPU and 3 stage)



Key:
NPU = extraction
_____ = enclosure boundary
.... = other boundary
= 3 stage airlock
= viewing panel

All comments and site observations are outside the scope of UKAS accreditation. Gully Howard Technical Ltd, Unit 5 St Georges Business Centre, St Georges Square, Portsmouth Hampshire. PO1 3EY Tel. 02392 728040.

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Source Gully Howard Technical Ltd

Figure 7.6c an example of laboratory air test report (page 3 of 3)

7.3 CLEARANCE SAMPLING AND CERTIFICATION

7.3.1 Introduction

Clearance inspection and sampling may be undertaken following removal of asbestos containing materials as part of the process to determine whether the work area is suitable for unrestricted re-occupation. Air samples are taken and analysed to establish airborne fibre levels and compared with a ‘clearance indicator’ or ‘clearance level’.

The requirement for clearance inspection and sampling may be determined by specific regulatory requirements or in the absence of these by normal risk assessment procedures. In general any work with friable asbestos products that required the use of an enclosure is likely to need independent clearance inspection and sampling, whereas removal of lower risk material such as asbestos cement products or textured coatings or small amounts of asbestos in an external location may only require a visual inspection to verify that the asbestos containing material has been removed satisfactorily.

The competency of the person conducting a clearance inspection is critical to a credible programme. It is highly recommended that the person responsible for the clearance inspection be independent of those undertaking the removal work. In some countries there will be specific regulatory requirements for when a clearance inspection must be done and who may do it.

For example, in Australia an independent clearance inspection is a requirement if requested by the relevant State or Territory Occupational Health and Safety Authority. In the UK all clearance monitoring must be undertaken by an organisation that is independent of the persons undertaking the removal and are accredited to ISO 17025 by UKAS for clearance inspection and monitoring.

While air monitoring is used to determine the airborne fibre concentration, it is important to realise that it only forms part of the clearance certification process. Of equal or greater importance is establishing the scope of the removal works and a thorough visual inspection.

Any protective barriers or enclosures between the asbestos work area and public areas should remain intact until completion of all asbestos removal work and successful completion of the clearance inspection and monitoring.

7.3.2 Visual inspection

In many respects the visual inspection is the most critical part of the clearance procedure. The first objective is to verify that all of the prescribed work has been performed in the manner specified. The presence of visible asbestos debris after the removal works have been 'completed' means that further decontamination is certainly required. If either the work has not been fully completed or visible contamination / debris remains, the site is not ready for clearance. Clearance sampling should not be initiated until the visible deficiencies have been corrected.

Asbestos containing dust produced during the removal process will have spread inside the enclosure. This and any residual dust on inadequately cleaned surfaces can present an on-going risk to building occupants. Therefore, a thorough visual inspection of all surfaces should be undertaken. This involves a close and detailed inspection e.g. kneeling down or using access equipment such as ladders as required. Awkward or difficult locations should not be excluded.

Particular attention should be paid to ledges, the tops of ducts, nuts and bolts on flanges, support brackets, cracks in the floor, folds in plastic sheeting and crevices or other areas which may have been overlooked during the initial clean-up. Airlocks should also be included. Inspection may be aided by use of a torch, together with a screwdriver and mirror if required.

Other locations where asbestos dust and debris are commonly found during a thorough visual inspection include:

- backs of pipes and vessels
- in screw holes or around nails and battens for asbestos insulation board

- cable trays
- holes in walls where pipes or cables pass through
- porous brickwork

Minor amounts of dust / debris may be cleaned by the asbestos removal workers at this stage. However, if the amount of dust / debris remaining is more substantial and indicates that the area has not been thoroughly cleaned the inspection should be stopped and the asbestos removal workers instructed to re-clean the area.

7.3.3 Air sampling

When the thorough visual inspection has been completed and the analyst is satisfied that all the asbestos in the plan of work has been removed and that no visible dust or debris remains then air sampling can be undertaken.

The most widely used method for determining fibre in air concentration is the WHO method (WHO 1997). The lowest airborne asbestos concentration that this method can reliably determine is 0.01 fibres / ml (based on a suitable sample volume – see below). This concentration has also been found from experience to be a level that it is reasonable to achieve with adequate cleaning and decontamination. This has led to the adoption of 0.01 fibres / ml as a 'clearance indicator' in many countries e.g. the UK, Australia, South Africa etc.

In the UK, the minimum volume of air required to be sampled for each measurement obtained during clearance monitoring is 480 litres. In the USA, the recommended volume for each measurement point is 3000 litres. While this might imply a better limit of detection, in reality both methods usually generate a limit of detection of 0.01 fibres per cubic centimetre. This is because the UK method uses a 25 mm diameter filter compared to a 37mm diameter filter in the USA. Also in the UK 200 graticule areas are examined by microscopy compared to 100 in the USA.

In order to ensure that future users of the area are not put at risk and that the air testing represents a 'worst-case' situation, dust raising activities should be undertaken as part of the clearance air sampling procedure. The purpose of this dust disturbance is to render airborne any traces of dust or debris that were not visible during the visual inspection.

The duration and extent of the dust disturbance undertaken can significantly affect the number of asbestos fibres rendered airborne during the clearance air sampling period. A number of attempts have been made to standardise the dust disturbance protocol. One example is that given in HSE Document HSG248 (2005) which specifies the use of brushing or sweeping of surfaces on which dust may have settled e.g. horizontal surfaces, floors etc as well as surfaces from which the asbestos has been removed. The duration of the dust disturbance will depend on the size of the work area – HSG248 (2005) suggests that it should be undertaken for at least 1.5 minutes per air sampling measurement point at the start of the sampling period.

Other dust raising techniques that have been used include using clipboards (covered with a plastic bag), unused asbestos waste bags (partly filled with air) or rubber hammers to hit surfaces. Other techniques (particularly in the USA) utilise leaf blowers, fans or compressed air as ‘aggressive sampling’ to render airborne settled traces of dust.

As stated before, air sampling for clearance certification should only be undertaken when the enclosure is dry and a visual inspection confirms that it is free from dust and debris. Sampling should be representative of the whole enclosure, with particular attention paid to areas where asbestos has been removed.

The number of samples (minimum of 480 litres each) that are taken will depend on the size of the enclosure and the intended use of the area when released. Except for very small enclosures there should always be at least two measurements. A formula for calculating the minimum number of measurements is given in the HSE document HSG248 (2005). More measurements may be appropriate in areas that are obviously sub-divided e.g. a floor of a building that is divided into a number of rooms. In the USA five samples are taken in each enclosure.

Table 7.2 - Typical minimum numbers of measurements (as derived from formula in HSG248)

Enclosure size		Number of measurements
Area (m^2)	Volume (m^3)	
N/A	<10	1
50	150	2
100	300	3
200	600	4
300	900	5
500	1500	6
1000	3000	9
2000	6000	11
5000	15000	16
10000	30000	20

7.3.4 Clearance certification

7.3.4.1 Multi-stage clearance certification

As stated earlier, the requirement for clearance inspection and sampling may be determined by specific regulatory requirements or in the absence of these by normal risk assessment procedures. Many regulatory authorities require some sort of clearance certification for certain types of removal works and any such requirements should be checked and followed. There is wide variation in the requirements of different jurisdictions.

To allow the inspection and assessment to be performed in a structured, systematic and consistent manner, the use of a multi-stage certification process is recommended in many countries. The following describes the clearance process adopted in the United Kingdom.

In the UK there are four stages to the site certification for reoccupation:

- Stage 1: Preliminary check of site condition and job completeness;
- Stage 2: A thorough visual inspection inside the enclosure/work area;
- Stage 3: Air monitoring;
- Stage 4: Final assessment post-enclosure/work area dismantling.

Stage 1: Preliminary check of site condition and job completeness

The analyst needs to establish the scope of the work by examining the plan of work that should be kept on-site until the work is completed. The plan of work should clearly show:

- where the asbestos to be removed was;
- if any asbestos materials were to remain in situ; and
- what the asbestos materials removed were.

The clearance certificate should include a diagram or photos so that the scope of the work is clear. It should contain the main features such as the enclosure (or work area) including airlocks, transit and waste routes, and skip and hygiene facilities. It should provide details of sizes or dimensions.

HSE Document HSG247 The Licensed Contractors' Guide (2005) also states:

When the scope of the work has been understood and verified, the analyst should ensure that the hygiene facilities are still intact, operational and clean. The analyst should then check the surrounding areas to the enclosure including the transit and waste routes, and the areas immediately adjacent to the enclosure.

The purpose of this inspection is to check for obvious signs of contamination arising from the work; either through leaks in the enclosure, burst waste bags or debris from inadequate decontamination procedures. This inspection does not require the detailed visual examination which is necessary inside the enclosure or work area.

The integrity of the enclosure should also be checked and any defects repaired. Air extraction equipment must still be in place and in operation. Air extraction equipment should be switched off just before starting the Stage 3 air monitoring and should not be removed until the third stage of the site certification procedure has been completed and the enclosure is being dismantled.

The analyst should examine the enclosure through the viewing panels before entering in order to gain an initial impression of the job completeness. Items to look out for include:

- *waste remaining in the enclosure;*
- *visible debris on the surfaces;*
- *inadequate lighting to conduct a visual inspection;*
- *essential equipment such as ladders or scaffolding are still present so it is possible to inspect all areas;*
- *puddles of water, wet patches and leaking pipes;*
- *evidence that sealant has been applied to exposed surfaces;*
- *potential hazards inside the enclosure.*

If any of these items need to be actioned, they should be dealt with before the enclosure is entered. The analyst should also discuss with the contractor if any of the items were identified in the plan of work as needing special attention (eg ingress of water).

The analyst must make a formal record of the scenarios encountered and the discussions and actions that took place to rectify them. Findings at Stage 1 should be recorded on the certificate of reoccupation and verified with the contractor before moving on to the second stage. A note should be made of any remaining asbestos that was outside the scope of the work.

Only when the analyst is satisfied with the Stage 1 inspection, should they enter the enclosure to carry out the Stage 2 visual inspection.

(Source: HSE Guidance Note HSG247 (2005) – Reproduced under the terms of the Click-Use Licence)

Stage 2: Thorough visual inspection inside the enclosure/work area;

The area should be free of all asbestos and therefore the analyst would not normally need to undergo full decontamination on exiting the enclosure. However, if extensive debris and surface contamination is present, the analyst should stop the visual inspection and exit the enclosure before any significant disturbance or clean-up takes place. Otherwise the analyst may become contaminated by the contractors' activity and will need to follow full decontamination procedures on leaving the enclosure (see section 6.2.5). Details of the visual inspection procedure are given in Section 7.3.2.

Stage 3: Air monitoring;
Details of the air monitoring procedure are given in Section 7.3.3.

Stage 4: Final assessment post-enclosure/work area dismantling.
When the enclosure (or work area) has passed the visual inspection (Stage 2) and air monitoring (Stage 3), the enclosure can be dismantled. The analyst usually remains on site during the dismantling.

Reassurance air monitoring may be carried out during this dismantling procedure. After the enclosure has been removed, the area should be visually inspected again by the analyst. At this stage the inspection is for obvious asbestos debris such as from the sheeting of the enclosure as it was dismantled or from debris which has been missed during cleaning. The analyst should also re-inspect the waste route and transit route for asbestos debris.

The analyst should record what has been inspected, what was found and the outcome on the certificate of reoccupation.

7.3.4.2 Independence and competence

It is important that the person assessing whether the area is thoroughly clean and fit for reoccupation (or, as appropriate, demolition) is competent. It is good practice that this person is not affiliated with the organisation which undertook the asbestos removal. In many countries these requirements can be met by using an organisation that is accredited to ISO 17025 for clearance inspection and monitoring by their relevant National accreditation body e.g. UKAS, NATA or AIHA.

If this assessment of the enclosure / work area is satisfactory, then a clearance certificate or certificate of reoccupation is issued. The clearance certification process is a vital component in asbestos removal work. The issue of a certificate by an impartial and competent organisation provides the crucial reassurance and security to the subsequent building users.

7.3.4.3 Certificate of reoccupation

The purpose of the certificate of reoccupation is to record completely and unambiguously the sequence of events that have occurred. This enables all parties to understand the scope and extent of the clearance and be aware of any particular matters that have been identified and dealt with.

At each stage the analyst and asbestos removal worker's representative should sign to acknowledge the outcome. If one stage fails, the reasons for the failure should be documented and the clearance certification process halted. The certificate issued, whether for a pass or a failure, provides evidence of when the outcome was communicated. Each certificate should bear a unique number.

7.3.4.4 Inspection certificate for the hygiene facilities

On completion of the removal works, the hygiene facility should also be inspected and air tested. It should be clean and dry before the inspection takes place and any potentially asbestos contaminated materials removed (eg bags containing used coveralls, used/discarded respirator filters). If the inspection is satisfactory, air tests including dust disturbance of surfaces should be undertaken in the dirty and shower areas. The clearance should be carried out using the same criteria as for enclosures. A separate inspection certificate should be issued for the hygiene facility.

8. ANALYSIS OF BULK SAMPLES

8.1 INTRODUCTION

The aim of this section is not to prepare the reader to be able to competently perform analysis of bulk asbestos samples. It is intended to familiarise the reader with the procedures used so that they appreciate what is involved and the strengths and weaknesses of the procedures.

There are six different types of regulated asbestos minerals each with slightly different compositions. It is these differences in composition and structure that are exploited to enable us to distinguish between the asbestos types, and between asbestos and other fibrous materials.

(Source: Gully Howard Technical Ltd)

Figure 8.1 – Six "standard" asbestos minerals

A representative sample of the material thought to contain asbestos is collected for examination. In the analytical laboratory, this is examined by eye, followed by more detailed examination using a low power (X 8 to X 40) stereo-microscope. One or more representative sub-samples may be prepared mechanically and/or chemically for further examination. Fibres observed in the course of these examinations are categorised tentatively on the basis of morphology and certain physical properties. Each fibre type so recognised is sampled by selecting a few fibres or bundles, and these are *mounted in a refractive index (RI) liquid chosen to match the most likely asbestos type. The fibres then are positively identified as one of the six regulated asbestos types on the basis of their detailed optical properties using polarised light microscopy (PLM) with magnifications from about X 80 upwards, as appropriate to the type of sample.*

(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

Polarised light microscopy is the most widely used method for determining whether or not a bulk sample contains asbestos, however, it should be noted that other analytical techniques may be used such as electron microscopy.

8.2 HEALTH AND SAFETY PRECAUTIONS

An important part of the analysis procedure is removing asbestos fibres from the matrix that binds them; this must be done in such a way as to minimise the risk of releasing fibres into the laboratory atmosphere.

The initial sample inspection, stereo microscope examination and sample preparation should be carried out in a suitable safety cabinet that has a minimum face velocity of 0.5 m/s (e.g. in the UK a safety cabinet which conforms to BS 7258). Sample bags should only be opened inside the safety cabinet and care taken to ensure that all waste is disposed of correctly.

(Source: Gully Howard Technical Ltd)

Figure 8.2 – Safety cabinet for asbestos bulk analysis

The safety cabinet should ideally be fitted with a visual system to demonstrate proper functioning, such as a permanently installed flow meter or at least a gauge showing the static pressure in the duct or plenum of the hood. This enables a check to be undertaken before each use. The system should be thoroughly inspected and tested at regular intervals (e.g. every six months). In order to confirm the cleanliness of the work environment, periodic air tests should be carried out at suitable intervals.

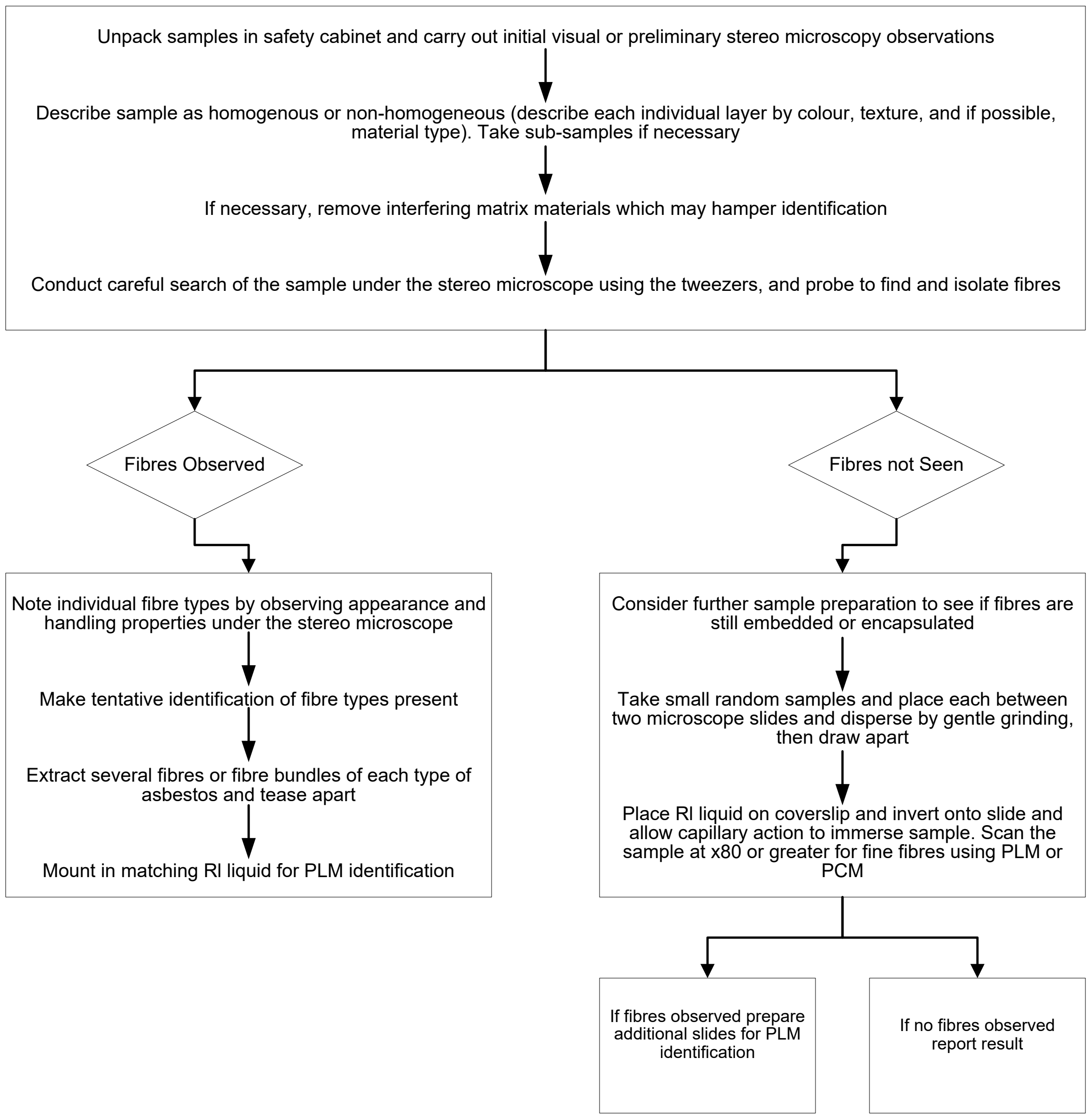
Suitable risk assessments should be undertaken for all the chemicals used in the preparation and analysis of the samples (e.g. dilute hydrochloric acid and refractive index solutions).

Of particular concern with use of acid is the need to avoid skin and particularly eye contact. Also it is important that if dilute acid is prepared from concentrated acid, this must be done by adding the concentrated acid (with stirring) to the water. Never add water to concentrated acids.

Refractive index solutions are a complex mix of various chemicals, many of which are harmful or toxic. Inhalation should be avoided and care taken to avoid skin contact.

8.3 FIBRE IDENTIFCATION

The following flow chart gives an overview of the bulk sample analysis process:



(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

Figure 8.3 – Overview of the bulk analysis procedure

8.3.1 Initial Examination

The following paragraph, taken from HSE Document HSG248 The Analyst's Guide (2005), describes the first step in the process of fibre identification:

'The entire sample should be examined by eye to describe the type of material or product present, and to establish whether or not visible fibres are

present. The natures of any binder materials should be noted, as they may influence treatment of the sample. Examination of insulation samples and many manufactured products under the stereo microscope will aid the detection of fibres and allow some initial assessment of the number of fibre types present. Certain products such as vinyl floor tiles, textured coatings and settled dusts, may contain asbestos fibres that are too fine to be detected in this initial examination. The appearance, colour and texture of the sample, and any fibre types observed, should be recorded. For non-homogeneous samples, each separate layer, part or variant may require individual description. Sample preparation and the analysis of the sample are dependent on the quality of the initial visual examination. Also, adequate description of the appearance of the sample is important in establishing where, or in which part, the asbestos material is present'.

(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

This initial examination may be carried out by eye and with the aid of the low powered stereo microscope

8.3.2 Sample Preparation

The purpose of sample preparation is to:

- Ensure that fibres are released from the matrix including those present in smaller concentrations.
- Remove fine particles adhering to the fibres.
- Obtain dry fibres (essential for dispersion staining techniques).

The amount and type of sample preparation will depend on the nature of the material. For example, loosely bonded insulation would require little preparation, whereas an asbestos-based cement board might require a mixture of chemical and physical techniques. Sample preparation is carried out in the safety cabinet or other work station with suitable local exhaust ventilation on a representative portion of the sample.

Sample preparation may include the following:

Physical extraction – if the fibres are clearly visible and easily separated from the matrix then tweezers may suffice. However, more vigorous mechanical manipulation by way of scraping the surface of the material, or breaking with pliers may have to take place in order to reveal fibres.

Acid digest – Dilute hydrochloric acid (e.g. 3 molar) may be used to remove calcium-based binders which are common in insulation and insulation board. The acid can be added to a subsample of the material and once the effervescence has stopped the samples is then filtered and dried.

Textured coatings are particularly difficult to analyse therefore a technique can be employed where drops of 3 molar hydrochloric acid are placed on a slide and then a random portion of small particles of the textured coating are added. The slide is then prepared and examined for fibres; if fibres are detected then further analysis can take place using the original sample and RI liquids.

Solvent extraction – binding agents such as bitumen can be treated by exposure to solvents, but this will require additional laboratory equipments and reagents.

Combustion – some organic binders may be removed by ignition at 400°C, but care must be taken as the optical properties of any asbestos fibres present may be affected.

Wet grinding - grinding the material in a pestle and mortar to separate fibres from the matrix and filtering the material through a filter. The filter is then washed with water and dried on a hot plate.

8.3.3 Stereo Microscopy

The stereo microscope is used (inside the safety cabinet) for the primary examination of samples taken for asbestos fibre identification.

Figure 8.4a – Stereo microscope
(Source: Gully Howard Technical Ltd)

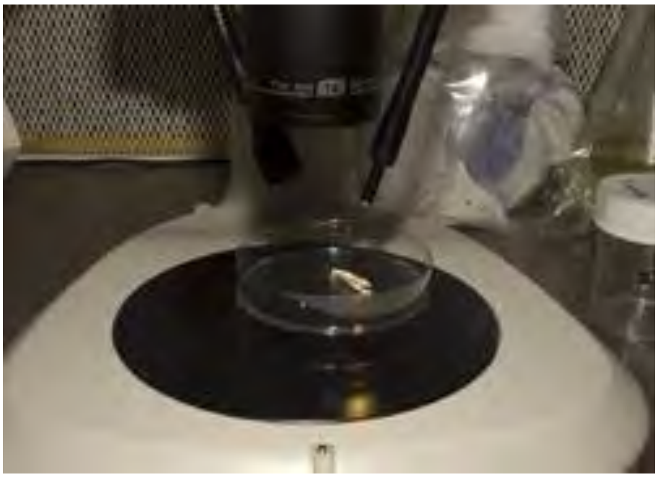


Figure 8.4b – Examination of sample
(Source: Gully Howard Technical Ltd)

Figure 8.4 – Use of stereo microscope

Using the stereo microscope the following physical characteristics of any fibres present should be noted:

- **Colour**

- **Lustre** - is a description of the way light interacts with the surface of a mineral, rock or crystal. For example chrysotile has a silky lustre and crocidolite has a metallic lustre.

- **Elasticity** – the ability of the fibre to return to its original shape when a distorting force is removed

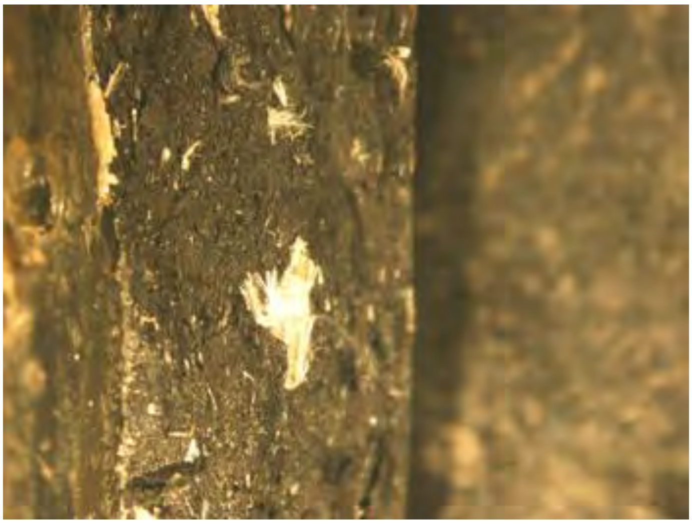
- **Tenacity** - resistance a mineral offers to breaking, crushing or bending

- **Morphology** - its form or structure

(Source: Gully Howard Technical Ltd)

Figure 8.5 – Chrysotile fibres

Asbestos fibres can primarily be recognised by the fineness of the fibres which are usually present in tight bundles. In addition an experienced analyst will be familiar with the characteristics above.

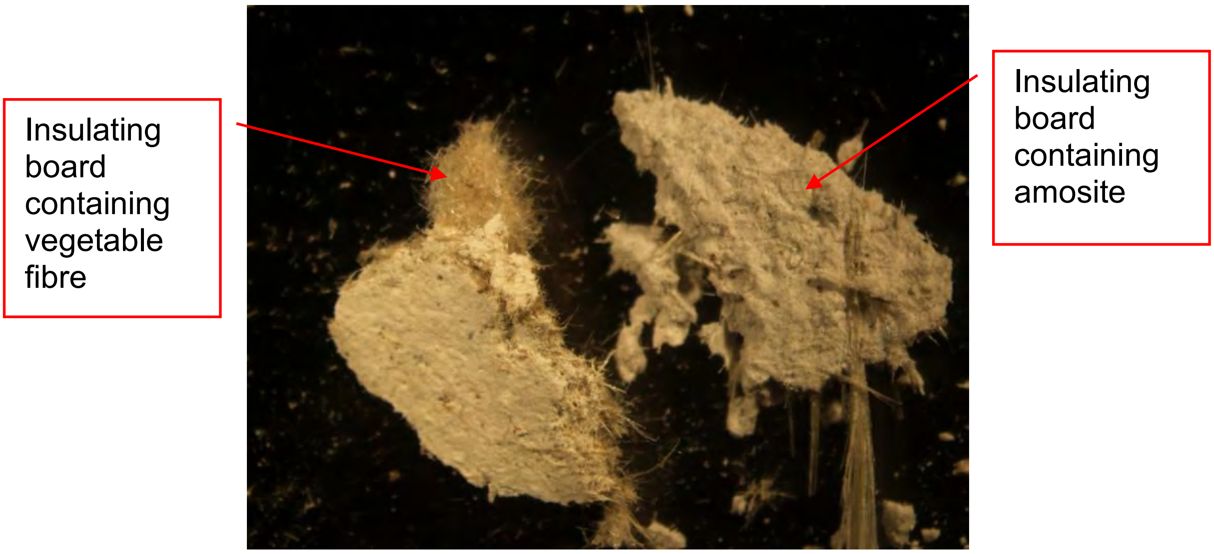


(Source: Gully Howard Technical Ltd)

Figure 8.6 – Chrysotile fibres in asbestos cement

(Source: Gully Howard Technical Ltd)

Figure 8.7 – Asbestos fibres in asbestos insulating board



(Source: Gully Howard Technical Ltd)

Figure 8.8 – Amosite fibres in asbestos insulating board next to insulating board containing vegetable fibres

A tentative identification based on the stereo microscopy evaluation is used to select the most appropriate Refractive Index mounting liquid (RI Liquid). Fibres should be dry and relatively free from other particulate matter. Representative fibres or fibre bundles are chosen and are placed on a clean microscope slide into a drop of RI liquid, and a clean cover slip is lowered gently onto the slide. The RI of the liquid selected should be close to one of the two observable fibre RIs for positive identification (for example 1.550 for chrysotile, 1.670 for amosite and 1.700 for crocidolite).

(Source: Gully Howard Technical Ltd)

Figure 8.9 – Refractive index liquids

Table 8.1 below gives a summary of the physical properties and appearance under the stereo microscope that can be used to determine the choice of refractive index liquid for Polarized Light Microscopy (PLM).

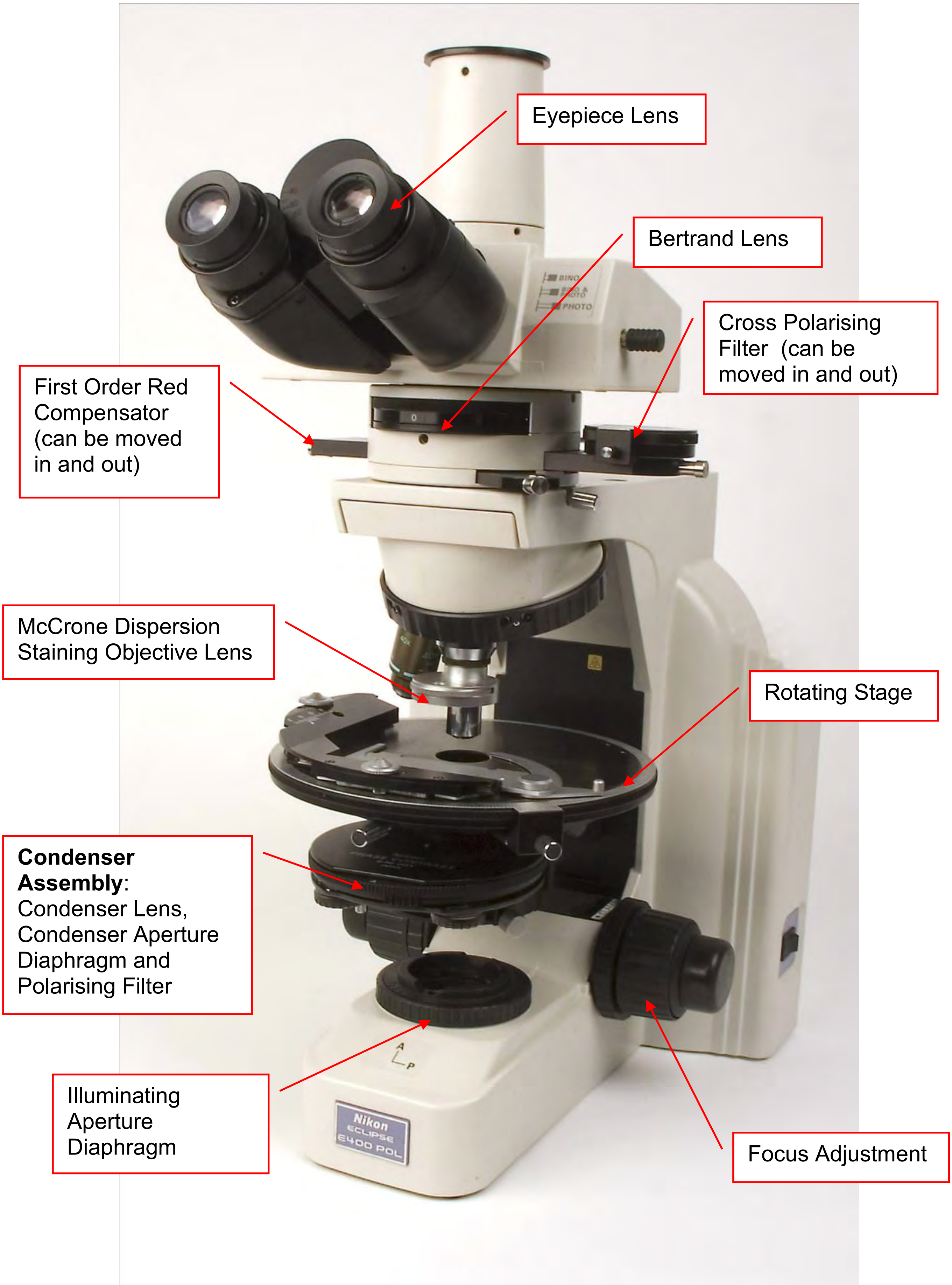
Table 8.1 – Physical properties and appearance under stereo microscope						
Morphology / appearance	Bundles of flexible sinuous fibres	Parallel, straight fibre bundles			Parallel, straight fibre bundles	
Colour	White	White to light brown			Pale green	Blue
Lustre	Silky	Vitreous	Vitreous	Vitreous	Vitreous	Metallic (dark and highly reflective)
Tenacity	Flexible	Flexible	Flexible	Flexible	Flexible	Flexible
Elasticity	Inelastic	Elastic	Elastic	Elastic	Elastic	Elastic
Tentative asbestos type	Chrysotile	Amosite	Antho-phyllite	Tremolite	Actinolite	Crocidolite

8.3.4 Polarised Light Microscopy

8.3.4.1 Polarisation of Light

Ordinary un-polarised light consists of a bundle of rays having a common propagation direction but different vibration directions. Polarised light, on the other hand, has a single vibration direction. The vibration direction is always perpendicular to the direction of propagation. Ordinary light can be polarised with a polarising filter and this method is used in microscopes

Only glasses, some plastics and crystals in the cubic system show a single refractive index, they are called isotropic. Other transparent particles (for example asbestos fibres) have different refractive indices depending on the direction of light through the particle and are known as called *anisotropic*. Polarised light is used to study anisotropic crystals.



(Source: Gully Howard Technical Ltd)

Figure 8.10 – Polarised light microscope

8.3.4.2 Colour and Pleochrosim

Pleochroism is the characteristic of coloured anisotropic substances to show different colours in different directions. The colour changes with orientation and can be seen only in polarised light. Orientation of the fibre with respect to the polarised light can be varied using a rotating stage on the microscope.

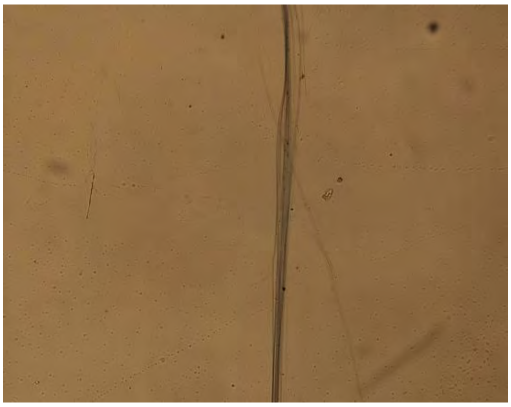


Figure 8.11a – Fibre perpendicular
(Source: Gully Howard Technical Ltd)

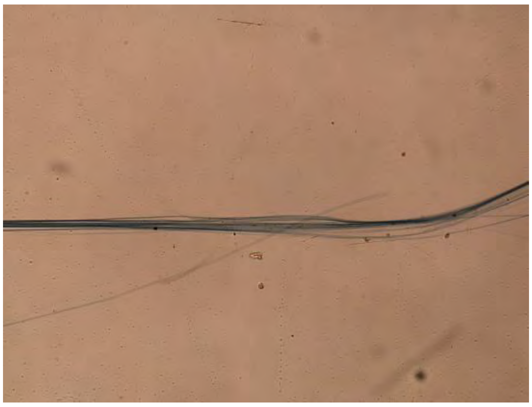


Figure 8.11b – Fibre parallel
(Source: Gully Howard Technical Ltd)

Figure 8.11 – Crocidolite under plane polarised light

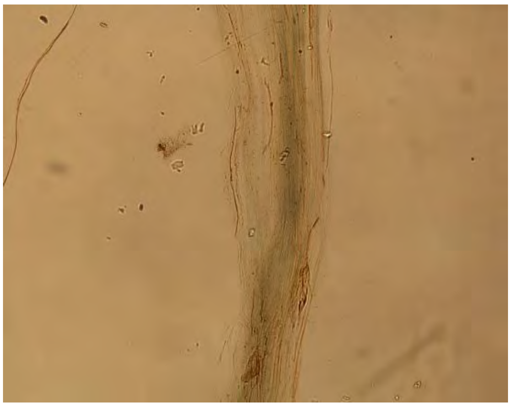


Figure 8.12a – Fibre perpendicular
(Source: Gully Howard Technical Ltd)

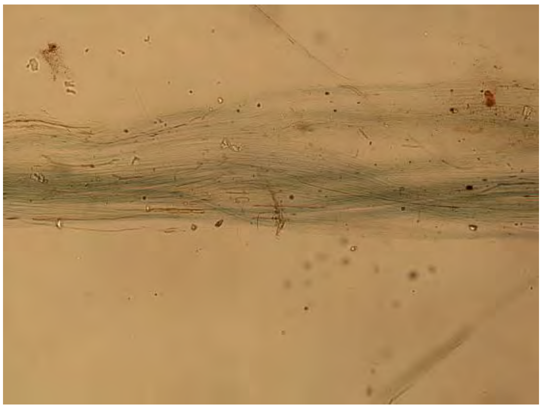


Figure 8.12b – Fibre parallel
(Source: Gully Howard Technical Ltd)

Figure 8.12 – Actinolite under plane polarised light

8.3.4.3 Birefringence

The numerical difference between the highest and lowest refractive indices of a mineral is known as the birefringence. When a particle with more than one refractive index is observed between crossed polars with its planes of vibration at 45° to those of the polariser, interference colours are observed against the dark background. For asbestos these interference colours depend on the fibre thickness, and on birefringence

(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

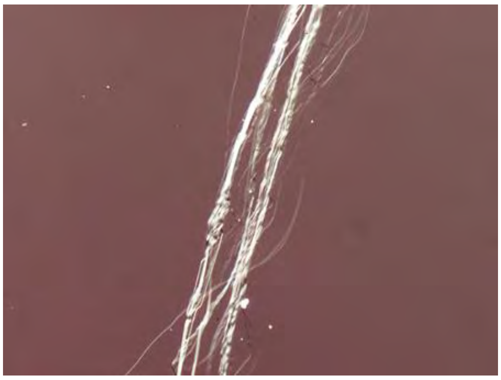


Figure 8.13a – Fibre at angle to polariser
(Source: Gully Howard Technical Ltd)

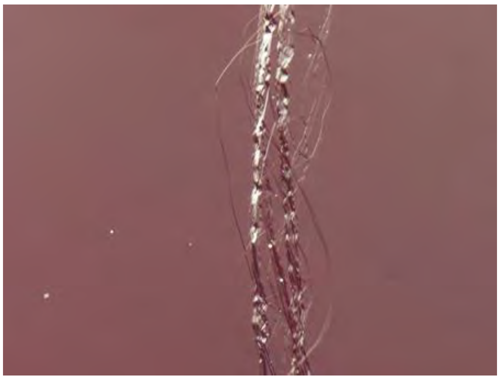


Figure 8.13b – Fibre in line with polariser
(Source: Gully Howard Technical Ltd)

Figure 8.13 – Chrysotile fibres showing low birefringence

(Source: Gully Howard Technical Ltd)

Figure 8.14 – Amosite fibres showing moderate birefringence

8.3.4.4 Angle of Extinction

Extinction is the condition when an optically anisotropic mineral appears dark when observed between crossed polars. As the microscope stage is rotated, asbestos fibres will go dark at particular angles before returning to the birefringent colours described above.

8.3.4.5 Sign of Elongation

With crossed polars and the first order red compensator inserted at 45^0 (refer to photo in 8.3.4.1) the optical orientation of the fibres can be determined.

Figure 8.15a – Blue (South West – North East)
(Source: Gully Howard Technical Ltd)

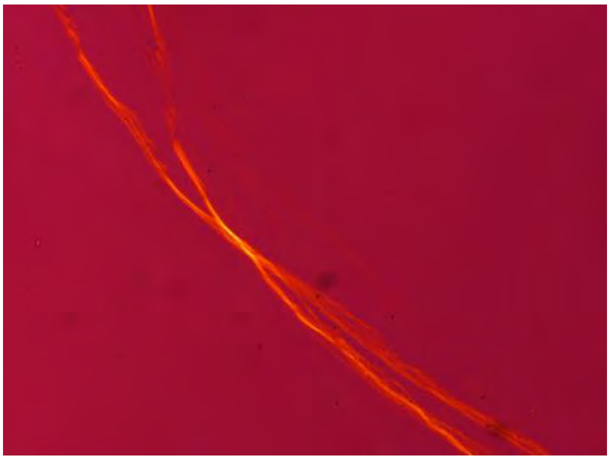


Figure 8.15b – Yellow (South East – North West)
(Source: Gully Howard Technical Ltd)

Figure 8.15 – Chrysotile fibres showing positive sign of elongation

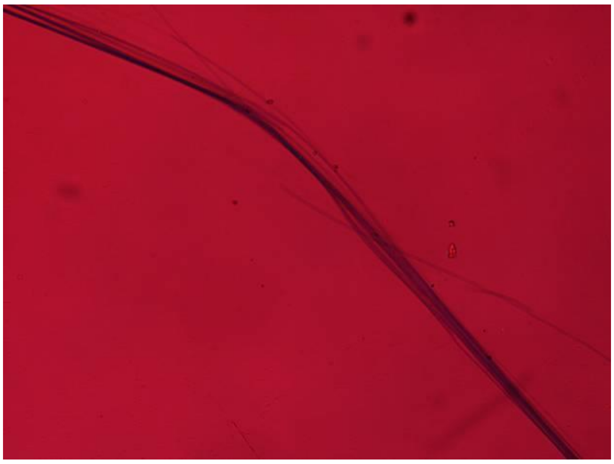


Figure 8.16a – Blue (South East – North West)
(Source: Gully Howard Technical Ltd)

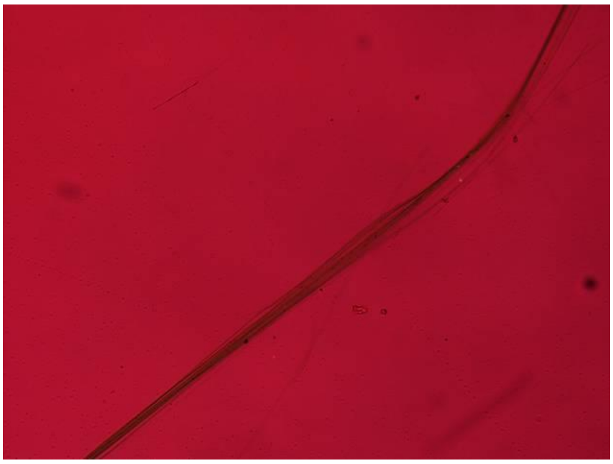


Figure 8.16b – Yellow (South West – North East)
(Source: Gully Howard Technical Ltd)

Figure 8.16 – Crocidolite fibres showing negative sign of elongation

The colour changes observed are determined by whether the high RI vibration plane is parallel to the long or short axis of the fibre.

Table 8.2 – Summary of optical properties under polarised light microscopy

Optical Properties							
Asbestos Type		**Chrysotile**	**Amosite**	**Anthophyllite**	**Tremolite**	**Actinolite**	**Crocidolite**
RI Liquid		1.550	1.670	1.605	1.605	1.640	1.700
Pleochroism	Fibre parallel	None	None	None	None	Green	Blue
	Fibre perpendicular	None	None	None	None	Grey	Grey
Birefringence		Low	Moderate	Moderate	Moderate	Moderate	Low
Extinction		Parallel	Parallel	Parallel	Parallel or small angle	Parallel or small angle	Parallel
Sign of elongation		Usually positive (length slow)	Positive (length slow)	Positive (length slow)	Positive (length slow)	Positive (length slow)	Usually negative (length fast)

8.3.4.6 Dispersion Staining

Dispersion staining is used to describe the colour effects produced when a particle or fibre immersed in a liquid (which has a refractive index near to the particle but greatly different dispersion curve) is viewed under a microscope by transmitted white light. With polarised light and anisotropic particles, different dispersion colours will be obtained, depending on the orientation of the particle or fibre. A McCrone's dispersion staining objective lens is used with the centre stop then the annular stop in place and the colour changes are noted as the orientation of the fibre is rotated from a north-south to an east-west alignment.

(Source: Gully Howard Technical Ltd)

Figure 8.17 – McCrone dispersion staining lens

Table 8.3 gives a summary of the expected dispersion staining colours:

Table 8.3 – Expected dispersion staining colours

RI LIQUID	TYPE OF ASBESTOS	CENTRE STOP	ANNULAR STOP
1.700	CROCIDOLITE	↑Blue →Blue	↑Grey →Blue
1.670	AMOSITE	↑Red/blue →Yellow	↑Pale yellow/green →Pale blue/grey
1.640	ACTINOLITE	↑Blue →Yellow/Brown	↑Pale yellow →Pale yellow/green
1.605	ANTHOPHYLLITE	↑Red/blue →Yellow	↑Pale yellow →Pale blue/grey
1.605	TREMOLITE	↑Red/blue →Yellow	↑Pale yellow →Pale blue/grey
1.550	CHRYSOTILE	↑Blue →Red/purple	↑Pale yellow →Pale yellow/green

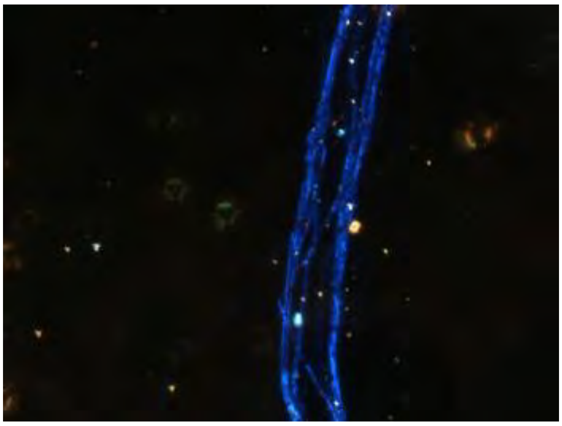


Figure 8.18a – Blue (Fibre perpendicular)
(Source: Gully Howard Technical Ltd)

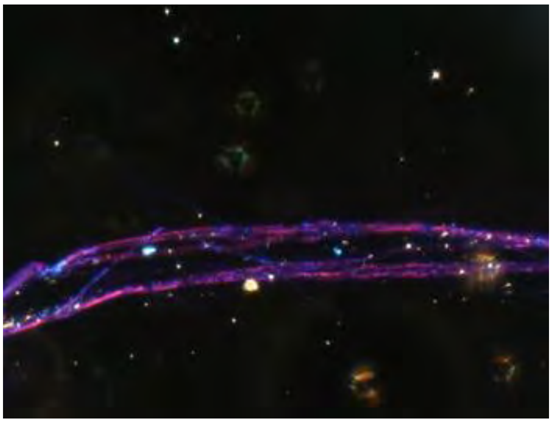


Figure 8.18b – Red-purple (Fibre parallel)
(Source: Gully Howard Technical Ltd)

Figure 8.18 – Dispersion staining colours (centre stop) chrysotile in RI liquid 1.55

Figure 8.19a – Yellow-green (Fibre perpendicular)
(Source: Gully Howard Technical Ltd)

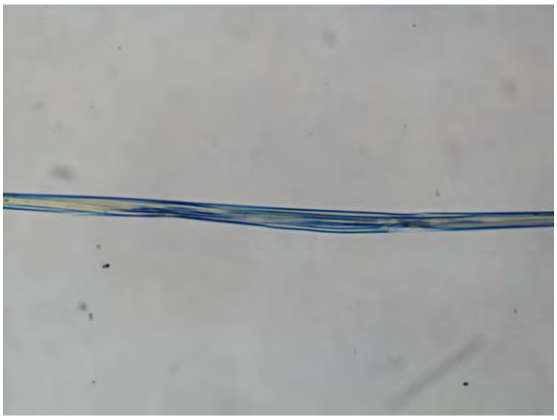


Figure 8.19b – Blue-grey (Fibre parallel)
(Source: Gully Howard Technical Ltd)

Figure 8.19 – Dispersion staining colours (annular stop) amosite in RI liquid 1.67

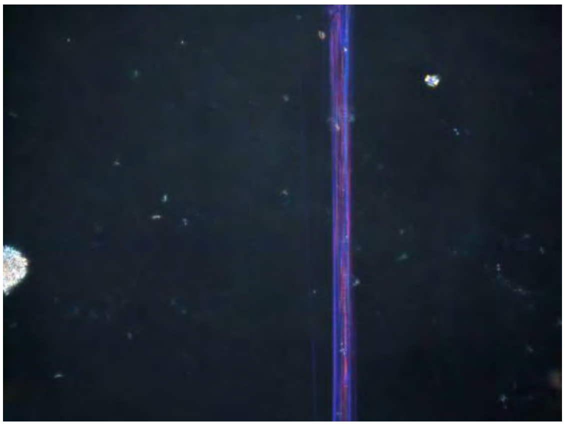


Figure 8.20a – Red-blue (Fibre perpendicular)
(Source: Gully Howard Technical Ltd)

Figure 8.20b – Yellow (Fibre parallel)
(Source: Gully Howard Technical Ltd)

Figure 8.20 – Dispersion staining colours (centre stop) amosite in RI liquid 1.67

8.4 QUALITY CONTROL

8.4.1 Quality Control procedures

Analysis of bulk samples should only be undertaken by a suitably trained and experienced analyst.

A routine quality assurance programme to assess the quality of the results produced by the laboratory should be developed and implemented. The purpose of a quality assurance programme is to ensure that the sampling, analysis, recording and reporting of the results all meet acceptable standards. A quality assurance programme will usually have a written protocol to describe how each stage of the procedure is conducted and will define the types of quality control measurements and checks required.

In addition to the in-house quality control measure described above, the laboratory should take part in an externally administered proficiency testing scheme. Two examples of these are the UK Health and Safety Laboratory Asbestos in Materials Scheme (AIMS) and the American Industrial Hygiene Association Bulk Asbestos Proficiency Analytical Testing (BAPAT) program.

The performance of an analyst will be affected by the variety, complexity and number of samples analysed in a day. Therefore some guidance on the amount of samples that an analyst should examine in a day is appropriate. In the UK the Health and Safety Executive has recommended that for samples that are more difficult to analyse such as textured coatings and vinyl floor tiles no more than 20 should be analysed in a day. For samples that are generally easier to analyse such as asbestos cement, asbestos insulating board, most insulation and sprayed asbestos no more than 40 should be analysed in a day.

8.4.2 Detection limits

According to HSE Guidance Note HSG248, *'With careful application of this method a single fibre may be found in a few milligrams of dispersed material.*

In theory, for a fibre about 100 micron long by about 2 micron diameter, this implies a detection limit in the order of 1 part per million by mass. With such a sensitive method ***it is important that all procedures be designed to avoid cross-contamination.***

(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

It is likely, however, that concentrations of asbestos in bulk samples at this order of magnitude may well not be routinely detected. This is generally not an issue as the vast majority of products that intentionally contained asbestos are likely to contain asbestos in the order of at least 0.1% or indeed much greater.

The percentage of asbestos in a sample cannot be determined by the method described earlier. Some testing laboratories may give an approximate indication of asbestos content in general categories such as 'trace', 'minor' or 'major' components.

Many regulatory authorities define 'asbestos containing' in terms of licensing or waste regulation requirements as being above some defined percentage of asbestos. This is typically about 0.1%. Materials that contain less than this amount are not 'asbestos-free' but may be at a level where the risk assessment, particularly for non-friable materials would not raise special concerns.

8.5 INTERFERING FIBRES AND PRODUCTS

The following fibres occur infrequently in samples for asbestos identification. The appearance or morphology of some types of fibres resemble chrysotile, however they can be distinguished by other properties.

- Shredded polyethylene resembles chrysotile and shows some similar dispersion staining colours with RI liquid 1.55. However, birefringence is high and they can also be differentiated as they melt in a flame.

- Leather swarf fibres have low birefringence and similar dispersion staining colours. While there are some similarities in morphology to chrysotile, differences in structure and how the material handles can be detected during low-power microscopical examination

- Macerated aramid fibres have similar morphology to chrysotile but show very high birefringence

- Natural organic fibres such as paper, feathers and even spider' webs can show similar dispersion staining colours with RI liquid 1.55. However, morphology generally distinguishes them from chrysotile, confirmation can be obtained by ashing the sample to remove the organic material

- Talc fibres can show some similarities in dispersion staining liquid 1.55 but can be recognised by characteristic morphology of bent (kinked) and twisted fibre structures

Similarly some mineral fibres superficially resemble amphiboles. These can also be differentiated by other properties. These include fibrous brucite and wollastonite

9 FIBRE COUNTING

9.1 PHASE CONTRAST MICROSCOPY

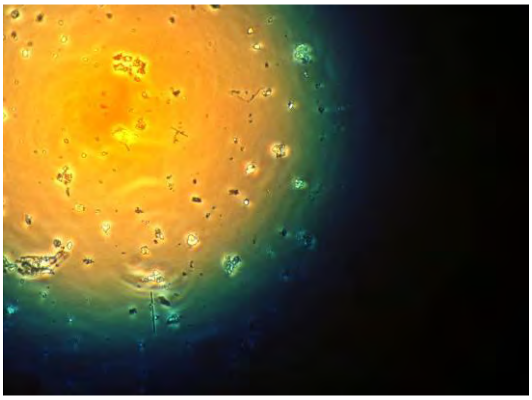
In simple terms phase contrast modifies the image formation and therefore enables us to see the image more readily.

9.1.1 Setting up the microscope

- Ensure the green filter is in place above the field lens.
- Place the slide on the stage of the microscope. Set the phase plates to the correct phase (PH1, PH2 or PH3) as indicated on the objective lens, then using the 40X objective lens focus on the specimen
- Adjust the interpupillary distance so that both the right and left view-fields become one.

9.1.2 Centring the Illuminating Field Diaphragm

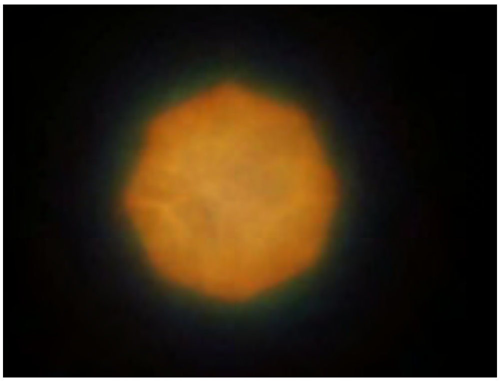
- Close the illuminating field diaphragm in the microscope base to its smallest size by means of the field diaphragm control ring. Rotate the condenser focus knob to move the condenser vertically so that the sharp image of the field diaphragm is formed on the specimen surface.



(Source: Gully Howard Technical Ltd)

Figure 9.1 – Centring of illuminated aperture (1)

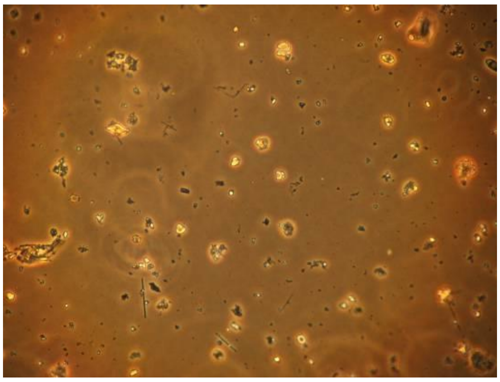
- Move the field diaphragm image to the centre of the field of view by means of the condenser centring screws.



(Source: Gully Howard Technical Ltd)

Figure 9.2 – Centring of illuminated aperture (2)

- Open the field diaphragm so that the image of the diaphragm is just outside the field of view.



(Source: Gully Howard Technical Ltd)

Figure 9.3 – Centring of illuminated aperture (3)

9.1.3 Centring the Phase Ring

- Remove one of the eyepieces and replace with the centring telescope; alternatively if the microscope is fitted with a Bertrand lens use this instead.

(Source: Gully Howard Technical Ltd)

Figure 9.4 – Centring of phase rings (1)

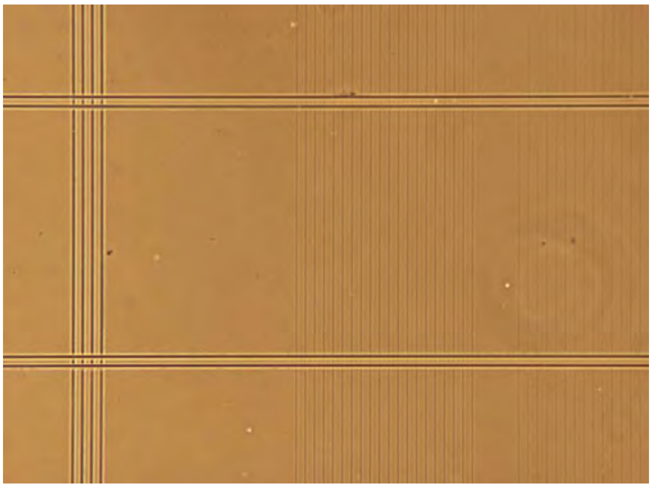
- Loosen the two small locking nuts/screws on the base of the phase contrast assembly. Using the two adjusting screws or adjusting keys on the base of the phase-contrast assembly, centre the light ring viewed through the centring telescope onto the darker ring. Tighten the locking nuts (or screws).

(Source: Gully Howard Technical Ltd)

Figure 9.5 – Centring of phase rings (2)

9.1.4 HSE/NPL Mk II Test Slide

- Place the test slide onto the microscope stage and adjust the focus. The field diaphragm image is focused using the condenser focus knob on the same plane as the test slide.
- All of the ridges of block 5 of the test slide should be visible while only parts of block 6 ridges might be visible.



(Source: Gully Howard Technical Ltd)

Figure 9.6 – Block 1 and part of block 2 of test slide

- If this is not the case, repeat the setting up procedure.
- If 5 sets of lines are still not seen, then count should not take place.
- Record the number of groups of ridges observed

9.1.5 Determination of the diameter of Walton-Beckett eyepiece graticule

Place the stage micrometer on the microscope and adjust the focus until the marked divisions are in focus. The divisions on the stage micrometer are used to estimate the diameter of the Walton-Becket graticule to the nearest micron. Record the measured diameter of the Walton-Becket graticule on the on-site worksheet – it should be 100 $\pm$ 2mm.

(Source: Gully Howard Technical Ltd)

Figure 9.7 – Image of stage micrometer scale

9.2 FILTER PREPARATION

To prepare the filter for optical microscopy it is rendered transparent and fixed to a microscope slide. The WHO (1997) method specifies the use of acetone and triacetin to mount and clear the filters. The method uses an 'acetone vaporiser' or 'hot block'.

(Source: Gully Howard Technical Ltd)

Figure 9.8 – Acetone vaporiser / hot block

The acetone vapour collapses the pores of the filter turning it into a transparent film with the collected fibres attached to the microscope slide. The triacetin forms the interface between the collapsed filter and the coverslip. The mounted filter and triacetin sets into a solid material and a slide prepared in this way will keep for many years without deterioration. It is good practice to retain these slides for a period of time so that they can be re-checked if necessary for quality control purposes or in the case of dispute. Some accreditation bodies (e.g. UKAS) specify that slides should be kept for a minimum of 6 months.

The filter clearing process is undertaken by placing the filter, (grid lines uppermost) on a clean microscope slide. The filter should be free from excessive moisture, if filters have been exposed to very high humidity they may need drying in a warm air cabinet prior to mounting.

The slide and filter are placed beneath the outlet of the acetone heater unit. Using a small syringe acetone (approximately 0.25 ml) is injected slowly into the heater unit so that a steady stream of acetone vapour emerges onto the filter clearing (making transparent) the filter.

When any residual acetone has evaporated from the filter, a drop or two of triacetin (approximately 120 microlitres) are placed on the filter and a coverslip gently lowered onto the filter. The amount of triacetin used should just sufficient to cover the whole of the filter when the coverslip is applied without excess liquid.

At this stage, the filter will still appear grainy when examined under the microscope. It can be left overnight to clear completely. However, in many situations, such as clearance or leak monitoring, a result may be required more quickly. In these cases, the partially cleared filter may be placed on the hot-plate for about 15 minutes at about 50 – 60^{o}C to complete the process.

9.3 FIBRE COUNTING

9.3.1 Fibre counting rules

The routinely used PCOM method cannot positively identify individual fibres as asbestos (or not). The basis of the method is that all objects noted during the microscopical examination of the filter that conform to certain size criteria are 'counted' and assumed to be asbestos. This principle applies to asbestos fibre counting (WHO 1997, HSE document HSG248 (2005)) and also to counting of MMMF (HSE document MDHS 59 (1998)) – where all structures that conform to the following counting rules are deemed to be MMMF for comparison with the relevant exposure limit.

The definition of a countable fibre in these methods is:

- A countable fibre is defined as any object which is longer than 5 µm, with an average width less than 3 µm and having an aspect (length / width) ratio greater than 3:1
  - Note: fibres attached to particles are assessed as if the particle does not exist and are counted if the visible part of the fibre meets the above definition
  - Note: if the width of the fibre varies along its length, the average width should be considered.

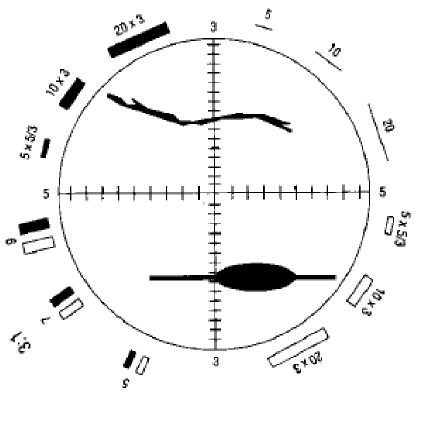
In addition there are a number of other rules given in the methods to clarify how countable fibres are recorded, including the following:

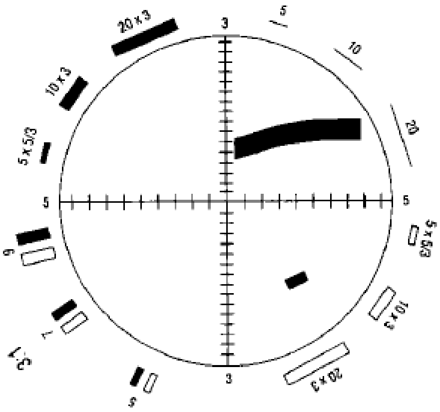
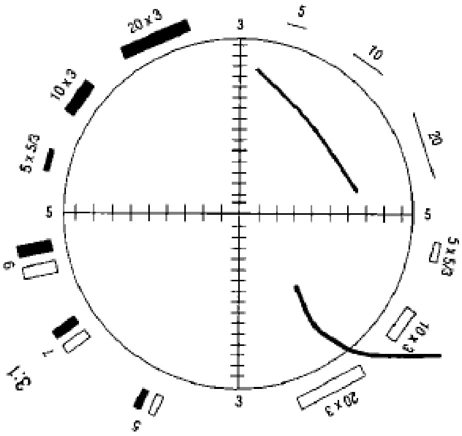
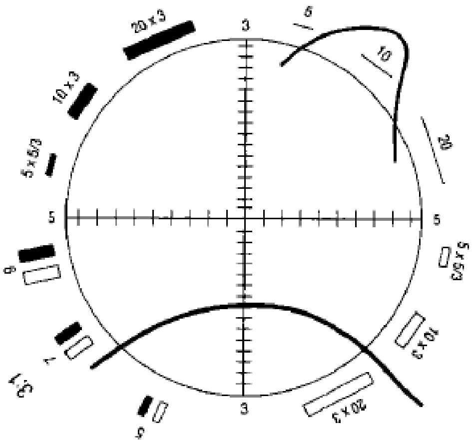
- o If both ends of a countable fibre are within the graticule area it is recorded as one fibre
- o If only one end of a countable fibre is within the graticule area it is recorded as half a fibre
- o If neither of the ends of a countable fibre are within the graticule area, it is not counted

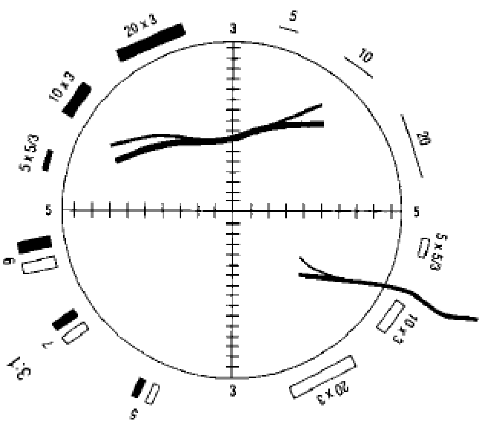
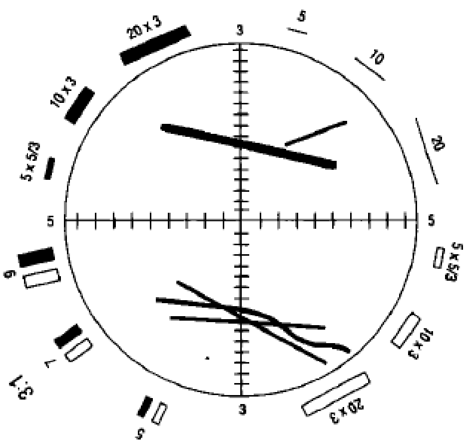
- o A split fibre is taken to be one countable fibre if it meets the above definition; a split fibre is defined as one which at one or more points on its length appears to be solid and undivided, but at other points appears to divide into separate strands

- o Loose agglomerates of fibres are counted individually if they can be distinguished sufficiently to determine that they meet the definition above

Examples depicting countable and non-countable fibres are given in Figure 9.9 – taken from WHO Method1997

	1 fibre 1 fibre – ignore the particle or 'bulb' of resin when estimating the width

	0 fibres – width too large 0 fibres – aspect ratio less than 3:1
	1 fibre ½ fibre – 1 end in field
	1 fibre – both ends in field 0 fibres – no ends in field

	1 fibre – split ends part of fibre ½ fibre – 2 fibre ends, split, count as one end
	2 fibres 3 fibres

(Source: WHO Determination of asbestos fibre number concentrations 1997 – reproduced with permission)

Figure 9.9 – Examples of countable and non-countable fibres

9.3.2 Evaluation of air samples

When the microscope has been set up correctly for fibre counting the slide is placed on the microscope stage. An initial examination is undertaken at low magnification to check uniformity of the deposit and the filter is not damaged. Filters are then examined at a magnification of at least 500 times. The fine focus will need adjusting at each area examined to ensure all fibres are seen.

Graticule areas for evaluation are chosen at random and should be representative of the whole exposed filter area. This is usually achieved by traversing across the filter and repeating this traversing in steps down the filter area. Graticule areas should be rejected for evaluation if:

- A filter grid line obscures all or part of the graticule area, or
- More than one eighth of the graticule area is occupied by an agglomerate of fibres and / or particles.

The number of graticule areas examined will depend on the sampling situation, the volume of air sampled and the limit of detection required. A guide to the number of graticule areas to be counted is given in Section 7.2.3. Further guidance is given in HSE Document HSG248 The Analyst's Guide (2005) as follows:

- *For evaluations related to personal sampling in connection with compliance sampling and the assessment of respirator protection, at least 100 fibres must be counted or 100 graticule areas must be inspected, whichever is reached first; at least 20 graticule areas must be inspected even if these contain more than 100 fibres;*
- *For evaluation of other samples (e.g. clearance indicator, background, reassurance and leak sampling), 200 graticule areas must be inspected on samples of the minimum of 480 litre volume. If the collected air volume (V) is more than 480 litres, the number (n) of graticule areas inspected may be reduced proportionately according to the formula*

$$n = 96,000 / V$$

For example, if 960 litres are collected, only 100 graticule areas need to be examined (to still have a limit of quantification of 0.01 fibres per millilitre).

- *Where two or more samples are being pooled to obtain 480 litres, V is the total volume of the pooled samples and n is the number of graticule areas inspected on each of the pooled filters*

(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

9.3.3 Limitations of fibre counting method

9.3.3.1 Introduction

The PCOM method for determining fibre in air concentrations offers a number of advantages, these include:

- Results can be obtained in a relatively short period of time, typically a filter can be cleared and analysed by an experienced analyst within about 30 minutes of completion of sampling
- The equipment required is portable and can be taken to site and set in an adjacent area, or in a small mobile laboratory
- The mounted filter is undamaged by the analysis and is available for re-counting if required

However, as stated earlier, the method can produce widely differing results when undertaken by different analysts and by different laboratories. Differences may occur due to variations in, for example, sampling methodology, sample preparation as well as the equipment specification and set-up.

The largest potential source of differences is as a result of subjective effects associated with the visual counting of fibres. These differences reinforce the need for analysts to be trained to the WHO standard and they should participate in inter-laboratory quality control programmes.

In addition, there are other limitations associated with the PCOM method:

- It does not positively identify fibres as asbestos fibres, all structures that conform to specified size criteria are counted
- An upper width limit means that some asbestos fibres are not counted (although these large diameter fibres are not likely to be respirable)
- Many fibres are too small to be visible by optical microscopy. In practice, the smallest visible fibres will be about 0.2 µm in width (WHO 1997). Since some fibres fall below the limit of visibility, the PCOM fibre count represents only a certain proportion of the total number of fibres present. (However, it is unclear how these smaller diameter fibres affect the risk and in any case they are not included in regulatory compliance standards or assessments).

9.3.3.2 Accuracy

Microscopists generally undercount dense deposits. When sampling fibres in atmospheres relatively free from interfering particulates, the density range for *optimum accuracy should be in the range 100 – 650 fibres / mm², for densities above 650 fibres / mm² the results may be underestimates, and above 1000 fibres / mm², fibre levels are subject to increased undercounting and are normally too dense to count. In mixed dust situations, the presence of other fibres and particles may interfere with the accuracy of the results.*

An important factor is that the counting procedure can result in systematic differences in counts produced by different microscopists within and, more particularly, between laboratories. These intra- and inter- laboratory differences must be controlled by proper training and periodic quality checks

(Source: HSE Guidance Note HSG248 (2005) – Reproduced under the terms of the Click-Use Licence)

9.3.3.3 Precision and lower limit of measurement

For fibre counting, precision is dependant on the uniformity of the fibre distribution on the filter and the number of fibres present. The distribution of fibres on the filter can be described statistically as a Poisson (random) distribution. However, because of the subjective nature of fibre counting the actual coefficient of variation (CV) is greater than would be expected for a Poisson distribution. It is given by the formula $(N + 0.04N^2)^{½} /N$ where N is the number of fibres counted. This formula has been used to derive the following table showing 95% confidence limits.

Table 9.1 - Intra-laboratory CV associated with number of fibres counted

Number of fibres	Expected CV	Confidence limits for the mean of repeated determinations			
		Lower 95%	Upper 95%	Lower 90%	Upper 90%
5	0.49	1.6	13.1	2.0	11.0
7	0.43	2.7	16.4	3.2	14.0
10	0.37	4.8	21.3	5.1	18.5
20	0.3	10.3	37	11.7	33.2
50	0.25	30	85	33	76
100	0.22	63	163	68	149
200	0.21	129	320	139	291

The figures in Table 9.1 show that the method becomes less precise as fewer fibres are counted. This is particularly the case when only a few fibres (e.g. below about 10 or 20 fibres) are counted. The number of fibres counted on many background, leak or clearance samples is often of this magnitude. It can also be seen that when the number of fibres counted exceeds 100 there are only limited improvements in precision as more fibres are counted.

The figures in Table 9.1 are for intra-laboratory (within the laboratory) variations. Inter-laboratory (between laboratories) variations may be much greater, particularly if quality control is poor.

As stated above, errors become large when the number of fibres counted is small. It is usually considered that the lowest measurable fibre level above 'background' (from blank filters etc) is 10 fibres per 100 graticule areas. The actual limit of quantification will depend on the sample volume and the effective area of the filter. As an example a sample of 480 litres sampled onto a 25 mm filter would give a lower limit of quantification of 0.01 fibres / cm^3. If only 240 litres were sampled the lower limit would be 0.02.

9.3.3.4 Human factors

The accuracy of the fibre count may be adversely affected by poor working practices or a poor working environment. The lighting should not be too bright or cause glare at the work area. The work position should be such that it enables the microscopist to sit with adequate legroom and clearance to enable adjustment of the seating position.

The work environment may be a particular concern where the microscope is set up in a 'temporary on-site laboratory'. This could introduce systematic errors not evident in a quality control programme based upon results obtained in a permanent 'base' laboratory. A suitable quality control programme should be in place to demonstrate satisfactory performance in the actual working conditions.

These and any other factors that may lead to discomfort or eyestrain may adversely affect the quality of the counts produced by the microscopist. One way that potential problems due to fatigue are taken into account is by limiting the amount of fibre counting undertaken.

WHO (1997) recommends a maximum daily working time of about 6 hours, with microscopists taking 10-20 minute breaks after about 1 hour, although the length of breaks will depend on the microscopist, the samples and laboratory conditions.

HSE Document HSG248 The Analyst's Guide (2005) recommends that the number of graticule areas examined each day by one counter should not normally exceed 2400, the equivalent of 12 samples if 200 graticule areas are counted on each. It also advises that counters take regular breaks (at least after every third or fourth slide counted in succession). If long shifts are worked or there are specific operational reasons that require more than 2400 graticule areas to be examined, additional quality control checks may be required to demonstrate that the results produced are still valid.

The time taken for a filter to be evaluated varies between microscopists, and also depends on the sample type, density of dust and laboratory conditions. It takes typically between 10 and 25 minutes to evaluate 200 graticule areas on a filter with low dust loading, but may be longer for more difficult samples.

9.4 CALCULATION OF RESULTS AND QUALITY CONTROL

9.4.1 Calculation of results

The airborne concentration of fibres is given by the following formula:

$$C = 1000\ N\ D^2 / V\ n\ d^2$$

Where C = concentration (fibres per millilitre)
N = number of fibres counted
D = diameter of exposed filter area (mm)
V = volume of air sampled through filter (litres)
n = number of graticules examined
d = diameter of the Walton-Beckett graticule (μm)

Worked examples:

Example 1. An air sample of 480 litres was drawn through a filter. Subsequent analysis by PCOM gave a fibre count of 18 fibres on 200 graticule areas examined. The diameter of the graticule was 100 μm and the area of exposed filter had a diameter of 22.5 mm.

$$\text{The fibre concentration } C = \frac{1000 \times 18 \times 22.5 \times 22.5}{480 \times 200 \times 100 \times 100}$$

Giving C = 0.0095 fibre / ml

This would be reported as < 0.01 fibres / ml

The result is reported as less than 0.01 as the count of 18 fibres is less than the lower limit of quantification established for the WHO method.

Example 2. An air sample was taken between 10.15 and 12.15 at a flow rate of 8 litres per minute. Subsequent analysis by PCOM gave a fibre count of 43 fibres on 100 graticule areas examined. The diameter of the graticule was 98 μm and the area of exposed filter had a diameter of 22 mm.

$$\text{The fibre concentration } C = \frac{1000 \times 43 \times 22 \times 22}{960 \times 100 \times 98 \times 98}$$

Giving C = 0.0226 fibre / ml

This would be reported as 0.02 fibres / ml

9.4.2 Fibre counting quality control schemes

To ensure the validity of results, organisations undertaking asbestos air sampling and fibre counting should meet recognised standards. Standards for competence of testing laboratories are set out in ISO 17025. Many countries have an accreditation system whereby organisations can be assessed against the requirements of the International Standard. Examples of these are the United Kingdom Accreditation Service (UKAS), the National Association of Testing Authorities (NATA) in Australia and the American Industrial Hygiene Association (AIHA).

The testing organisation should ensure that all work is undertaken by competent trained staff using documented validated methods. Equipment should be suitable, regularly maintained and calibrated. Suitable management systems should also be in place to ensure accuracy, suitability and confidentiality of reports, together with secure archiving and storage of records and samples. A comprehensive auditing programme should be in place to ensure that the requirements of the ISO standard are being met, together with a system to address complaints and to investigate, correct and prevent incidents of non-conforming work.

An essential part of quality assurance is participation in internal quality control programmes and external proficiency testing programmes. This is particularly important for fibre counting due to the large potential differences in results within and between laboratories.

There are a number of external proficiency testing programmes in place, for example, RICE (Regular Inter-laboratory Counting Exchange – UK), IHPAT (Industrial Hygiene Proficiency Analytical Testing – US) and AFRICA (Asbestos Fibre Regular Informal Counting Arrangement – International).

Satisfactory performance in these proficiency testing schemes is normally a pre-requirement for accreditation. In all these schemes slides are sent to the testing laboratory for fibre counting. The results are returned to the administrating body, compared with the 'Reference value' for the slide and the performance of the testing organisation assessed as satisfactory or unsatisfactory.

'Good' performance in the RICE scheme is defined as at least 75% of fibre counts being within target band 'A'. For high density slides (>63.7 fibres/mm^2) this corresponds to a range of 0.65 to 1.55 as a ratio when compared to the

reference value'. (With low density slides a slightly different ratio would be used depending on fibre density)

HSE Committee on Fibre Measurement (2004)

For example if the reference value was 200 fibres / mm^2 on the filter, a reported result between 130 and 310 fibres / mm^2 would be in category 'A'.

This range of values may seem to be extremely wide; however, it is a reflection of the subjective nature of the fibre count, the difficulties caused by any uneven distribution on the filter and the variations in the set-up of the microscope. In fact these performance criteria have become more stringent over the years and have helped to improve the consistency and comparability of fibre counting results.

The early RICE rounds showed far larger variations between and within laboratories. The first round in 1984 showed unacceptable variations – *'Up to ten-fold systematic differences occur between visual-counting laboratories' whilst random differences in counts of up to 100-fold occur on the same sample'.*

Crawford and Cowie (1984)

'Performance improved appreciably in the next round. Further improvements were achieved and maintained in subsequent rounds. Similar patterns of both short- and long-term improvements also occurred in AFRICA'.

Crawford, Brown and Cowie (1992)

The real impact of inter-laboratory proficiency testing has been to reduce systematic differences associated with the fibre counting method.

Evidence that harmonisation of fibre counting results across different countries was being achieved was found in a comparison of fibre counting across three European National proficiency testing schemes in 2005. This report examined the results of slides sent to laboratories in Spain, Belgium and the UK and stated that:

'*Densities from counts in this sample exchange served as a common basis against which we compared the national reference values (R). This produced a geometric overall mean of (R) to exchange mean density of 0.94 for the UK scheme, 1.01 for the Spanish and 0.97 for the Belgian scheme, and thus indicated remarkably similar levels*' (Jones et al 2005)

9.5 ELECTRON MICROSCOPY

9.5.1 Introduction

The determination of airborne fibres is normally carried out by phase contrast optical microscopy (PCOM). This method gives a total fibre count and cannot positively distinguish between asbestos and other fibres. It should be noted that in most cases the use of techniques to discriminate between different fibre types is unnecessary and in the case of compliance sampling it is not allowed by most regulatory authorities.

Similarly HSE Document MDHS 87 Fibres in air (1998) states that *'It is not recommended that this (fibre discrimination) be generally applied to clearance testing, since the determination of results above the clearance indicator demonstrates that the enclosure is not clean, even if some of the dust is non-asbestos'.*

However, it does allow discrimination in exceptional circumstances where after cleaning it is suspected that non-asbestos dust is being drawn into the enclosure from operations outside (e.g. from MMMF based insulation).

However, in some situations it may be required to establish whether the counted fibres are asbestos or not. For example, if during background testing airborne fibre concentrations are found to be greater than 0.01 fibres / cm^3 then it may need to be established whether this is due to non-asbestos fibres. Similarly, these high ambient background fibre levels (non-asbestos) would need to be taken into account when checking for leaks from an asbestos working area.

Electron microscopy is one technique that can be used to distinguish between different fibre types. However, one drawback is that filters already mounted using acetone-triacetin cannot be further analysed by electron microscopy. This means that either filters must be cut in half prior to analysis or separate samples must be taken and reserved for electron microscopy.

The electron microscope uses an electron beam instead of a light beam as in an optical microscope. When used in conjunction with a suitable Energy Dispersive X-ray Analysis (EDXA) system it enables asbestos fibres to be identified by chemical composition. For example, chrysotile has high concentrations of magnesium and silicon; crocidolite has high concentrations of iron and silicon with some sodium; and amosite has high concentrations of silicon and iron with no sodium.

Another reason that electron microscopy may be used is in a situation where monitoring is undertaken to assess health risk, rather than for compliance or clearance monitoring. In this situation knowing what proportion of the fibres in a sample actually is asbestos may be important. It should be noted that although electron microscopy is capable of 'seeing' much smaller diameter fibres than optical microscopy it is unclear how these smaller fibres affect possible health risk.

9.5.2 Scanning electron microscopy (SEM)

Scanning electron microscopy analysis is either undertaken on a portion of a mixed cellulose ester filter or as a separate sample collected on a polycarbonate or polyvinyl chloride (PVC) filter. Filters from batches to be used for scanning electron microscopy fibre counting should be checked by before use to ensure that they are not contaminated.

The scanning electron microscope is set up as follows:

- Magnification used for searching the filter is 2000 times or greater
- Fitted with suitable energy dispersive X-ray analysis (EDXA) system for elemental analysis of fibres

- The energy dispersive X-ray analysis detector should be capable of detecting X-ray energies within the range 980 to 10,000 electron volts

An initial scan at low magnification is undertaken to check that the dust deposit is uniform and that the filter is not damaged. The analysis of the filter is undertaken by means of a systematic search so that areas of filter examined are not repeated. The fibre counting rules are identical to those given in the WHO method. In order to achieve comparability with the routinely used phase contrast optical microscopy method fibres of less than 0.2 micrometre diameter are not counted.

Any counted fibre greater than 5 micrometre in length is analysed by energy dispersive X-ray analysis. X-rays generated from within the fibre are collected and compared with standard spectra from known samples. This enables the classification of a fibre as asbestos or non-asbestos. This information can be used to report a 'discriminated' fibre count as well as a total fibre count.

It should be noted that *'fibres having diameters of less than 0.1 micrometre are unlikely to generate enough X-rays above background to give an identifiable spectrum'.* HSE Document MDHS 87 (1998)

9.5.3 Transmission electron microscopy (TEM)

'Transmission electron microscopy has the ability to discriminate between mineral fibres of all sizes. Specimen grids are examined at both low and high magnifications to check they are suitable for analysis before conducting a quantitative structure count on randomly selected grid openings. In transmission electron microscopy analysis, selective area electron diffraction (SAED) may be used to examine the crystal structure of a fibre, and its elemental composition is determined by energy dispersive X-ray analysis'.

(Source: HSE Guidance Note MDHS 87 (1998) – Reproduced under the terms of the Click-Use Licence)

As with scanning electron microscopy a discriminated fibre count can be derived. Whereas scanning electron microscopy can be used to give fibre counts comparable to phase contrast optical microscopy, transmission electron microscopy is used more as a research tool. It can characterise individual fibres as small as 0.01 micrometres in width. Sample preparation for transmission electron microscopy is more complex than for scanning electron microscopy.

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Appendix

Asbestos-containing materials in buildings

(listed in approximate order of ease of fibre release)

Source: HSE Document HSG 264 (2010) –

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Appendix 2: ACMs in buildings listed in order of ease of fibre release

Asbestos product	Location/use	Asbestos and type/date last used	Ease of fibre release and product names
Loose insulation			
Bulk loose fill, bulk fibrefilled mattresses, quilts and blankets. Also 'jiffy bag' type products used for sound insulation.	Bulk loose fill insulation is now rarely found but may be encountered unexpectedly, eg DIY loft insulation and firestop packing around cables between floors. Mattresses and quilts used for thermal insulation of industrial boilers were filled with loose asbestos. Paper bags/sacks were also loose-filled and used for sound insulation under floors and in walls.	Usually pure asbestos except for lining/bag. Mattresses and quilts usually contain crocidolite or chrysotile. Acoustic insulation may contain crocidolite or chrysotile.	Loose asbestos may readily become airborne if disturbed. If dry, these materials can give rise to high exposures. Covers may deteriorate or be easily damaged by repair work or accidental contact.
Sprayed coatings			
Dry applied, wet applied and trowelled finish.	Thermal and anticondensation insulation on underside of roofs and sometimes sides of industrial buildings and warehouses. Acoustic insulation in theatres, halls etc. Fire protection on steel and reinforced concrete beams/columns and on underside of floors. Overspray of target areas is common.	Sprayed coatings usually contain 55%–85% asbestos with a Portland cement binder. Crocidolite was the major type until 1962. Mixture of types including crocidolite until mid–1971. Asbestos spray applications were used up to 1974.	The surface hardness, texture and ease of fibre release will vary significantly depending on a number of factors. Sprays have a high potential for fibre release if unsealed, particularly if knocked or the surface is abraded or delaminates from the underlying surface. Dust released may then accumulate on false ceilings, wiring and ventilation systems. 'Limpet' (also used for non-asbestos sprays).
Thermal insulation			
Hand-applied thermal lagging, pipe and boiler lagging, pre-formed pipe sections, slabs, blocks. Also tape, rope, corrugated paper, quilts, felts, and blankets.	Thermal insulation of pipes, boilers, pressure vessels, calorifiers etc.	All types of asbestos have been used. Crocidolite used in lagging until 1970. Amosite was phased out by the manufacturers during the 1970s. Content varies 6-85%. Various ad hoc mixtures were handapplied on joints and bends and pipe runs. Pre-formed sections were widely used, eg '85% magnesia' contained 15% ▶	The ease of fibre release often depends on the type of lagging used and the surface treatment. Often it will be encapsulated with calico and painted (eg PVA, EVA, latex, bitumen or proprietary polymer emulsions or PVC, neoprene solutions), eg 'Decadex' finish is a proprietary polymer ▶

Asbestos product	Location/use	Asbestos and type/date last used	Ease of fibre release and product names
Thermal insulation (continued)			
		amosite, 'Caposil' calcium silicate slabs and blocks contained 8–30% amosite while 'Caposite' sections contained ~ 85% amosite. Blankets, felts, papers, tapes and ropes were usually ~100% chrysotile.	emulsion. A harder chemical-/ weatherresistant finish is known as 'Bulldog'.
Asbestos boards			
'Millboard'.	'Millboard' was used for general heat insulation and fire protection. Also used for insulation of electrical equipment and plant.	Crocidolite was used in some millboard manufacture between 1896 and 1965; usually chrysotile. Millboards may contain 37–97% asbestos, with a matrix of clay and starch.	Asbestos 'Millboard' has a high asbestos content and low density so is quite easy to break and the surface is subject to abrasion and wear.
Insulating board.	Used for fire protection, thermal and acoustic insulation, resistance to moisture movement and general building board. Found in service ducts, firebreaks, infill panels, partitions and ceilings (including ceiling tiles), roof underlay, wall linings, soffits, external canopies and porch linings.	Crocidolite used for some boards up to 1965, amosite up to 1980, when manufacture ceased. Usually 15–25% amosite or a mixture of amosite and chrysotile in calcium silicate. Older boards and some marine boards contain up to 40% asbestos.	AIB can be readily broken, giving significant fibre release. Also significant surface release is possible by abrasion, but surface is usually painted or plastered. Sawing and drilling will also give significant releases. 'Asbestolux', 'Turnasbestos', 'LDR', 'asbestos wallboard', 'insulation board'. Marine boards known as 'Marinite' or 'Shipboard'.
Insulating board in cores and linings of composite products.	Found in fire doors, cladding infill panels, domestic boiler casings, partition and ceiling panels, oven linings and suspended floor systems. Used as thermal insulation and sometimes as acoustic attenuators.	Crocidolite used for some boards up to 1965, amosite up to 1980, when manufacture ceased. 16–40% amosite or a mixture of amosite and chrysotile.	Can be broken by impact; significant surface release possible by abrasion, but usually painted or plastered. Sawing and drilling will also give significant releases. 'Asbestolux'. Caposil.
Paper, felt and cardboard			
	Used for electrical/heat insulation of electrical equipment. Also used in some air-conditioning systems as insulation and acoustic lining. Asbestos paper has also been used to reinforce bitumen and other products and as a facing/ lining to flooring products,	Asbestos paper can contain ~100% chrysotile asbestos but may be incorporated as a lining, facing or reinforcement for other products, eg roofing felt and damp-proof courses, steel composite wall cladding and roofing (see asbestos	Paper materials, if not encapsulated/combined within vinyl, bitumen, or bonded in some way, can easily be damaged and release fibres when subject to abrasion or wear (eg worn flooring surface with paper backing). Asbestos paper, asbestos felt, 'Novilon'

Asbestos product	Location/use	Asbestos and type/date last used	Ease of fibre release and product names
Paper, felt and cardboard (continued)			
	combustible boards, flame-resistant laminate. Corrugated cardboard has been used for duct and pipe insulation.	bitumen products below), vinyl flooring. Asbestos paper is also sometimes found under MMMF insulation on steam pipes.	flooring, Durasteel laminates, vinyl asbestos tile, roofing felt and damp-proof course etc. Pax felt'. 'Viceroy' (foilcoated paper). 'Serval'.
Textiles			
Ropes and yarns.	Used as lagging on pipes (see above), jointing and packing materials and as heat/fire-resistant boiler, oven and flue sealing. Caulking in brickwork. Plaited asbestos tubing in electric cable.	Crocidolite and chrysotile were widely used due to length and flexibility of fibres. Other types of asbestos have occasionally been used in the past. Chrysotile alone since at least 1970. Asbestos content approaching 100% unless combined with other fibres.	Weaving reduces fibre release from products, but abrading or cutting the materials will release fibres, likely to degrade if exposed, becoming more friable with age. If used with caulking, fibres will be encapsulated and less likely to be released.
Cloth.	Thermal insulation and lagging (see above), including fire-resisting blankets, mattresses, protective curtains, gloves aprons and overalls. Curtains, gloves etc were sometimes aluminised to reflect heat.	All types of asbestos were used. Since the mid-1960s the vast majority have been chrysotile. Asbestos content approaching 100%.	Fibres may be released if material is abraded.
Gaskets and washers.	Used widely in domestic and industrial plant and pipe systems ranging from hot water boilers to industrial power and chemical plant.	Variable but usually around 90% asbestos, crocidolite used for acid resistance and chrysotile for chlor-alkali. Some gasket materials continued to be used after asbestos prohibition in 1999 (through exemption).	May be dry and damage easily when removed. Mainly a problem for maintenance workers. 'Klingerit', 'Lion jointing', 'Permanite', 'CAF' – compressed asbestos fibre or 'It' in German gaskets.
Strings.	Used for sealing hot water radiators.	Strings have asbestos content approaching 100%.	
Friction products			
Resin-based materials.	Transport, machinery and lifts, used for brakes and clutch plates.	30–70% chrysotile asbestos bound in phenolic resins. Used up to November 1999.	Normal handling will produce low emissions. Minor emissions when braking. Dust may build up with friction debris. Grinding brake and clutch components to fit and brushing or blowing clean can produce significant peak airborne levels.
Drive belts/conveyor belts.	Engines, conveyors.	Chrysotile textiles encapsulated in rubber.	Low friability, except when worn to expose textile.

Asbestos product	Location/use	Asbestos and type/date last used	Ease of fibre release and product names
Cement products			
Profiled sheets.	Roofing, wall cladding. Permanent shuttering, cooling tower elements.	10–15% asbestos (some flexible sheets contain a proportion of cellulose). Crocidolite (1950–1969) and amosite (1945–1980) have been used in the manufacture of asbestos cement, although chrysotile (used until November 1999) is by far the most common type found.	Likely to release increasing levels of fibres if abraded, hand sawn or worked on with power tools. Exposed surfaces and acid conditions will remove cement matrix and concentrate unbound fibres on surface and sheet laps. Cleaning asbestos-containing roofs may also release fibres.
			Asbestos cement, Trafford tile, 'Bigsix', 'Doublesix', 'Supersix', 'Twin twelve', 'Combined sheet', 'Glen six', '3' and 6' corrugated', 'Fort', 'Monad', 'Troughsec', 'Major tile and Canada tile', 'Panel sheet', 'Cavity decking'.
Semi-compressed flat sheet and partition board.	Partitioning in farm buildings and infill panels for housing, shuttering in industrial buildings, decorative panels for facings, bath panels, soffits, linings to walls and ceilings, portable buildings, propagation beds in horticulture, domestic structural uses, fire surrounds, composite panels for fire protection, weather boarding.	As for profiled sheets. Also 10–25% chrysotile and some amosite for asbestos wood used for fire doors etc. Composite panels contained ~ 4% chrysotile or crocidolite.	Release as for profiled sheets. Flat building sheets, partition board, 'Poilite'.
Fully compressed flat sheet used for tiles, slates, board.	As above, but where stronger materials are required, and as slates, board cladding, decking and roof slates (eg rollerskating rinks, laboratory worktops). Higher asbestos content sheets produced for industrial applications as a high grade arc and heat-resistant material.	As for profiled sheets. Up to 50% chrysotile.	Release as for profiled sheets. Asbestos-containing roofing slate (eg 'Eternit', 'Turners', 'Speakers'), Everite', 'Turnall', 'Diamond AC', 'JM slate', 'Glasal AC', 'Emalie, Eflex', 'Colourglaze', 'Thrutone', 'Weatherall'. 'Sindanyo'.
Pre-formed moulded products and extruded products.	Cable troughs and conduits. Cisterns and tanks. Drains and sewer pressure pipes. Fencing. Flue pipes. Rainwater goods. Roofing components (fascias, soffits etc). Ventilators and ducts. Weather boarding. Window sills and boxes, bath panels, draining boards, extraction hoods, copings, promenade tiles etc.	As for profiled sheets.	Release as for profiled sheets. 'Everite', 'Turnall', 'Promenade tiles'.
Other encapsulated materials			
Textured coatings.	Decorative/flexible coatings on walls and ceilings.	3–5% chrysotile asbestos. Chrysotile added up to 1984 but old stock may have been used for several more years.	Generally fibres are well contained in the matrix but may be released when old coating is sanded down or scraped off. 'Artex', Wondertex',

Asbestos product	Location/use	Asbestos and type/date last used	Ease of fibre release and product names
Other encapsulated materials (continued)			
		Non-asbestos versions were available from the mid-1970s.	'Suretex', ''Newtex', 'Pebblecoat', 'Marblecoat'.
Bitumen products.	Roofing felts and shingles, semi-rigid asbestos bitumen roofing. Gutter linings and flashings. Bitumen damp-proof courses (dpc). Asbestos/bitumen coatings on metals (eg car body underseals). Bitumen mastics and adhesives (used for floor tiles and wall coverings).	Chrysotile fibre or asbestos paper (approximately 100% asbestos) in bitumen matrix, usually 8% chrysotile. Used up to 1992. Adhesives may contain up to a few per cent chrysotile asbestos. Used up to 1992.	Fibre release unlikely during normal use. Roofing felts, dpc and bitumen-based sealants must not be burnt after removal. See felts and papers.
Flooring.	Thermoplastic floor tiles. PVC vinyl floor tiles and unbacked PVC flooring. Asbestos paper-backed PVC floors. Magnesium oxychloride flooring used in WCs, staircases and industrial flooring.	Up to 25% asbestos. Normally 7% chrysotile. Paper backing approximately 100% chrysotile asbestos. Used up to 1992. About 2% asbestos.	Fibre release is unlikely to be a hazard under normal services conditions. Fibre may be released when material is cut, and there may be substantial release where flooring residue, particularly paper backing, is power-sanded. 'Novilon', 'Serval asbestos'. Very hard, fibre release unlikely.
Reinforced PVC.	Panels and cladding.	1–10% chrysotile asbestos.	Fibre release is unlikely.
Reinforced plastic and resin composites.	Used for toilet cisterns, seats, banisters, window seals, lab bench tops.	Plastics usually contain 1-10% chrysotile asbestos. Some amphiboles were used to give improved acid resistance, eg car batteries. Resins were reinforced with woven chrysotile cloth, usually contain 20–50% asbestos.	Fibres unlikely to be released, limited emissions during cutting. 'Siluminite', 'Feroasbestos'.