BOHS British Occupational Hygiene Society

The Chartered Society for Worker Health Protection

IP404 International Proficiency Qualification:

Air Monitoring and Clearance Inspections for Reoccupation following the Removal of Asbestos Student Manual

www.bohs.org

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Contents

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About British Occupational Hygiene Society

BOHS is the Chartered Society for Worker Health Protection. Our vision is to create a healthy working environment for everyone by preventing exposure to hazardous substances in the workplace.

Founded in 1953, we have developed over the last 64 years into a highly respected and influential body on workplace health issues, working closely with organisations in the UK and overseas to promote our vision. We are a registered charity, professional society and a member of the International Occupational Hygiene Association which is recognised as a non- government organisation by the International Labour Organisation (ILO) and the World Health Organisation (WHO).

We were awarded a Royal Charter in 2013 in recognition of our pre-eminent role in protecting worker health.

BOHS is a membership organisation, open to anyone who has an interest in workplace health issues, and we have 1800 members in 57 countries.

We are one of the leading awarding bodies in our field. Our UK courses and qualifications are recognised and respected by independent agencies such as the Health and Safety Executive (HSE) and the United Kingdom Accreditation Service (UKAS), and further afield by industry and employers worldwide. Over 60,000 people have taken one of our qualifications through our network of training providers.

Our courses and qualifications are overseen by a team of highly experienced professionals who are dedicated to developing the competence and career opportunities for the many thousands of people who play a key role in protecting worker health, in diverse fields such as asbestos, legionella and control technologies.

Further information about BOHS can be found at the website: www.bohs.org

Course overview

i. Introduction

This student manual is the key text for *IP404 - Air Monitoring and Clearance Inspections for Reoccupation following the Removal of Asbestos*. It provides an overview of the content of the course, for students to develop a comprehensive understanding of the full syllabus during the course.

Students are strongly encouraged to explore the references listed on pages 48-49, many of which are available to download free of charge, to gain a deeper understanding of the subject.

ii. Aim of the course

The aim of this course is to provide students with an understanding of the techniques and processes involved in air sampling; an overview of asbestos removal work; the process of sign-off and reoccupation following removal works; and how to undertake this work in a safe manner.

Students are expected to have prior knowledge and experience of the processes detailed in this book.

iii. Educational objectives

By the end of this course, students should:

- Be able to understand the scope of asbestos assessment work by undertaking a thorough review of the removal methodology.
- Be able to confirm by means of on-site inspections that removal has been undertaken in line with the methodology.
- Understand the risks/hazards associated with asbestos removal work, and to ensure that appropriate safety measures are in place – specifically in regard to cleanliness and decontamination.
- Be able to verify that work has been completed by means of thorough visual inspections and air testing within work areas.
- Understand the importance of communicating any findings and observations, and how to document these appropriately.
- Have an understanding of the limitations of the method, common issues that can arise and potential conflicts of interest.

iv. Format of the student manual

This student manual broadly follows the structure of the IP404 syllabus. The main sections align with the main subject headers on the syllabus (although it should be noted that tutors may alter the teaching sequence to suit their requirements).

v. Assessment and examinations

Students are required to pass three components to be awarded the qualification:

- A formative practical assessment.
- A closed-book written theory examination covering sections 1 to 4 of the syllabus, comprising 40 short-answer questions to be answered in two hours.
- An open-book written practical examination covering section 5 of the syllabus, comprising up to 30 questions to be answered in two hours.

1.0 Introduction to asbestos

1.1 What is asbestos?

Asbestos is the word used to describe 'a group of naturally occurring silicate minerals formed through a metamorphic process when rocks are subjected to conditions of extreme heat and pressure' (Sanderson, 2007). The high temperatures and subsequent cooling processes form fibrous silicate mineral veins in certain rock types across the globe.

There are two separate mineral types that are classed as asbestos:

- **Serpentine group -** These are **sheet silicates**. Chrysotile is the only asbestos type that falls into this group.
- **Amphibole group -** These are **chain silicates**. Amosite (Fibrous Grunerite); Crocidolite; (Fibrous) Anthophyllite; (Fibrous) Tremolite; and (Fibrous) Actinolite. 'Fibrous' is used to describe asbestos types because these minerals also have a non- asbestos (i.e. non-fibrous) form.

Of the six asbestos types, the most commonly used (accounting for about 95% of production) is chrysotile (white asbestos). Amosite (brown asbestos) was mined mainly in the Transvaal in South Africa. Its name comes from AMOSA, the acronym for the mining company Asbestos Mines of South Africa. Crocidolite (blue asbestos) was mined in South Africa, Bolivia and at Wittenoom, Western Australia.

There are three 'minor' types of asbestos that were not mined in significant quantities commercially:

- **Anthophyllite** was mined commercially in Finland and in Japan.
- **Tremolite** is mainly known as a contaminant of vermiculite (used in fire proofing) and talc. It is also mined in small quantities in India.
- **Actinolite** was not mined commercially in significant quantities, although there was some mined in Australia.

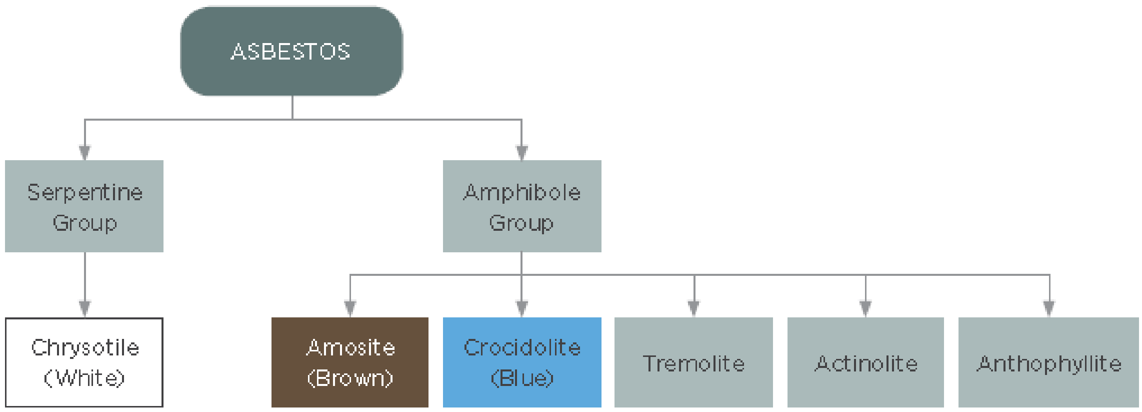

Figure 1.1 Asbestos groups and types (Source: New Zealand ACoP: Management and Removal of Asbestos, 2016)

Asbestos production increased over the years and peaked in the USA at 650,000 tons in 1975. Imports of raw asbestos mineral to the UK also peaked in the mid-1970s when approximately 170,000 tons were imported each year for use in different applications within the building trades (Sanderson, 2007). The production and use of asbestos then gradually declined, and it is now banned in many parts of the world - but huge amounts of asbestos remain in buildings and industrial installations.

Our knowledge about the adverse health effects of asbestos has developed in line with the increasing use of asbestos. The early evidence can be traced back to the first century when Pliny the Elder noted that slaves working in asbestos mines died prematurely of lung disease. In 1898, the first formally documented case of asbestos disease was recorded by a factory inspector, Lucy Dean Streatfield. She commented on the adverse consequences of asbestos exposure, regarding an individual who had been working for 12 years in a newly established textile factory in London.

Similar reports appeared 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 1927.
Following extensive research, asbestos is now classified by the IARC as a **'Group 1 human carcinogen'** (cancer-causing).

1.1.1 The properties of asbestos

Asbestos is an inert material (i.e. it does not easily react to other materials or forces). This makes it very useful, and it was known as a 'wonder material' that was used in thousands of products. The main properties of asbestos include:

- **Thermal insulation**: Asbestos does not conduct heat easily. It was therefore used to insulate pipes to prevent heat loss and as fire protection in buildings.
- **Acoustic insulation**: Asbestos does not conduct sound easily. It was used as sound proofing.
- **Electrical insulation**: Asbestos is a poor conductor of electricity.
- **Chemical resistance**: The amphiboles are resistant to acids and Serpentines are resistant to alkalis. They were used in the chemical industry.
- **Condensation barrier**: Because of its thermal insulating properties, asbestos was often used to prevent condensation (e.g. in swimming pools).
- **Tensile strength:** By far the most useful property of asbestos is its tensile strength, and this accounts for over 90% of its use.

Tensile strength is defined as the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. A material with a high tensile strength is elastic - it will bend without breaking and return to its original shape. An eraser has a high tensile strength (bend it and it will return to its original shape), whereas a wooden pencil has a low tensile strength (bend it and it will snap). Tensile strength is different from hardness. A hard material (e.g. cement) does not bend easily if force is applied. However, when it does bend it breaks rather than returning to its original form.

If cement is made into sheets, these are hard but they have a low tensile strength. In other words, they are brittle and will snap easily if bent.

To make them stronger as well as harder, it was necessary to add something to increase tensile strength. Chrysotile asbestos was ideal for this because it increases tensile strength, was relatively cheap and easy to work into the cement.

Other products have a low tensile strength that was increased by adding asbestos. These include bitumen and early plastics such as Bakelite. Both are too brittle to use without modification. Chrysotile and crocidolite both have very high tensile strengths, so were often woven into textile products and rope.

1.1.2 The uses of asbestos

Because of its many useful properties, asbestos was added to thousands of commercial and building products from the late 19th century onwards. Asbestos products were widely used in buildings in North America, Europe, Australia, New Zealand and South Africa. Although the use of asbestos is now banned in most countries, it is still present in these older buildings.

Asbestos Cement (AC) sheets were used as roofing and cladding on commercial buildings, and as shingles on domestic properties. Asbestos was added to plastics that were used in the commonplace floor tiles found in both commercial and domestic properties.

Insulating boards were used as fire protection in both commercial and domestic properties.

In commercial buildings, asbestos was used as fire protection on steelwork and as thermal insulation to pipework. Sprayed asbestos was also used on steelwork and concrete as a thermal and acoustic insulator.

1.2 Health effects of asbestos

The properties of asbestos which have led to its widespread use present a potentially deadly hazard. When inhaled, asbestos fibres are particularly resistant to the internal defence mechanisms of the body.

Asbestos fibres can split into increasingly finer fibres which are readily released into the air, often remaining airborne for long periods of time. During inhalation, the fibres can be carried into different sections of the respiratory tract, depending on the fibre size. The size is expressed in micrometres (also known as microns) commonly using the symbol μm. 1 μm is one thousandth of a millimetre.

According to Doll and Peto (1985):

> *"The hazard from airborne asbestos is greatest from fibres of between 5 and 100 μm in length (above which they cease to be respirable), with diameters less than 1.5 or 2 μm, and with aspect ratios (ratios of length to diameter) of more than five to one. Very short fibres of 1-2 μm in length may not be carcinogenic at all (Wagner, personal communication) but there is no evidence of any cut-off point down to diameters of 0.05 to 0.1 μm or less."*

Large fibres (considered as greater than 3 µm 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 can reach the more sensitive sections of the 'deep lung' known as the alveoli.

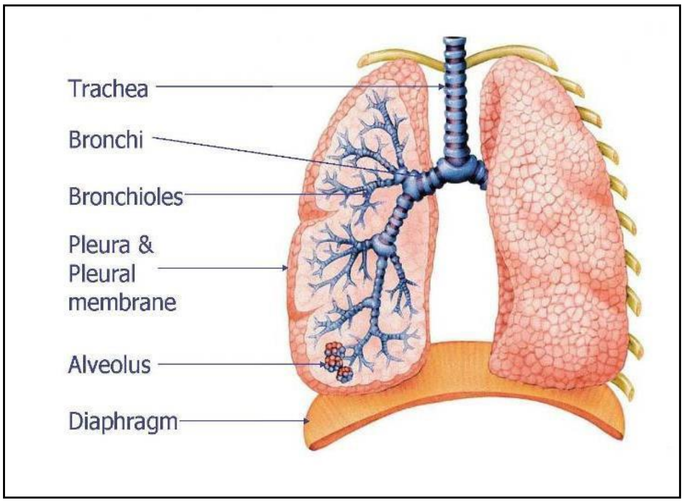

Figure 1.2 Simplified lung structure (Source: Gully Howard Technical Ltd)

The World Health Organization (WHO) estimates that more than 107,000 people die each year from asbestos-related lung cancer, mesothelioma and asbestosis resulting from exposure at work.

The extensive use of asbestos in the past, together with less stringent control procedures has led to many 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:

- **USA** - in 2009, the National Institute for Occupational Safety and Health (NIOSH) reported that between 1999 and 2005 there were a total of 18,068 deaths of persons with malignant mesothelioma, increasing from 2,482 deaths in 1999 to 2,704 in 2005.
- **UK** - the Health and Safety Executive (HSE) conducted a study into mesothelioma mortality and concluded that the number of deaths from mesothelioma has increased from 153 in 1968 to 2037 in 2005.
- **Australia** - Safe Work Australia (2013) reports that the total number of new cases of mesothelioma diagnosed has risen steadily in most years since 1982, when national data first became available, reaching peak of 675 cases in 2007.

The three most serious diseases associated with the inhalation of asbestos fibres are:

Asbestos	• **What is it?** Scarring and inflammation of the lung tissue
Mesotheliom	• **What is it?** Cancer of the external lining of the lung or the abdominal cavity
Lung cancer	• **What is it?** A malignant growth of abnormal cells in the lungs

1.2.1 Asbestosis

Asbestosis is an irreversible scarring and inflammation of the lung tissue, caused by the inhalation of any of the asbestos fibre types at high levels of exposure over many years. Asbestosis can cause shortness of breath, persistent cough, fatigue, laboured and rapid breathing and chest pain. There is no cure for asbestosis and over time the build-up of scar tissue can interfere with oxygen uptake through the lungs leading to respiratory and heart failure.

When the lungs become exposed to dust through inhalation, the body's macrophages (a form of white blood cell) in the alveoli engulf and ingest the fine particles by secreting enzymes and other chemicals. However, the size of hazardous asbestos fibres means that the cells cannot engulf and therefore digest the entire fibre; but instead burst and die releasing the partially digested particle along with the digestive enzymes and chemicals. These chemicals 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.

In 1985, Doll and Peto wrote:

> *"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."*

This statement describes the dose response relationship for asbestosis.

What is a 'dose-response relationship'?

A 'dose-response relationship' describes the effect on the body caused by differing levels of exposure (or dose) to a stressor. It is important because the dose-response curve illustrates:

- The 'no-effect range', where the body's defense mechanisms prevent an effect from occurring;
- The threshold-dose of the 'stressor', the point where the body's defense mechanisms are overwhelmed and the body shows a response to the stressor;
- The points where the stressor will cause adverse health effects.

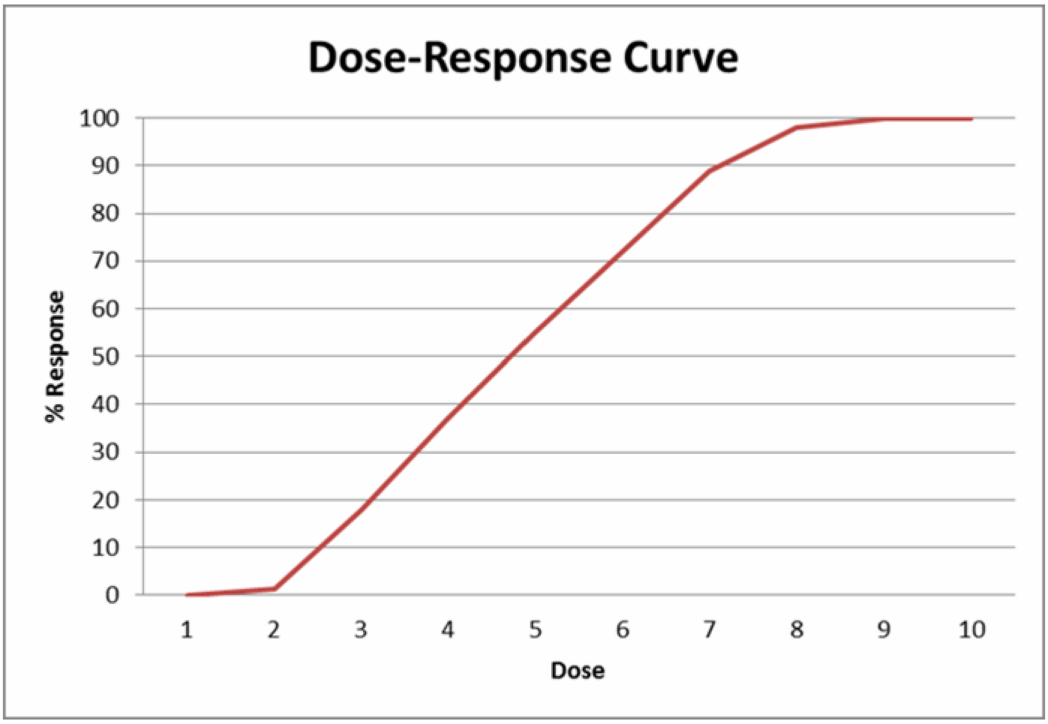

Figure 1.3 Typical dose-response curve

*These relationships for asbest*os were explored in textile workers in the 1930s, forming the basis of the first 'Threshold Limit Values' and the first 'Control Regulations' in the United States of America (USA) and United Kingdom (UK).

1.2.2 Mesothelioma

Mesothelioma is a form of cancer that most commonly affects the pleura (the external lining of the lung). It is almost always fatal, with most individuals usually dying within twelve months of diagnosis. The cancerous cells migrate (metastasize) from the original tumour to other parts of the body. Asbestos-related mesothelioma usually occurs first 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 and symptoms typically do not appear until between 20 and 30 years after exposure, extending up to 40 years in some cases.

Mesothelioma differs from asbestosis in that asbestosis appears to require a certain threshold of exposure before the adverse effects occur. There is no known safe threshold for mesothelioma.

Research by Hodgson and Darnton (2000) concluded that:

> *"The exposure specific risk of mesothelioma from the three principal commercial asbestos types is broadly in the ratio 1:100:500 for chrysotile, amosite and crocidolite respectively".*

Doll and Peto (1985) proposed that the curly shape of the chrysotile fibres makes them less hazardous than the straight crocidolite fibres:

> *"The explanation may, perhaps, lie in the configuration of the curly fibres which make them more likely to be trapped in the upper air passages than the straight fibres or in the greater rapidity with which chrysotile is cleared from the lungs."*

It is also noted that crocidolite is more biopersistent, and resists the body's chemical attacks.

1.2.3 Lung cancer

Lung cancer is a malignant growth of abnormal cells in the lungs. Symptoms do not usually appear until it has spread through the lungs or other parts of the body meaning that survival rates are relatively low.

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.
- There is a latency period after exposure before symptoms appear, typically at least 10 years, and may be as much as 30 or 40 years.

The chances of developing lung cancer are increased with the intensity and duration of exposure.

One difference between mesothelioma and lung cancer is the **synergistic** effect of exposure to asbestos fibres and smoking tobacco. A synergism effect occurs when two factors acting at the same time produce an outcome that is much greater than that which would be predicted by simply adding the effects of each factor acting alone.

The effect is shown in Figure 1.4, 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 three times the expected effect if the two effects were acting independently).

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

Figure 1.4 Asbestos, smoking and lung cancer (Source: HSE Asbestos Awareness Campaign)

1.2.4 Other asbestos-related diseases

Asbestos is also known to cause non-fatal conditions. These are associated with high dose occupational exposures:

- **Non-malignant pleural disease** is a non-cancerous condition affecting the outer lining of the lung (the pleura). It includes two disabling forms of disease: diffuse pleural thickening and the less serious pleural plaques.
- **Asbestos warts** or corns are caused when the fibres lodge in the skin and are overgrown, causing benign callus-like growths. They generally grow on the hands and lower arms.

1.3 Asbestos control and prohibition

As awareness of the adverse health effects of asbestos increased, there were attempts to control occupational exposure to asbestos dust. The first legislation in the UK for example was The Asbestos Industry Regulations (1931). This attempted to address serious lung disease through providing ventilation and masks.

Modern health and safety legislation started with the Occupational Safety & Health Act (1970) in the USA. The OSHA law makes it clear that the right to a safe workplace is a basic human right (OSHA 3302-11R). Similar acts followed in other developed countries such as The Health and Safety at Work Act (1974) in the UK.

Legislation attempted to control occupational exposure to asbestos. Exposure limits were introduced as well as rules governing asbestos work and removal in many countries. Work on high risk, 'friable' (easily crumbled) materials was made licensable, for example in the UK under The Asbestos Licensing Regulations (1983).

As the link with cancer and asbestosis became more established, outright bans on the import, mining and use of asbestos were introduced. To begin with it was only the amphiboles that were banned, in New Zealand (1984), the UK (1985) and in the Australian states (from 1985). Total bans followed in all the European Union countries including the UK

(1999). There were total bans in Australia (2003), South Africa (2008) and finally in New Zealand (2016).

Banning asbestos and controlling asbestos removal cannot protect people from occupational exposure to asbestos where it is found in existing buildings. Trades people such as plumbers and electricians can easily disturb asbestos as they go about their work activities. Legislation and regulations have therefore been put in place to manage all asbestos materials in the workplace, even when those materials are not being directly removed or worked on.

2.0 Work with asbestos

2.1 Overview

Section 2.1 covers the accepted levels of airborne asbestos fibres that a person can be exposed to, during and after asbestos removal work. The volumes of measurement are listed as fibres/cm^3, which is equivalent to fibres/ml and fibres/cc:

1 fibre/cm^3 = 1 fibre/ml = 1 fibre/cc

In Australia, New Zealand, South Africa and the UK, asbestos fibre counting measurements are generally written as f/cm^3 or f/ml. In the USA, fibre counting measurements are written as f/cc.

These are the three main factors that should be taken into account for asbestos removal work, in order to ensure that the risk of exposure to asbestos is reduced:

1. **Exposure limit** – the *maximum* acceptable level of asbestos fibres in the air **during asbestos work**
2. **Acceptable background level** – the acceptable level of asbestos fibres in the air **after asbestos work**
3. **Action levels –** the steps that should be taken by asbestos removalists depending on the measured background level

2.1.1 Exposure limits

Because of the dangers posed by exposure to asbestos, most countries have set an **exposure limit** on the level of airborne asbestos fibres that a person can be exposed to during asbestos work. In developed countries (with some exceptions), this is set at **0.1 fibres/cm^3** of air measured over a time weighted average (TWA) of 8 hours.

Higher levels of asbestos exposure for shorter time durations are permitted in some countries, provided that the 8 hour TWA is not exceeded. This limit is known as the **Short Term Exposure Limit (STEL).** The table below shows a summary of some of the national exposure limits:

Country	Official name of exposure limit	Maximum limit	STEL
Australia	National Exposure Standard (NES)	0.1 f/cm^3	N/A
New Zealand	Airborne Contamination Standard (ACS)	0.1 f/cm^3	N/A
South Africa	Occupational Exposure Limit (OEL)	0.2 f/cm^3	N/A
United Kingdom	Control limit	0.1 f/cm^3 (TWA 4 hours)	0.6 f/cm^3 (10 min)
United States	Permitted Exposure Limit (PEL)	0.1 f/cm^3	1 f/cm^3 (30 min)

Figure 2.1: International exposure standards (Source: New Zealand ACoP 2016)

The exposure limit is not set as a **safe** level of asbestos exposure. There is no threshold limit below which it can be proven that asbestos does not cause cancer. The exposure limit set is a compromise between safety and practicality. When working on asbestos to repair or remove it, there will always be some exposure that cannot be controlled; it is not possible to completely remove all asbestos from the air.

Because there is no safe limit of asbestos exposure, the regulations in most countries place a further obligation on the employer to reduce exposure to as low a level as is reasonably practicable. Under normal circumstances, where work is not being directly carried out on asbestos, this level should be as close to zero as possible.

2.1.2 The trace level/control level

The exposure limit is **not** an acceptable ambient background level: it is only intended as an acceptable exposure level for asbestos work when there are other control measures in place (e.g. an enclosure is being used or RPE is being worn).

Instead, the acceptable background level is set at **0.01 fibres/cm^3**. This level indicates that an area is clean *following asbestos work,* and is the level that must be achieved inside an enclosure after the clearance air test. In New Zealand, this acceptable background level is known as the **Trace Level** and in Australia as the **Control Level.** In the UK, this level is commonly known as the **Clearance Indicator**.

Even this lower level is not intended as a 'safe level' for exposure to asbestos. It has been chosen because it is the same as the **Limit of Detection** (or Limit of Quantification) used to measure how much asbestos there is in the air. Air samples are taken by an asbestos assessor and sent to an independent laboratory to analyse how much asbestos is in the air, by counting the number of fibres present (commonly known as **fibre counting**).

There are different means of carrying out fibre counting, but the most commonly used method is the World Health Organization's **Membrane Filter Method**. This is the method most commonly used in New Zealand, Australia and the UK. This method uses a Phase Contrast Microscope (PCM) to count asbestos fibre concentrations in air samples.

The limitation of the Membrane Filter Method is that it does not discriminate between asbestos and non-asbestos fibres: all fibres are counted. There is always a background count even when 'clean' air is sampled (usually from contaminating fibres on the filter). It is not possible to determine whether there is zero asbestos present, so 0.01 f/cm^3 has been set as the lowest level of fibres that can be accurately counted. Fibre levels below 0.01 f/cm^3 are only ever recorded as <0.01 f/cm^3 when the WHO method is used, because a more precise result is not possible using a Phase Contrast Microscope.

More detailed analysis of asbestos fibre concentrations can be done by using Transmission Electron Microscopy (TEM) or Scanning Electron Microscopy (SEM). These methods are more sensitive, can discriminate between asbestos and non-asbestos fibres, and therefore have a lower Limit of Detection. However, they are much more expensive and time- consuming, so the WHO method is generally used as it is cheaper and more practicable.

More information on fibre counting methods can be found in *IP403 – Asbestos Fibre Counting (PCM).*

2.1.3 Action/control levels

Asbestos fibre levels can be summarised as follows:

- **The exposure limit of 0.1 f/cm^3** – this is intended as an acceptable operative *exposure* limit *during* work.
- **The trace/control level of 0.01 f/cm^3** – this is intended as acceptable ambient background level *after* work has taken place.

There is a third level that is used to put a limit on acceptable asbestos fibre levels outside the work area during asbestos removal work. These are known as **action levels** in New Zealand, and **control levels** in Australia. Action levels are not required in New Zealand by law, but are recommended by the ACoP (2016) as actions that should be taken by the licenced asbestos removalist. In other countries, there are no prescribed action levels as there are in New Zealand and Australia, but in practice similar procedures take place. Action levels are associated with control monitoring, the methods of which are discussed in Section 3.1.2.

The table below summarises the actions that should be taken depending on the level of asbestos fibres present, based on the New Zealand ACoP (2016). These action levels are also used in Australia, but they are known as first and second control levels rather than action levels.

Action level	Control	Action
< 0.01 fibres/ml (trace	No new control measures necessary	Continue with existing control measures
≥ 0.01 fibres/ml, but < 0.02 fibres/ml	1. Investigate	Investigate the cause
	2. Implement	Put controls in place to prevent exposure
	3. Prevent	Prevent further fibre release
≥ 0.02 fibres/ml	1. Stop	Stop Class A asbestos removal work
	2. Notify	Notify WorkSafe. Include the results of the air monitoring.
	3. Investigate	Conduct a thorough visual inspection of the enclosure (If used) and associated equipment in consultation with all asbestos workers. Review controls.
	4. Put controls in place to prevent exposure and further asbestos fibre release	1. Extend the isolated/barricaded area around the work area/enclosure as far as reasonably practicable (until fibre levels are below or at 0.01 fibres/ml). 2. Wet-wipe and vacuum the surrounding area, seal any identified leaks. 3. Smoke test the enclosure until it is satisfactorily sealed.

Figure 2.2 Action levels in New Zealand (Source: New Zealand ACoP: Management and Removal of Asbestos 2016, p.200)

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2.2 Legislative controls on asbestos work

2.2.1 Licensing

In Australia and New Zealand, asbestos removal work is required to be carried out by a licensed asbestos removalist. The only exceptions are the removal of small amounts of low risk non-friable asbestos (<10m^2).

There are two types of license that an asbestos removalist can have:

- **Class A licence** - permitted to remove all types of asbestos, including both friable and non-friable asbestos.
- **Class B licence** - can only remove non-friable asbestos.

In the UK, work on high risk friable asbestos materials requires a license, but work on low risk non-friable asbestos materials does not. The work is still covered by the asbestos regulations, so it must be carried out using adequate control measures by competent and trained operatives.

In the USA, asbestos work in some states requires a license.

2.2.2 Friable and non-friable asbestos

Asbestos is rarely found in its pure form. It was added to other products because of its thermal and acoustic insulating properties and high tensile strength. It is the material nature of the products that asbestos was added to more than anything else that determines the level of risk.

In some products, asbestos fibres are tightly bound in the matrix, and these fibres are not easily released into the air if the products are broken or disturbed. These products are classed as **non-friable** and are considered lower risk. Work on these products if carried out using good control measures are unlikely to exceed the exposure limit. These include:

- Bitumen products.
- Cement products.
- Gaskets.
- Paints and decorative plaster coatings.
- Plastics.

Other products release asbestos fibres into the air more readily because they have a matrix that is easily broken and turns to dust if disturbed. These products are classed as **friable** and are considered high risk. Work on these products, even if carried out using good control measures, is likely to exceed the exposure limit. These include:

- Insulating boards.
- Sprayed insulation.
- Thermal Insulation (e.g. lagging).

If the asbestos material is friable, then it requires a license in the UK, and the higher-level Class A license in Australia and New Zealand. The rules and control measures governing the

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removal of friable asbestos are stricter. Sections 2.3 and 2.4 are applicable to work on both friable and non-friable asbestos materials. Section 2.5 covers the additional standards that apply to work on friable asbestos materials.

2.3 The Asbestos Removal Control Plan

All organisations carrying out any type of asbestos work must have a written risk assessment that assesses the asbestos risk (including the expected fibre release), as well as non- asbestos risks such as:

- Confined spaces.
- Electrical hazards.
- Heat stress.
- Work at height.

They should also have a written method statement that gives:

- Site details.
- A description of the work.
- The control measures used.

The Asbestos Removal Control Plan (ARCP) is specified in Australia for all types of asbestos work.

In New Zealand, the regulations state that a licensed asbestos removalist must prepare an asbestos removal control plan for **any** licensed asbestos removal work that they are commissioned to undertake. The definition of licensed asbestos removal work is 'asbestos removal work for which a Class A asbestos removal licence or a Class B asbestos removal licence is required'.

It is the responsibility of the asbestos removalist to prepare and complete the plan before the removal work starts, to ensure that both workers and members of the public are not put at risk of asbestos exposure. The ARCP should include:

- Details of how the asbestos removal work will be carried out.
- Any tools, equipment and PPE that will be used.
- The location, type and condition of the asbestos being removed.
- A detailed description of the asbestos removal area, including air sampling points.
- Disposal and transport routes for asbestos waste.

A work area plan (or work method statement) should also be included, with details such as sketches of the work site. Where relevant, this should indicate the locations of:

- Decontamination units.
- Enclosures.
- Extraction units.
- The entrances and exits for the asbestos removal site.
- Warning signage (to prevent entry from those not involved in the project).
- Where asbestos waste will be contained.

The ARCP should be made available to the **Person Conducting a Business or Undertaking** (PCBU) at the workplace, the workers and their representatives. It is also legally required by New Zealand's Health and Safety (Asbestos) Regulations 2016 for the ARCP to be made available for inspection by the asbestos assessor.

It is the responsibility of the asbestos assessor to thoroughly check the ARCP, and raise any issues with the removalist before removal work begins. At the end of the clearance inspection, the asbestos assessor will complete the visual clearance section of the ARCP, which covers all site checks they need to make, including clearance certificates.

An example template of an ARCP can be found in the New Zealand ACoP: Management and Removal of Asbestos 2016, p. 248-262.

2.4 Control measures and the Hierarchy of Controls

All work on asbestos whatever the level of risk is regulated, and the organisation carrying out the work must put control measures in place to ensure that, as far as reasonably practicable, no one is put at risk from the work.

The Hierarchy of Controls is a widely-used system which seeks to prioritise how the control of risk should be managed. It underpins the approach taken by national occupational safety and health administrations in the USA, UK and elsewhere. For example, the New Zealand ACoP: Management and Removal of Asbestos 2016 describes the control of risks using these terms.

The hazard controls in the hierarchy are illustrated in order of decreasing effectiveness (from the most effective to the least effective control):

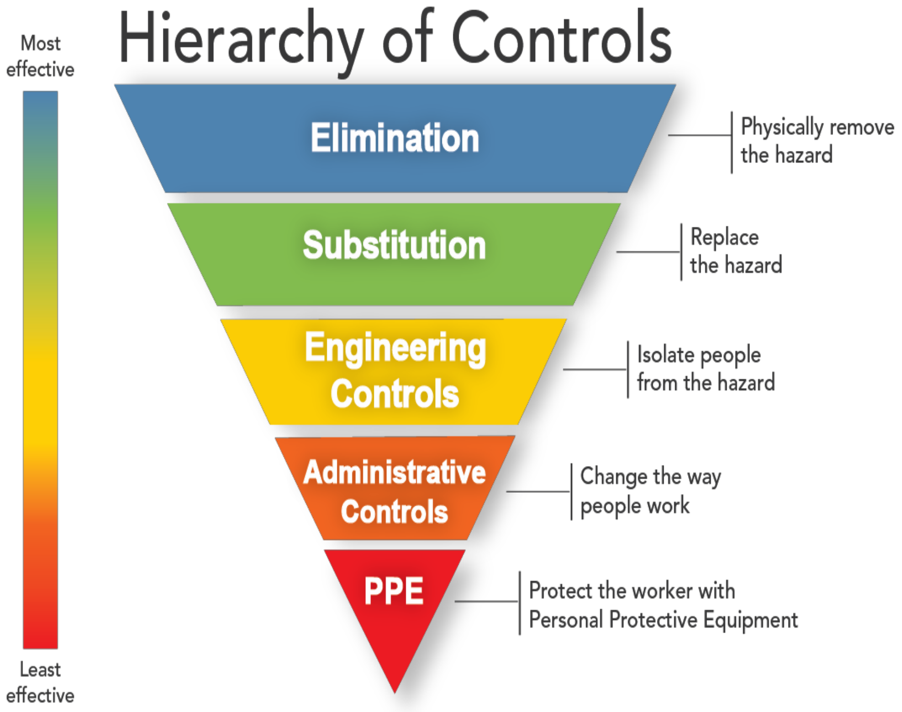

Figure 2.3 Hierarchy of Controls (Source: NIOSH)

A mixture of engineering and administrative controls are used along with RPE when asbestos work is carried out. The Hierarchy of Controls highlights the relative importance that these controls have when planning the work.

2.4.1 Elimination and substitution: is the work necessary?

All work on asbestos, however effective the controls measures used, results in the spread of asbestos to enhanced fibres levels and exposure. The most effective way of controlling asbestos exposure is to avoid working with it at all. If asbestos materials are in good condition, the risks are small. The estimated fibre concentrations in buildings where asbestos material is well managed and in good condition is 0.0005 f/cm^3.

Fibre concentrations rise well above these levels when removal work is carried out. Even after the clearance, there would be some residual dust and levels would be above the pre- work level. If electric wiring is planned to go above an asbestos ceiling in a refurbishment project, re-routing the wiring should be considered before removal of the asbestos material.

2.4.2 Engineering controls: reducing fibre release at source

Sometimes asbestos work cannot be avoided. In the above example, there might be no other way of routing the wiring. Sometimes asbestos material is damaged and sometimes it is vulnerable to disturbance, so it needs to be repaired or removed. Engineering controls are preferable to administrative controls, because these rely on changing human behaviour and can easily fail (New Zealand ACoP: Management and Removal of Asbestos 2016, p.139).

The common engineering controls used on all asbestos work are discussed below. If work is being carried out on friable asbestos materials, further mandatory engineering controls are required (these are discussed in Section 2.5). The overriding principle for asbestos engineering controls is to reduce fibre release to as low a level as possible at source.

2.4.2.1 Wetting

Using a water spray to suppress dust is a simple and effective way of controlling fibre release at source. The amphibole asbestos types are hydrophobic (they repel water), so a wetting agent or surfactant is added. A common garden spray or a purpose-built spray can be used, but they must be low pressure so that they do not degrade the material and lead to spread of asbestos dust and debris. The use of high pressure water sprays is forbidden.

Alternatively, pastes and gels can be applied to the asbestos material. These have the advantage of adhering to the material, not degrading it through saturation and not causing contaminated run-off.

Asbestos materials should never be dry stripped as fibre concentrations can rise to as high as 1000 fibres/cm^3 on friable materials, and as high as 100 fibres/cm^3 on some non-friable materials.

2.4.2.2The ‘Type H’ vacuum

Vacuum cleaners are another simple and effective control. They can be used to vacuum up any waste and debris created, but they are also used for ‘shadow vacuuming’ - a good way of removing dust while the work is being carried out.

Normal vacuum cleaners must not be used. Class H (high hazard) vacuums should be used that comply with the relevant national standard AS/NZS 60335.2.69 (New Zealand); 3544- 1988 (Australia); BS5415 (UK), and should be fitted with High Efficiency Particulate Air (HEPA) filters that comply with AS 4260 (Australia, NZ) or BS EN1822 (UK).

2.4.2.3Barriers and signs

It is not possible to eliminate all fibre release at source, so it is necessary to restrict access to the work area by means of a physical barrier and/or signs. Sometimes the work area is completely enclosed in an enclosure. This is mandatory for work on friable asbestos or where the exposure level is likely to be exceeded. These are examined in detail in Section 2.5.

2.4.2.4Tools

The tools used must be those that are designed in a way that do not cause fibre release. Power tools including angle grinders, sanders, saws and drills should never be used unless they are used with dust suppression or extraction controls inside an enclosure. Fibre levels for cutting asbestos materials with power tools can be between 1 and 10 fibres cm^3 when wet, and between 2 and 20 when dry (New Zealand ACoP: Management and Removal of Asbestos 2016, p.267).

2.4.2.5 Glove bags

The use of a glove bag to enclose asbestos work is another effective way of controlling fibre release. These are single-use bags constructed from transparent, heavy-duty polyethylene with built-in arms that contain the waste within them. A Type H vacuum can then be used to control fibre release and create a negative pressure.

In Australia and New Zealand, these are permitted for use on small removal projects where friable, licensed material is being removed (e.g. a small section of pipe lagging). The problem with them is that it is hard to control the waste and they often fail. In the UK, they are only permitted as a secondary control within an enclosure, if the work is on friable material.

2.4.2.6 Wrap and cut method

The ‘wrap and cut’ method is where asbestos material is securely wrapped in polythene before removal. This is not suitable for work on friable asbestos material, as it is difficult to completely enclose the material and prevent the spread of dust. It is not permitted in the UK, but it is permitted in New Zealand and Australia. However, inside an enclosure it is a very effective secondary control.

2.4.3 Administrative controls: information and training

Regardless of whether the material is friable or non-friable, licensed or unlicensed, an employer or Persons Conducting a Business or Undertaking (PCBUs) must ensure that every worker who works with asbestos is knowledgeable and experienced with asbestos; they are aware of the other risks that the work may present; and are adequately trained in how to safely use everything that they need to work with, including protective clothing and RPE.

Additional training is required for operatives or removalists carrying out licensed work, especially if this work is Class A in New Zealand or Australia. More detail of training requirements for workers in New Zealand can be found in the Health and Safety at Work (General Risk and Workplace Management) Regulations 2016.

2.4.4 Respiratory Protective Equipment (RPE)

There is an absolute legal duty to use RPE whenever the exposure limit is exceeded. As exposure must also be reduced to as low a level as possible, RPE should also be used by those carrying out work on asbestos (including the asbestos assessor) if there is a risk of exposure above trace levels. Entry into an asbestos enclosure is a potential risk that should be controlled by wearing RPE, even after the removal work has been completed.

There are several respirators that can be used. These include:

Disposable orinasal masks

Full face masks

Half face masks

Hood

RPE is used with filters. There are three types of filter:

- Particle filters.
- Gas/vapour filters.
- Combined filters (particles and gases/vapours).

For work with asbestos, a particle (or combined) filter must be used. A filter designed to protect against gases and vapours will not protect the wearer from asbestos dust. Filters designed to protect against particles are prefixed with a ‘P’.

There are three levels of particle filters:

P1: Low efficiency - for use with APF4 (Minimum required PF) respirators.
P2: Medium efficiency - for use with APF10 (Minimum required PF) respirators.
P3: High efficiency - for use with APF20 or APF40 (Minimum required PF) respirators

2.4.4.1 Assigned Protection Factors (APF)

RPE has an Assigned Protection Factor (APF) that indicates how much protection the RPE should theoretically give. The higher the APF, the more protection a respirator can offer. This is known as the Minimum Required Protection Factor (PF) in New Zealand and Australia.

An APF of 20 means that the contaminant concentration inside the mask should be no more than one-twentieth (5%) of the concentration outside the mask. If the RPE fits the wearer and is correctly worn, they will inhale no more than 5% of the dust in the surrounding air.

Assigned Protection Factor	RPE type
4	**Half face mask with P1 filter**
10	**Half face or full face mask with P2 filter**
10	**TH1 Hood**
20	**Half face mask with P3 filter.**
20	**TH2 Hood**
40 (UK/EU measurement only)	**Full-face mask with P3 filter**
40 (UK/EU measurement only)	**TH3 Hood**
200	**Compressed airline suit**
2000	**Positive demand self-contained (SCBA)**

Figure 2.4 APFs of respiratory protective equipment (UK standards)

A P3 filter should always be used for work on high risk friable asbestos materials. In the UK, a P3 filter is specified for all asbestos work, including that of the asbestos assessor (analyst) and surveyor.

In Australia and New Zealand, a P2 filter can be used for lower risk work such as removing asbestos cement. A P2 filter can also be used by the asbestos assessor or surveyor.

2.4.4.2 Face-fit testing (FFT)

To ensure that the respirator is achieving the theoretical protection factor, it should be face fit tested to the individual before use and a record kept. The tests should be repeated when:

- A new model of respirator is used.
- The wearer has gained or lost weight.
- The wearer has had major dental work.

It is good practice to repeat the test either annually or six monthly. This is especially the case where RPE is being used for work on friable, licensable materials where it is likely that the exposure limit will be exceeded.

The **qualitative FFT** is suitable for half masks and disposables. It cannot be used for full face masks. It provides a simple pass/fail test, based on the wearer's subjective assessment of whether they can initially smell or taste a 'sensitivity' agent (bitter or sweet substance). This type of test should not be used for full face masks that have an APF of 40.

The **quantitative FFT** provides a numerical measure of the fit, which is called the **fit factor**. These tests give an objective measure of face fit and require specialised equipment. This test must be used for full face masks with an APF of 40, but it is also suitable for half face masks with an APF of 20 or 10.

2.4.4.3 Training and use of RPE

It is important that the wearer is properly trained on how to use the RPE that they use. If worn incorrectly or it becomes damaged, the mask will not provide the level of protection that it was designed for. Inspections need to be carried out before each use.

It is also important that the wearer is clean shaven if they are wearing a mask. If they have a beard or stubble, a hood with the appropriate protection factor must be worn.

2.4.4.4 Assigned Protection Factors and the exposure limit

Wearing RPE allows the operative to work in areas where the national exposure limit may be exceeded.

To assess the fibre concentrations that are permissible when the mask is being worn, the APF of the mask is multiplied by the exposure limit. For example, if a full face mask (APF 40) is being worn, then the wearer can be exposed to fibre levels of:

40×0.1 fibres/cm^3 = 4 fibre/cm^3

This assumes that the exposure limit is 0.1 fibres/cm^3. In South Africa, where the exposure limit is 0.2 fibres/cm^3, exposure to fibres levels of 8 fibres/cm^3 are permitted.

In most countries (including the UK, Australia and New Zealand), there is a further duty to reduce levels to as low as is reasonably practicable using other controls. The 4 fibre/cm^3 limit is not a working limit, but an absolute maximum for which someone can never be exposed above, even when wearing RPE.

2.4.5 Personal Protective Equipment (PPE)

When working on asbestos, clothing must prevent the build-up of asbestos fibres, be cleanable and protect the wearer from fibre penetration. The coveralls used are Type 5 category 3 that conform to ISO13982-1. The material repels fibres and prevents fibre penetration. They have elasticated cuffs and a hood. Laceless, cleanable boots are used. Gloves are also used to protect hands.

2.5 Work with friable asbestos material

The rules for work on friable asbestos materials are much stricter. In Australia and New Zealand, work on friable asbestos requires a Class A license. In the UK, work on friable asbestos requires a license, although work with non-friable asbestos does not.

Specific controls measures must be put in place:

- ✓ An enclosure must be constructed around the work area.
- ✓ The enclosure must be under negative pressure.
- ✓ The enclosure must be a respirator zone and the respirator should be full face with a P3 filter.
- ✓ Decontamination facilities with three separate stages should be either attached to the enclosure, or a mobile Decontamination Unit (DCU) should be located nearby.

2.5.1 Notification

In addition to the licence requirement, work on friable material must be notified to WorkSafe in New Zealand, or the state health and safety organisation in Australia five days prior to commencement of the work. Some Australian states may have stricter rules about notification.

In the UK, the enforcing authority must be notified 14 days prior. Notification is also required in some US states.

South Africa does not have a licensing regime, but all asbestos work should be notified to the Provincial Director.

The rules vary between countries and states within countries about what information is included in the notification. The following information is typical and is submitted in both New Zealand and the UK:

- The date of the notice.
- The name, address and license details of the asbestos removalist.
- The name of the supervisor of the licensed asbestos removal work.
- The name and contact details of the person for whom the work is to be carried out.
- The site address where the work is being carried out.
- The start date of the work and the estimated duration.
- Details of the asbestos material type.
- Details of the control measures to be used.
- The estimated quantity of asbestos to be removed and the means of transport and disposal of the asbestos waste.
- The number of workers who are to carry out the asbestos removal work.

2.5.2 The enclosure

An enclosure is a physical barrier constructed around the asbestos work area which contains asbestos dust and waste arising from the work. They are designed to prevent exposing people to asbestos and to prevent the spread of asbestos.

2.5.2.1 Enclosure design

Enclosures are constructed as temporary self-supporting units made with a timber framework and high quality polythene sheeting. In Australia and New Zealand, the polythene must be at least 200 µm thick (800 gauge) and the UK it must be 250 µm (1000 gauge). It is acceptable for the enclosure to use existing parts of a building structure (e.g. floor, walls, ceiling etc.) so long as these surfaces are smooth and impervious to fibres.

The enclosure should have vision panels that allow those supervising or inspecting the work to see what is going on inside the enclosure without having to enter the area. They should be located in suitable positions that allow the progress of the work and the effectiveness of control measures to be monitored. For more complex enclosure layouts, closed-circuit television (CCTV) cameras or webcam systems can be used.

The enclosure is a restricted area and a respirator zone. No one other than the asbestos removalists and the asbestos assessor should enter it. It should have signs that identify it as such.

2.5.2.2 Three stage airlock and baglock

Entry and exit from an enclosure should ideally be via a decontamination facility that has a dirty area, a shower area and a clean area. If it is not possible to attach a decontamination facility, a remote unit can be used with a dedicated transit route. Entry to the enclosure is via a three-stage airlock with self-closing flaps between each stage.

Unless there is no room to attach one, asbestos waste should be taken out of the enclosure through a separate three stage airlock called a baglock.

These airlocks need to be as big as reasonably practicable to allow transfer of waste and personnel, and accommodate necessary clothes changing and decontamination procedures. A size of 1 metre x 1 metre x 2 metres is the minimum standard used in the UK, although this can be altered if access is restricted (such as by a corridor or fire escape). They should be of the same robust construction with the same grade polythene as the main enclosure.

2.5.2.3 The negative pressure unit and air management

An enclosure must be under a negative pressure. This ensures that clean air always flows from the outside into the enclosure rather than dirty air flowing from the enclosure to the outside. This is achieved by using a Negative Pressure Unit (NPU), a form of local exhaust ventilation. NPUs are usually comprised of a pre-filter; HEPA (high efficiency) filter; fan (usually centrifugal); reverse flow damper (in case of fan failure or environmental factors); and an exhaust.

The NPU must conform to BS 8520-2 and have filters that comply with BS EN1822 in the UK and New Zealand. In Australia, the filters should comply with AS4260:1997. The units should regularly have Dispersed Oil Particulate (DOP) tests to ensure that they are working efficiently.

The NPU(s) should be of a suitable size to ensure that there is a suitable pressure differential between the inside and outside of the enclosure. In New Zealand, a minimum differential of 12 Pa (Pascals) is recommended. In the UK, it is 5 Pa. The differential should be enough to ensure that the air flow is always from the outside to the inside, but it should not be so high as to compromise the enclosure structure. A flow rate of 0.2 metres^3/second for every 100 metres^3 of enclosure that gives approximately eight air changes per hour should be adequate.

The NPU should be positioned to ensure an optimum smooth flow of air through the enclosure. Usually this would be opposite the air locks as shown in the diagram below. If the enclosure is complex, NPUs should be positioned in a way that minimizes dead spots.

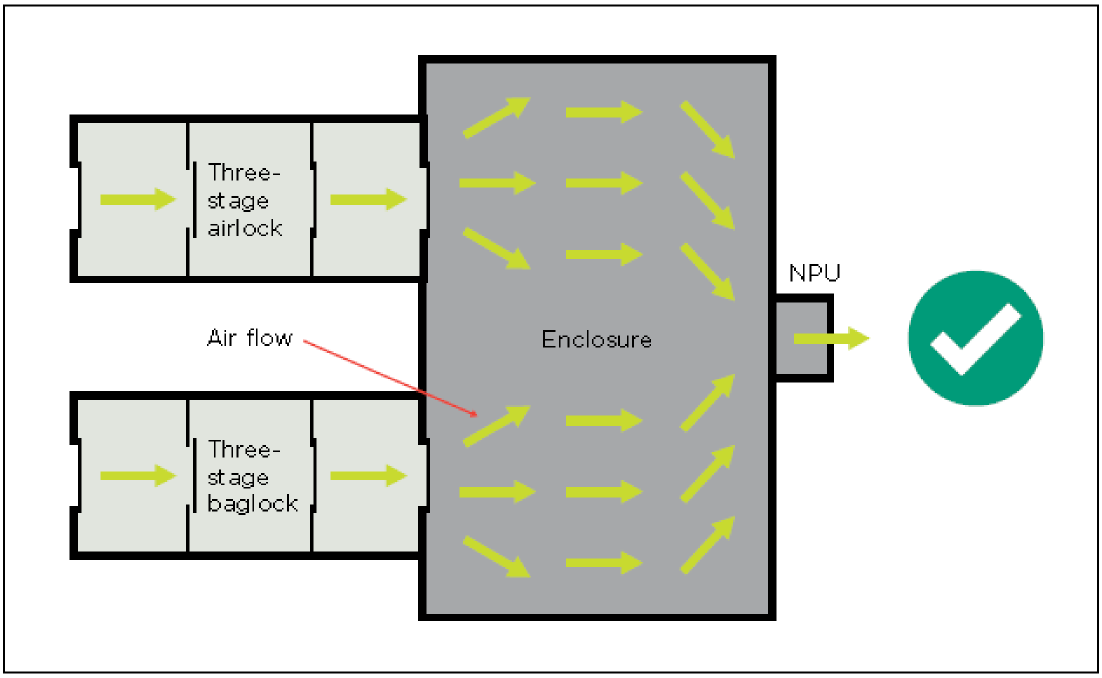

Figure 2.5a Example of good practice with the layout of an asbestos enclosure (Source: New Zealand ACoP: Management and Removal of Asbestos 2016)

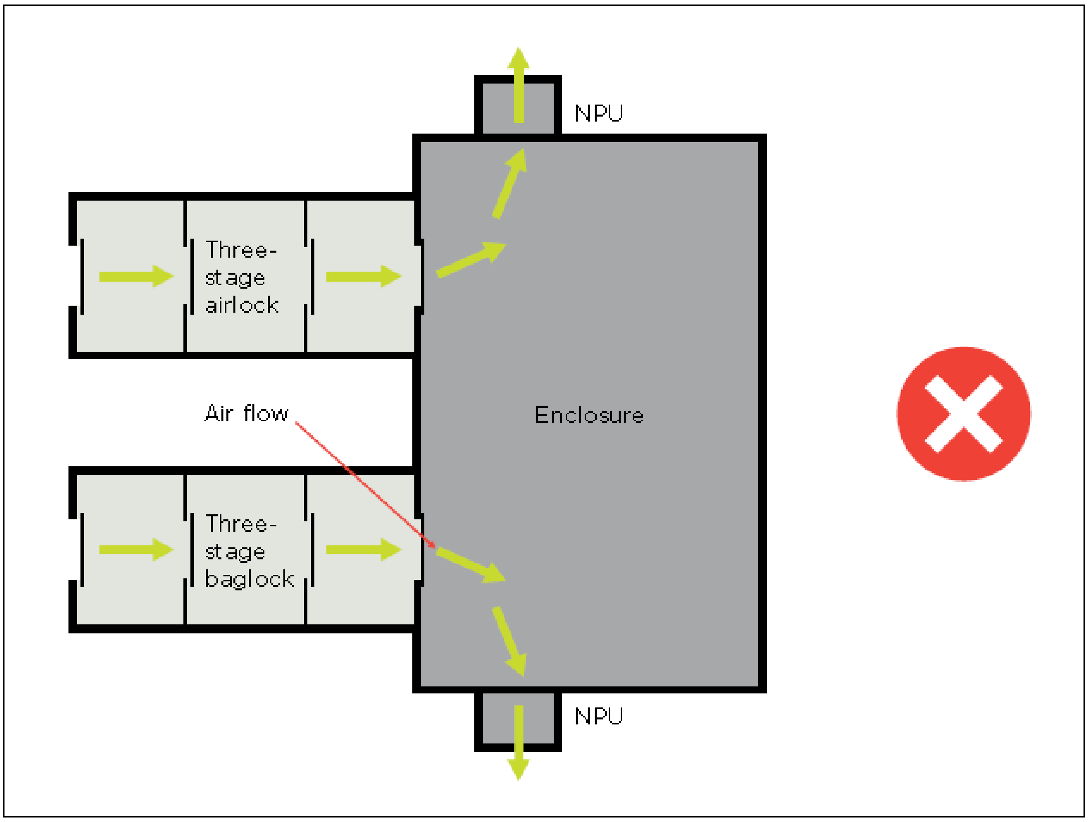

Figure 2.5b Example of bad practice with the layout of an asbestos enclosure (Source: New Zealand ACoP: Management and Removal of Asbestos 2016)

2.5.2.4 Enclosure evaluation and smoke test

Before work can commence, the enclosure must be checked to ensure that it is fit for purpose and is adequately sealed. Areas of weakness often include taping around the negative pressure unit, where the airlock/baglock join the main enclosure, and where pipework or cabling crosses from the external to internal enclosure areas.

The visual checks are followed by a smoke test. The NPU is switched off and a smoke generator (which should not be oil-based) is used to fill the enclosure. A Tyndall beam dust lamp or simple torch is used to observe the outside of the enclosure for any smoke leaks.

The person carrying out these checks should be independent of the asbestos removal contractor. The visual inspection and smoke test should be recorded.

2.5.3 The Decontamination Unit

A decontamination Unit (DCU), also known as a decontamination facility, is where the worker who has been contaminated with asbestos material in an asbestos area or enclosure cleans and decontaminates themselves. It must have a ‘dirty end’ where the worker can remove their contaminated clothing, a separate shower compartment, and a ‘clean end’ where the worker can put their clean uncontaminated clothing back on.

In an ideal site situation, the decontamination unit should be attached directly to the enclosure with buffer zones separating the three stages. Figure 2.6 is an example from the New Zealand ACoP: Management and Removal of Asbestos (2016). The unit has separate dirty, shower and clean areas with self-closing doors.

Minimum specifications for DCUs are higher in some countries. In the UK for example, the guidance is very detailed: the DCU must be purpose-built, have an independent NPU to generate air flow and have self-closing hinged doors.

The procedure for entry through a DCU and into an enclosure is similar, irrespective of the unit specification:

1. Remove everyday clothing in the clean end. Put on the protective coveralls and RPE.
2. Pass through the shower area.
3. Pass through the dirty end (and any intermediate or buffer areas) into the enclosure or work area. If entry to the enclosure is via a three-stage airlock, put transit clothes in the outer stage (furthest from the enclosure).

Decontamination procedures are a little more complex. Any worker who enters an asbestos enclosure is very likely to become contaminated with asbestos fibres; therefore a thorough and efficient decontamination process is necessary. The procedure is:

1. Remove visible contamination to clothing using an asbestos vacuum cleaner. This can be carried out inside the enclosure or within a buffer area that connects the enclosure the DCU.
2. Pass into the dirty end of the DCU, remove work clothing (but not the RPE).
3. Shower with RPE on until clean and then remove.
4. Pass to the clean end and put on uncontaminated everyday clothing.

If the decontamination unit is located remotely to the asbestos enclosure, with a three- stage airlock connected to the enclosure, different decontamination procedures must be followed:

1. **In the enclosure -** Remove visible contamination to clothing using an asbestos vacuum cleaner.
2. **In the inner stage of the airlock (closest to the enclosure) -** Vacuum off overalls again and wipe down respirator.
3. **In the second (middle) stage of the airlock –** take off overalls and boots (keep RPE on).
4. **In the outer stage of the airlock (furthest from the enclosure) –** put on transit overalls and shoes.
5. Leave the airlock and enter the dirty end of the decontamination unit.
6. Remove transit clothing (keep RPE on).
7. Shower with RPE on until clean and then remove.
8. Pass to the clean end and put on uncontaminated everyday clothing.

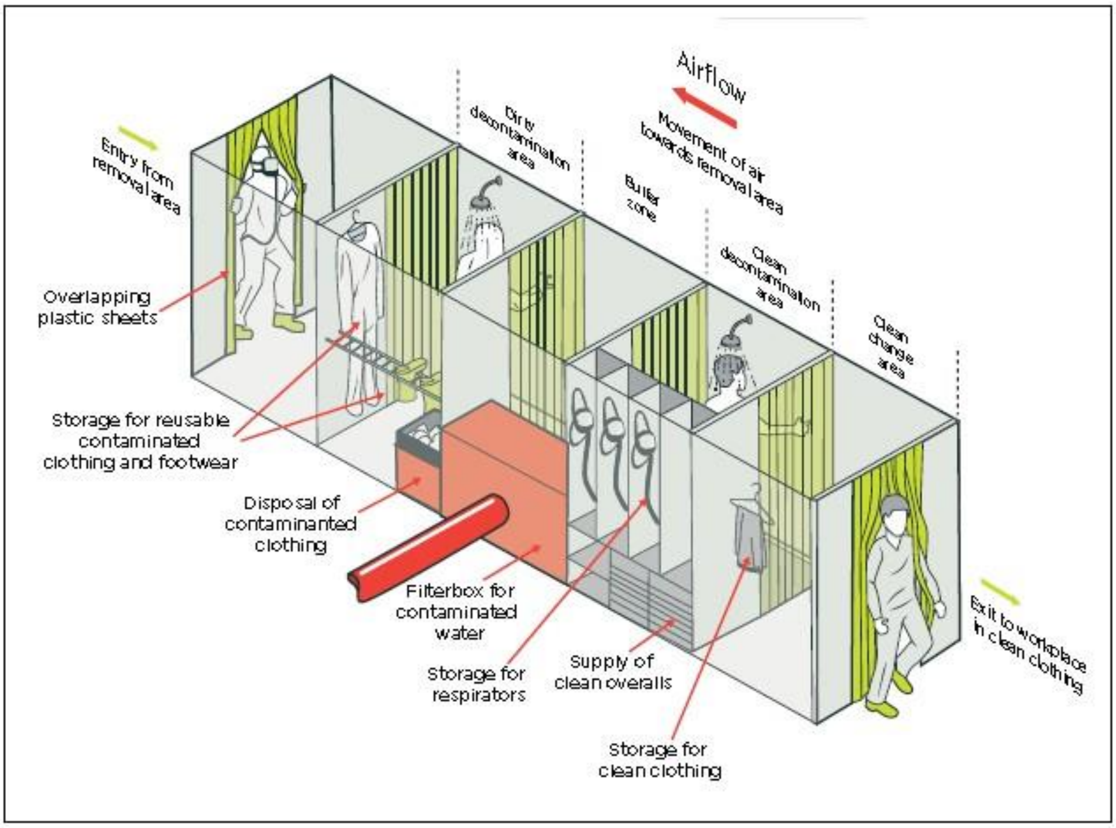

Figure 2.6 Diagram of a three stage decontamination area attached directly to enclosure **(Source: New Zealand ACoP: Management and Removal of Asbestos 2016)**

2.5.4 Controlled stripping techniques

Although the enclosure prevents the spread of asbestos, further control measures (secondary control measures) are required to reduce removalist exposures inside the enclosure. Methods must be used that reduce fibre release at source. RPE should not be used as the primary control measure, as it offers only limited protection from the sort of fibre concentrations that poor removal techniques cause. Figure 2.7 below illustrates this:

Exposure limit	**0.1 f/cm^3**
Protection given by a full face APF40 mask (if correctly used)	**4 f/cm^3**
Well controlled work with asbestos containing materials	
Controlled wet stripping of lagging using manual tools	up to 1 f/cm^3
Careful removal of whole asbestos insulating board	up to 3 f/cm^3
Drilling asbestos insulating board with shadow vacuuming	up to 1 f/cm^3
Poorly controlled work with asbestos containing materials	
Stripping pipe/vessel lagging – partially wetted or dry areas	up to 100 f/cm^3
Stripping spray coating – partially wetted or dry areas	up to 1000 f/ cm^3
Drilling asbestos insulating board without shadow vacuuming	up to 10 f/ cm^3
Power sawing asbestos insulating board	up to 20 f/ cm^3
Hand sawing asbestos insulating board	5 – 10 f/ cm^3

Figure 2.7 Likely concentrations of fibres for work related activities (Source: HSG247 (2006))

As with work outside an enclosure, removal techniques should be chosen that reduce fibre levels to as low a level as possible. The best methods are those that do not damage the asbestos material, and should always be chosen over destructive methods. They include:

- Cutting and wrapping.
- Removing the material whole. Fibre

release can be further reduced by:

- Wet spraying.
- Shadow vacuuming with a Type H vacuum.

2.5.4.1 Wet Injection of thermal lagging

Even inside an enclosure, asbestos materials should never be dry stripped. Wetting by using a spray should always be used. If thermal lagging is being removed (and it is not possible to remove it whole or in sections), then it can be injected with a wet injection system. A wet injection system uses a series of needles to distribute a wetting agent into the whole of the pipe (or sprayed surface coating). The material must be wetted to dough-like consistency and not over-wetted. This is to stop the material falling off and becoming unmanageable.

The equipment used must conform to local standards and must be regularly tested. In the UK, this is once every six months.

2.5.5 Project management and control monitoring

In Australia and New Zealand, it is mandatory during Class A removal jobs to have the asbestos assessor on site to carry out control monitoring air tests. These air tests are described in Section 3.1.2. In the UK, it is not a mandatory requirement but is recommended, especially for larger jobs where there are people working in adjacent areas. It is best practice for the asbestos assessor to be employed directly by the client who has instructed the work rather than the removalist.

Being on site allows the asbestos assessor to check that the correct low-fibre release techniques are being used inside the enclosure. If the removal work is carried out properly, the clearance inspection should run smoothly.

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3.0 Air sampling

3.1 Static air sampling

Static sampling is where a pump is used to sample a volume of air at a fixed location. Static sampling pumps should have the facility to locate the sample holders within 1-2 metres from the ground. This may be by means of stands and flexible tubing or by the use of fixed sampling masts. It must also be possible to position the filter holder with the open end facing downwards. These pumps are capable of sampling volumes of air of up to 1000 litres.

The sampling strategy should aim to achieve fibre densities in the range of 100 to 650 fibres/ml^2. Volumes higher than 1000 litres would generate too great a fibre density and there would be too many other particles on the filter. If lower volumes are collected, then the results are too inaccurate. The Limit of Detection (or Quantification) for the method would also exceed the trace level of 0.01 f/cm^3.

In the UK, a minimum volume of 480 litres of air (using a flow rate between 1 and 16 litres/min) is specified for static sampling. In Australia, the minimum volume sampled must be 100 litres. Flow rates above 8 litres/min are not allowed and they must be above 0.4 litres.

There is no distinction made in Australia between sampling rates that are appropriate for larger static pumps and smaller personal pumps. However, a flow rate of 2 litres/min for 4 (or 8) hours is recommended for static sampling. This would generate a volume of 480 litres over 4 hours (the same as the UK).

3.1.1 Clearance sampling

Clearance sampling takes place following asbestos removal work, using static pumps to show that the area is fit for re-occupation (i.e. that fibre levels are below the 0.01 f/cm^3 trace level). Clearance sampling is part of the wider clearance process that also involves a visual inspection of the area after work has been completed (see Section 4).

It is associated with high risk work on friable asbestos materials that takes place within an enclosure, and is a mandatory requirement in most countries, including the UK, Australia and New Zealand. This test can be used, however, in areas where an enclosure was not used. It can also be used following the completion of lower risk work on non-friable products.

3.1.2 Control monitoring

Control monitoring is a term used in the Australian Approved Code of Practice for the Safe Removal of Asbestos 2005 [NOHSC:2002], to describe air tests carried out to monitor the effectiveness of the control measures listed in the ARCP.

In Australia and New Zealand, control monitoring is mandatory during work on high risk friable materials. In other countries, it is recommended to show compliance. Control monitoring cannot be used to measure occupational exposures – these must be measured using personal sampling, which is described below.

There are three types of control monitoring: background, leak and reassurance monitoring.

3.1.2.1 Background/baseline monitoring

This is used to measure the ambient fibre concentrations in the air *before* work begins. In the USA, the background count can be subtracted from the final count. Elsewhere this is not permissible, although further analysis by TEM can be used to discriminate between asbestos and non-asbestos fibres.

3.1.2.2 Leak monitoring

This is used to ensure that fibres are not leaking from the enclosure. Samples are taken in vulnerable locations *outside* of the enclosure where leaks might be expected to occur. These include locations such as adjacent to the NPU, airlock and baglock, or where pipes pass into the enclosure. It is used to support the smoke test and visual inspections of the enclosure's integrity.

3.1.2.3 Reassurance monitoring

Reassurance monitoring checks that control measures are working in areas not adjacent to the enclosure, such as transit routes, waste routes or nearby occupied areas. The term 'reassurance test' is also used to describe the air test carried out **after** work has been completed on low risk, non-friable products outside of an enclosure.

3.2 Personal sampling

Personal sampling is where small, portable battery-operated pumps are attached to the worker to measure occupational exposures (i.e. the actual fibre levels that the worker is being exposed to rather the levels within in an area). A sampling cowl is attached to the wearer in the breathing zone. This is defined as within 300mm (Australia and New Zealand), 200mm (UK) or 100mm (US) of the mouth.

Personal sampling is used to ensure that control measures are working inside the enclosure (or work area), so that the worker is not exposed to fibre concentrations that exceed the exposure limit. It is also used to ensure that the type of respirator and filter is sufficient.

Personal sampling volumes vary significantly depending upon the purpose of the sample. Larger sample sizes are better as these give higher limits of detection and greater accuracy. However, as these pumps are much smaller than static pumps, it is not easy to sample larger volumes of air.

In Australia, the minimum volume of air required is 100 litres using a flow rate between 1.0 and 0.4 litres/min. Higher volumes are possible using a flow rate of 2 litres/min.

In the UK, a minimum volume of 240 litres is recommended using a flow rate of 1 litre/min (although a minimum volume of 40 litres is allowed for short duration samples).

3.3 Air sampling methodology

The accuracy of the calculated result depends on the way that the air sample is taken on site. The equipment used (the pump, the filter holder and the filter) must be of the correct type and be fit for purpose.

It is also important that the measurements taken on site to calculate the volume are accurate. This is achieved by using equipment that has been calibrated against a master that has **measurement traceability**. The term measurement traceability is used to refer to an unbroken chain of comparisons relating an instrument's measurements to a known standard. Calibration to a traceable standard can be used to determine an instrument's bias, precision, and accuracy. It may also be used to show a chain of custody.

In many countries, national standards for weights and measures are maintained by a National Measurement Institute (NMI), which provides the highest level of standards for the calibration/measurement traceability infrastructure in that country. Examples include the Australian National Measurements Laboratory and the National Physical Laboratory (NPL) in the UK.

It is important that the person carrying out site sampling is competent and trained. Set procedures should be followed to ensure consistency, and the results should be recorded.

The air sampling procedure is often covered by accreditation to ISO/IEC 17025:2005. In the UK, accreditation to ISO 17025 for asbestos air sampling is mandatory.

The procedure and the equipment specification for carrying out air sampling is described in the sub-sections below.

3.3.1 The pump

The pumps used must be robust and be able to maintain stable power for the duration of the test. For static pumps this can be up to 8 hours. They must be able to maintain a stable flow rate and be free from pulsation throughout the sampling period. Variation must not exceed ±10% (additionally in the UK, flow rates <2 litres/minute must not exceed ±5%).

Pumps that comply with ISO 13137:2013 meet these criteria.

The flow rate should be adjustable on the pump. On some types of pump this is adjusted electronically, on others by a knob or screw.

3.3.2 The membrane filter

The membrane filters used must be made of mixed esters of cellulose or cellulose nitrate, and have a printed grid on one side. The WHO method specifies that a 25mm diameter filter must be used, and this is also specified in the UK and US methods. In the Australian method, other sizes can be used as long as the exposed area is not less than 9.5mm using a 13mm diameter filter.

If a smaller filter is used, the volume collected must be reduced to prevent the fibre densities being outside the optimum range. For example, a 500ml sample using a 25mm filter with an exposed area of 22mm would have to be reduced to a 100ml sample using a 13mm filter with an exposed area of 10mm [NOHSC:3003(2005), p.28]. This is why smaller filters are not suitable for most air tests. The WHO method specifies pore sizes between 0.8 and 1.2 µm (in Australia, the pore size must be 0.8 µm).

It is important that the membrane filter used is not contaminated. To ensure that unused filters are clean, 1% of filters are mounted and analysed to ensure that the batch is clean. In the UK, a minimum of four per batch must be tested. Filters must be loaded into the filter holder in a clean environment and must only be handled with tweezers.

3.3.3 The filter holder (cowl)

The membrane filter is held in a filter holder (cowl) for the duration of the sampling test. Filter holders must be open-faced with a conducting cylindrical cowl which can be capped at the open end to prevent cross-contamination. The conductivity of the cowl should help prevent fibres adhering to the sides (electrostatically), and ensure that they are collected on the filter. The cowl normally extends between 1.5-3 times the exposed diameter of the filter.

It is the exposed or effective filter area rather than the area of the filter itself that is used to calculate the fibre concentration, so it is important that this is measured for each of the types of cowl used. This can be measured by sampling dark dust, and then measuring the diameter using a microscope Vernier or callipers.

In Australia, the exposed filter area must have a diameter of no less than 9.5mm. For the UK method, the filter and holder should provide an exposed area that is at least 20mm in diameter.

It is important that the filter holder is free from contamination and must be thoroughly cleaned between uses.

3.3.4 Measuring the flow rate

Accurate measurement of the flow rate is important as it determines the volume of air required to calculate the fibre concentration. The flow rate is recorded at the start of the test and at the end of the test.

For longer sampling periods, it is best practice to take intermittent flow readings, to ensure the maintenance of a steady flow rate. In the UK, readings must be taken every hour. It is the mean flow between the start and end rate that is used to calculate the volume. The flow rate should not deviate by more than ±10 % (in the UK this is reduced to ±5% for samples less than 480 litres), and it should be discarded if it does. Flowmeters must be sufficiently sensitive and have marked gradations that allow the flow rate to be accurately read. It is normal to use a smaller flow meter with larger gradations for measuring low flow rates below 2 litres/minute; and a larger flow meter with smaller gradations for measuring higher flow rates up to 8 litres/minute in Australia (or 16 litres/minute in New Zealand, the UK and other countries).

The flow meter must be capable of measuring the flow rate to within ±5%. It must be calibrated with a primary calibration device that is traceable to a national standard.

The flow rate can be affected by temperature and pressure. The WHO method states that if there is more than a 5% difference between the temperature and pressure of where the flow meter was calibrated and the site where it is being used, then a correction should be made. In most circumstances, the difference has little effect on the flow rate; but if it does, the site temperature and pressure must be recorded and an adjustment made if necessary.

The thermometer and barometer must be calibrated with primary devices that are traceable to national standards. Details of how to calculate the adjustment can be found in the WHO's Determination of airborne fibre numbers concentrations (1997), p.14 and in HSE document HSG248 (2005), p.48.

3.3.5 Measuring sample duration

It is the volume of air sampled that is used to calculate fibre concentrations, not the flow rate. The volume of air sampled is calculated using this formula:

Volume (litres) = Flow rate (l/min) x Time (min)

Therefore, a timepiece is used to record the start time and finish time of the air test. The time recorded should be accurate to within ±2.5%. The allowances are:

Duration	±2.5% allowance
1 hour	90 seconds
30 minutes	45 seconds

Figure 3.1 Air test durations

The timepiece must be calibrated with a primary calibration device that is traceable to a national standard.

3.3.6 Recording of measurements on site

It is important that all measurements are recorded on site in a systematic way by the person carrying out the air test. The paperwork used should be standardised and controlled. The information recorded should include:

- Site address.
- The name of the person conducting the test.
- The date.
- Location details of the samples.
- The sample type (e.g. leak test).
- The equipment used to carry out the test (e.g. pump, filter holder).
- The details of the calibrated measuring equipment used (e.g. timepiece, flow meter).

The start and finish time and the start and finish flow rate also need to be accurately recorded. Figure 3.2 on page 41 is an example of a form that could be used to collect site data. The form used must be standardized and issued throughout the organisation as part of their quality procedures. These procedures may be accredited to a standard such as ISO:17025.

Figure 3.2

Site:	**Flow Meter:** **Timepiece:**	
Sampler:	**Thermometer:**	**Temp (^{0}C):**
Date:	**Barometer:**	**Pressure (Pa):**

No.	**Location / name / activity**	**Pump**	**Cowl**	**Time**			**Flow rate (litres/minute)**				**Volume sampled (l)**
				Start	**Finish**	**Total (min)**	**Sta**	**Mid**	**Finish**	**Average**	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

4.0 The clearance inspection process

4.1 Visual inspection and clearance air monitoring

A visual inspection of the asbestos work area or enclosure should be carried out before the area is returned to normal use. The visual inspection should be carried out by an independent asbestos assessor or competent person. Independence is mandatory for licensed removal work to avoid a conflict of interest.

Clearance air monitoring for licensed removal work should also be carried out by an independent asbestos assessor. A satisfactory visual inspection does not remove the need to carry out clearance air monitoring.

The person and organisation carrying out these tests should always be trained and competent. In New Zealand, from April 2018 the person carrying out tests on Class A licensed asbestos work must have a licence from WorkSafe. In the UK, only organisations that have been accredited by UKAS to ISO:17025 standards are allowed to carry out visual inspections and air tests following work on licensable asbestos materials.

4.2 The four stage clearance procedure

The four stage clearance procedure has been mandatory for licensed work in the UK for years, and a similar procedure has been adopted in New Zealand. In other countries such as Australia, the visual clearance and air tests are mandatory, but there is no specific documented 'four stage' procedure. In practice, however, similar procedures take place to comply with legislation. The four stage clearance described here could be used to show compliance and best practice in countries such as Australia, South Africa and the USA without compromising national and local standards.

The four stage clearance as described in the New Zealand ACoP: Management and Removal of Asbestos 2016 as:

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

This is the same basic procedure that is described in much more detail in the UK guidance document HSG248 (HSE, 2005).

The procedures described below are taken from HSG248 as well as the New Zealand ACOP: Management and Removal of Asbestos (2016). Where the guidance in HSG248 contradicts New Zealand's ACoP or Australia's NOHSC:2002 (2005), this is either not described or the differences are highlighted.

4.2.1 Stage 1: Preliminary check of site condition and job completeness

The first stage is a preliminary check of site conditions and job completeness. The asbestos assessor or competent person should first check the Asbestos Removal Control Plan (ARCP, or Plan of Work/method statement as it is known elsewhere) for the following:

- What asbestos material was removed.
- Where the asbestos material was removed from.
- What asbestos material (if any) is to remain in situ.

If the ARCP is not on site, or fundamental details are missing or incorrect, then the clearance cannot proceed until these issues have been resolved.

The decontamination facility (whether directly attached to the enclosure or a mobile unit) should be on site, intact, operational and clean. The shower facilities should still be functional.

The site area should be inspected for obvious signs of contamination, such as leaks, burst waste bags or debris from inadequate decontamination procedures. The waste or transit routes should be checked for signs of asbestos debris.

The enclosure should be fully intact with no rips or tears, and the airlocks should be present and functioning. The NPU(s) should be in place and operating.

Finally, the enclosure should be inspected from the viewing panel before entry. If there is waste or visible debris, signs of wetness or hazards inside the enclosure, then these issues should be resolved before the inspection begins. The enclosure should normally have adequate lighting and there should be access equipment available (e.g. working platforms). If these are not present, they will need to be installed before the second stage.

4.2.2 Stage 2: thorough visual inspection inside the enclosure/work area

The second stage is the key stage. Before this can begin, the assessor must be satisfied in the first stage that all the specified material has been removed and that the area is dry.

The asbestos assessor must enter the enclosure wearing adequate PPE. This should always include suitable disposable coveralls (e.g. Category 3, Type 5) that give protection against fibre penetration and cleanable laceless boots. They must always wear suitable RPE with a suitable filter; in the UK this must be at least a P3 filter, and in New Zealand and Australia at least a P2 filter.

Entry into the enclosure should normally be via the decontamination unit. All areas of the enclosure should be inspected, including any areas which appear awkward or difficult to reach.

The assessor must check:

- ✓ The completeness of the asbestos removal from underlying surfaces.
- ✓ The presence of any visible Asbestos Containing Debris (ACD) left inside the enclosure, airlocks or work area.
- ✓ The presence of fine settled dust.

The assessor should be accompanied by an asbestos removalist, who will be able to clean small amounts of debris with a cloth or Type H vacuum. If the level of contamination is more serious or asbestos materials have not been fully removed, then the assessor should leave the area and fail the clearance at this stage.

The inspection should be thorough and should take some time to complete. For example, a small boiler room should take a minimum of 1.5 hours, and a large boiler room may take a day.

All elements of the room should be inspected. Care should be taken to inspect those areas where dust and debris is likely to accumulate. Examples include:

- Horizontal surfaces and ledges.
- Cracks in the floor.
- Folds in the plastic sheeting used in the enclosure construction.
- Air conditioning ducting.
- Cable trays and conduits.
- Underneath plant.
- Crevices and voids.

The assessor should take some tools to assist with the inspection. These should include:

- A high-powered torch.
- A small mirror to access areas that cannot be seen.
- A screwdriver to access crevices.

There are two specific problems that are encountered which are highlighted in both the New Zealand ACoP (2016) and HSG248: **wet enclosures** and **sprayed sealant**.

- **Wet enclosures**. Enclosures should dry before the inspection begins, as it is impossible to inspect for settled dust in an area that is wet. Often an enclosure is wet because of over-wetting of materials and poor control of the water runoff. If there is an issue with an ingress of water in an area, this issue should be addressed before work commences. If a pipe bursts during work, then it should be repaired. In some cases, an area may be wet due to ground water and this cannot be avoided. In these cases, allowances can be made but the circumstances should be noted in the ARCP.

- **Sprayed sealant.** Sprayed sealants such as PVA should not be used to seal surfaces. If the asbestos assessor finds that sprayed sealant has been used prior to the visual inspection, then they should ask for it to be removed. In some circumstances, where the enclosure contains significant amounts of non-asbestos dust that cannot be controlled (e.g. from old brickwork or wood) a sealant can be used, but this should be applied after the visual inspection has taken place. Its application should be on the advice of the assessor, and should only be used if it is likely that non-asbestos particles would make it difficult to conduct an air test.

In Australia the use of PVA sealant is permitted, but this should be after and not before the visual inspection has been carried out. It should be noted, however that sealing of surfaces after the visual inspection is recommended (NOHSC:2002 (2005)].

4.2.3 Stage 3: air monitoring

The clearance air test must be carried out following the visual inspection. Settled dust sampling cannot be used as a substitute for air sampling.

Static sampling pumps should be evenly distributed throughout the area, and some should be placed next to those surfaces where asbestos was removed from.

The number of pumps needed is determined by the layout of the enclosure. Some areas are not uniform and have internal partition walls or separate rooms. In New Zealand, the minimum number of samples is outlined in their ACoP (2016).

Enclosure area (m^2)	Enclosure volume (m^3)	Number of samples
50	150	2
200	600	4
500	1,500	6
1,000	3,000	9
5,000	15,000	16
10,000	30,000	20

Figure 4.1 Recommended number of samples to be taken from an enclosure (UK standards)

This is based on the UK guidance document HSG248 (2005) where an equation is used to generate these numbers. It has no theoretical significance; it is just a means of generating reasonable numbers.

If an enclosure is less than three meters high, then the number of pumps can be calculated $A^{1/3} -1$, where A is the area of the enclosure. If an enclosure is greater than three meters high, then A is the volume divided by 3.

$A^{1/3} -1$ is sometimes expressed as $\sqrt[3]{A} -1$. The equation for enclosures over three meters is therefore $\sqrt[3]{A/3} -1$. If an area has large pieces of equipment that have been sheeted out (e.g. boilers in a plant room) then these can be subtracted from the volume.

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The procedure for running and recording the air test is described in Section 3. Additional procedures are:

- ✓ The NPU should not be running and should be capped during the air test.
- ✓ In the UK, dust disturbance is carried out (1.5 minutes per sample) using a brush to simulate normal activity in the room. Dust disturbance is also a requirement in New Zealand for Class A work. In Australia, however, dust disturbance is prohibited in the Guidance Note NOHSC:3003 (2005), p.20.

In the UK, it is usual for the asbestos assessor to prepare, mount and read the sample (usually while still on site). For this reason, the assessor is known as the analyst in the UK. In other countries, the samples are prepared and read by a separate microscopist working from a laboratory.

Care must be taken when transporting the samples to the laboratory. The cowls should be sealed and carefully treated. Alternatively, filters can be transported in sealed containers, but these must be transferred in a clean area. It is also important to ensure traceability and that the filters are correctly identified.

The fibre counting results will be sent from the laboratory to the assessor. To pass Stage 3 of the four-stage clearance process, all samples must be below 0.01 fibres/cm^3. They cannot be averaged, although the UK method allows 20% of samples to be <0.015 fibres/cm^3.

More information on asbestos fibre counting can be found in *IP403 – Asbestos Fibre Counting (PCM)*.

4.2.4 Stage 4: Final assessment post-enclosure/work area dismantling

Only when both the visual inspection and the clearance air test have been passed can the asbestos removal enclosure be taken down.

Even after the thorough visual inspection carried out in Stage 2, there is a risk that asbestos debris and dust could have become trapped within the enclosure. It is important that the assessor inspects the area and the transit route for signs of this. If suspect debris is found, then this must be cleaned by the removalist using a suitable control method (such as vacuuming with a Type H vacuum). In extreme cases, the enclosure may need to be re- erected.

It is good practice, especially in cases where additional cleaning has had to be carried out, to carry out a further reassurance air test in the area from where the enclosure has been removed from.

In Australia, surface testing is recommended, and in New Zealand is compulsory for Class A removals. It should be noted that this method is not a substitute for clearance air monitoring. Surface testing is where a sample of dust is taken using a wipe or micro-vacuum and analysed by either Polarised Light Microscopy (PLM) or Transmission Electron Microscopy (TEM). The result is either positive or negative.

The assessor should ensure that all waste and materials have been removed from site. Only when they are satisfied that as far as reasonably practicable, the site does not pose an asbestos risk, should a clearance certificate be issued.

The clearance certificate (known as the certificate of reoccupation in the UK) must contain certain information. In the New Zealand ACoP (2016), the following information is listed as a minimum requirement:

- ✓ The name of the asbestos assessor who has issued the certificate.
- ✓ The address from where the asbestos material has been removed from.
- ✓ The results of the visual inspection.
- ✓ The air monitoring results.
- ✓ An opinion that as far as the assessor can tell, that the area does not pose a risk to health and safety from asbestos.

A sample certificate is provided in Appendix I of the New Zealand ACoP (2016). A more detailed sample certificate is provided in Appendix 3 of UK guidance document HSG248. It is recommended to refer to the country of work's Approved Code of Practice for full details of what to provide in the clearance certificate.

The asbestos assessor should issue copies of the clearance certificate to the asbestos removalist(s), the client's workers and their representatives.

The findings of the clearance inspection should be communicated both verbally and in writing to the asbestos removalists and clients. The asbestos assessor should give clear instructions to the removalists about any additional work required, and technical findings should be reported to the client.

4.3 Conflict of interest

It is important that the asbestos assessor or competent person chosen to do the clearance inspection is independent, and does not work for the same company as anyone else involved in the removal project. This is because it is a potential conflict of interest; the asbestos assessor may be leaned on to miss out certain parts of the inspection, in order to speed up the removal work. It is imperative that all stages of the clearance inspection are thoroughly carried out to prevent risk of asbestos exposure to both the workers and members of the public.

If the asbestos assessor is put under undue pressure by anyone to carry out the clearance process incorrectly or in an unsafe way, they have the right to either stop work immediately and fail the clearance, or decline and continue with clearance.

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