A TASK BASED EXPOSURE ASSESSMENT OF AIRBORNE ASBESTOS FIBRES DURING BOILER DE-LAGGING.

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Public Health (Occupational Hygiene).

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DECLARATION

I, Robert Randolph declare that this research report is my own work. It is being submitted for the degree of Master of Public Health (Occupational Hygiene) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

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R.W. Randolph

…….. day of ………………, 2008.

ABSTRACT

Asbestos has been extensively used to insulate boilers and associated heated pipe work throughout the world. Managing human health risks posed by asbestos during the removal of lagging poses many challenges. For this reason, acquiring a better understanding of factors that lead work tasks to produce high airborne fibre concentrations is important for the development of improved control methods.

Aim: The aim of this study was to link observed work tasks and work practices with measured airborne concentrations of fibres in order to identify those factors contributing to high airborne concentrations generated during boiler de-lagging. The investigation was based on a study of two employees working on a boiler de-lagging contract lasting twenty-one days and resulting in a total of 79 measurements of airborne asbestos fibres. The primary form of asbestos dust control for the duration of the contract was the application of non-amended water.

Objectives: To definitively identify the presence and type of asbestos lagging as well as quantify airborne fibre concentrations for two work tasks i.e. Stripping (removing lagging) and Bagging (placing removed lagging into bags as well as cleaning spills), in order to demonstrate how they may influence airborne fibre concentrations.

Methodology: The type of asbestos was confirmed by Scanning Electron Microscopy. Phase Contrast Microscopy (PCM) was selected as the primary measure of airborne asbestos fibres. A Work Practice Checklist was developed to link observed daily Work Tasks and Work Practices with the concurrent airborne fibre concentrations. The geometric mean was a useful measure of central tendency for the data since it was highly skewed to the right (positively skewed). However, for public health purposes the arithmetic mean was also considered because it provides some idea of health risk where the human respiratory system is assumed to accumulate fibres linearly with concentration.

Results: Bulk sample analysis confirmed the presence of both chrysotile and amosite asbestos lagging. Work Practices such as Wetting, Stripping and Bagging asbestos, were undertaken in a relatively uncontrolled manner during the first three days of the project resulting in mean airborne fibre concentrations of 1.171 f/ml for the Stripper, ranging from 0.612 to 1.236 f/ml and 0.315 f/ml for the Bagger, ranging from 0.107 to 0.631f/ml. These means were 4.5 times and 2.3 times respectively, greater than the means calculated for the entire project. The overall mean fibre concentration was approximately five times greater for personal samples, 0.198 f/ml (± 1.647) than for the concurrent static samples, 0.039 f/ml (± 0.129).

The analysis of log transformed data revealed several strong tendencies for airborne fibre concentrations when related to Work Tasks and Work Practices. The difference between stripping asbestos in small manageable as opposed to larger unmanageable pieces was highly significant ($p < 0.001$). Smaller manageable pieces resulted in much lower concentrations. The manner with which asbestos was bagged was also highly significant ($p < 0.001$). Bagging in an uncontrolled manner resulted in much higher airborne concentrations. Surprisingly, the degree of wetting was not as important as expected: working dry did not generate significantly more fibres than working with saturated insulation but did generate significantly more fibres ($p < 0.005$) than working with partially wet insulation (which lead to the highest concentrations). A limitation to interpreting the Wetting work practice was the low number of samples taken within the dry category ($n = 5$).

The difference in mean sample concentrations between personal and static samples for this study demonstrates the importance of spatial and temporal proximity as a determinant for airborne fibre concentrations. It also showed clear associations between what can be described as rushed, reckless Work Practices, and the resulting high levels of airborne fibre concentrations (exceeding the OEL). Within the context of this project, these findings demonstrate the utmost importance of providing the appropriate training and supervision of employees, not only for protecting themselves against airborne asbestos fibres, but for removing asbestos in manner that results in the generation of the least amount of airborne fibres possible.

Key words: Airborne asbestos fibres, boiler de-lagging, asbestos dust control.

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NOMENCLATURE

- Approved Inspection Authority (AIA)
- Asbestos Containing Materials (ACM’s)
- Coefficients of variation (CV’s)
- Energy Dispersive Spectroscopy (EDS)
- Environmental Protection Agency (EPA)
- Fibers per cubic centimeter (f/cc)
- Fibres per milliliter (f/ml)
- High Efficiency Particlulate Air (HEPA) filter
- Interquartile range (IQR)
- Methods for the Determination of Hazardous Substances (MDHS 39/4)
- National Institute for Occupational Health (NIOH)
- Occupational Exposure Limit (OEL)
- Occupational Safety and Health Administration (OSHA)
- Phase Contrast Microscopy (PCM)
- Scanning Electron Microscopy (SEM)
- Short Term Exposure Limit (STEL)
- Southern African Institute of Occupational Hygienists (SAIOH)
- Stereo Light Microscopy (SLM).
- Time Weighted Average (TWA)

DEFINITIONS

De-lagging	De-lagging refers to the removal of heat insulation either comprising of asbestos or Asbestos Containing Materials (ACM's), from boilers, associated pipe work and equipment.
Demolition Work	Includes demolition, alteration, stripping, removing, repair, cleaning of any spilt asbestos, or high pressure water jetting of any structure containing asbestos lagging or insulation, but does not include work performed on asbestos cement sheeting and related products and asbestos cement products that form part of the structure of a workplace, building, plant or premises.
Hardset	A layer of cement containing asbestos which is used to encase heat-insulating material.
Amended Water	The addition of wetting agents such as surfactants to water in order to improve penetration into asbestos lagging and improve airborne asbestos dust suppression.
Breathing Zone	The area from which the employee draws air and has been defined as being as close as possible to the nose and mouth and a hemisphere forward of the shoulders with a radius of 15 to 20 centimeters.
Approved Asbestos Inspection Authority	An approved inspection authority for the monitoring of asbestos concentrations in the air.
Approved Inspection Authority	An inspection authority approved by the Department of Labour.

Occupational Exposure Limit for asbestos	Means an occupational exposure limit of 0.2 regulated asbestos fibres per milliliter of air averaged over any continuous period of four hours measured in accordance with MDHS 39/4.
Personal Sample	A sample taken on a person usually within the persons breathing zone. The person carries the personal sampler with them for the sample period.
Registered Asbestos Contractor	A mandatory or employer conducting demolition work, who is registered with the chief inspector.
Regulated Asbestos Fibre	Regulated fibres (within a South African legal context) are defined as particles with a length > 5 µm and < 3µm in diameter, and with a length to width ratio > 3:1.
Static Sample	A sample taken at a fixed position for the duration of the sample period.
Short-term Exposure Limit	The concentration to which workers can be exposed continuously for a short period of time, which is a 10-minute TimeWeighted Average (TWA) exposure for asbestos, which should not be exceeded at any time during the working day even if the 4-hour TWA is within the OEL-TWA.
Time Weighted Average	Time Weighted Average (TWA) - an average value of exposure calculated over the course of a 4 hour work shift (MDHS 39/4).
Work Face	The general area in which lagging is in the process of being removed.

Work Practices	The manner in which asbestos lagging is wet (application of water), stripped (removed from the boiler and pipe-work) and bagging (placed into polyethylene bags).
Work Tasks	For this project Work Tasks are defined as the titles assigned to employees undertaking stripping and bagging i.e. Stripper and Bagger.

CHAPTER ONE

1. INTRODUCTION

The aim of this chapter is to provide background information on the central issues relating to this study. These include brief descriptions of the health impacts of asbestos, protection mechanisms against occupational exposures during boiler de-lagging, air monitoring methodology, legal requirements and occupational exposure limits implemented in the United States (US), United Kingdom (UK) and South Africa, boiler de-lagging processes, various safe work practices as well as a statement on the importance of the study. The chapter ends with the aims and objectives of the study described in this research report.

1.1 Health impacts of asbestos

The inhalation of all forms of respirable asbestos can cause serious lung diseases, including asbestosis, cancer of the lungs and mesothelioma (1). Asbestos has been called one of the most potent cancer-producing substances known to humankind. The asbestos cancer epidemic may take as many as 10 million lives before asbestos is banned worldwide and exposures are brought to an end (2). Until recently, it was thought that those now dying from asbestos related diseases were exposed to large amounts of asbestos either regularly or during a single spell of work lasting from a few weeks to a few years (3). According to an internet publication by the Health and Safety Executive entitled *Asbestos and You*, it is thought possible that repeated low level exposures that occur during routine repair work may also lead to asbestos induced cancers. The scientific evidence on exactly what levels of exposure cause disease are unclear, but the more asbestos dust that is inhaled the greater the actual risk (4).

1.2 Protection against asbestos containing dust

Various control measures may be implemented to prevent occupational exposures as well as public and environmental contamination. In most cases these controls are used in various combinations depending upon the risk of asbestos inhalation and degree of air and environmental contamination. These controls have been individually described as follows:

1.2.1 Enclosures

This entails sealing off either a small work area e.g. a small enclosure constructed around a section of asbestos pipes, or the entire work area e.g. a room, office, entire floor of a building or boiler house. A relatively airtight seal is created using materials such as polyethylene sheets, duct tape and expandable foam, which is applied to all openings to the external environment. Polyethylene sheets applied to rigid wood frames are used to seal larger openings, entrances and passageways. The work area can then be provided with a high efficiency filter fan, which is exhausted externally. The filter having a filtration efficiency of 99% for particles of one micrometer in size. Also known as a High Efficiency Particlulate Air (HEPA) filter. This extraction creates a negative air pressure within the enclosure thereby preventing the escape of airborne asbestos fibres into the external environment. Enclosures are therefore primarily used to protect surrounding work environments from asbestos contamination. Access to and from the work area (enclosure) is normally through a two or three chambered decontamination unit.

1.2.2 Glovebags

For smaller work tasks, normally asbestos lagging on a section of pipe with smaller diameters, a glovebag comprising of a disposable polyethylene sack with inward facing gloves, is sealed over the pipe lagging to be removed. The employee then places his / her hands into the gloves and removes the asbestos containing material from the pipe. Tools such as mesh cutters, pliers, scrapers and water bottle with a spray nozzle can be placed into the glovebag before it is sealed to the pipe. If used correctly, glovebags provide both protection to the worker as well as limit contamination of the surrounding environment.

1.2.3 Wet removal techniques

Wet removal techniques entail the wetting of asbestos with water to reduce the amount of airborne asbestos fibres produced. Sawyer (1977) mentions that this technique has been widely used in the asbestos manufacturing industry and was adopted at a relatively early stage for asbestos removal work in the United States (5). The delivery systems for water and amended water (water containing wetting agents such as surfactants) include spray guns, a single injection gun and injecting the liquid through a series of needles inserted into the lagging. Wet removal techniques will be discussed in more detail in the following chapters as they play a central role in exposure assessment and control of airborne asbestos fibres.

1.2.4 Protective clothing

This normally entails the use of overalls or similar full body protective clothing with head covering and gumboots. Since asbestos does not cling to garments manufactured from man made fibres, overalls made from such materials are recommended (1). Such clothing may be disposable or washable for reuse. Alternatively, wet weather suits that can be washed down are also used. A Tyvek™ full-body coverall with elastic wrists, attached hood and booties, combined with nitrile gloves and goggles are specific examples of protective clothing commonly used for boiler de-lagging in the US and UK.

1.2.5 Respiratory Protective Equipment

There are many forms of respiratory protection available on the market today providing varying levels of protection. In the UK, respiratory protection is utilised for Boiler De-lagging and is normally dictated by the type of asbestos, nature of the work, control measures implemented and airborne concentrations of asbestos fibres produced. These include:

1.2.5.1 Disposable respirators (dust masks)

This mask covers the mouth and nose only and is manufactured from filtering materials to provide protection in airborne concentrations generally not exceeding 2 f/ml, e.g. Filtering Face Piece 2 (FFP 2). FFP 2 usually denotes a filtration capability of up to ten times the Occupational Exposure Limit (OEL), depending upon manufactures specifications.

1.2.5.2 Half mask dust respirator

This mask also covers the mouth and nose only and normally manufactured from silicon or rubber compounds. The mask is fitted with a suitable asbestos filter or filter cartridges through which air required by the wearer is drawn.

1.2.5.3 High efficiency dust respirators

These masks have full facepieces, which cover the eyes, nose, mouth and chin. The mask is fitted with a suitable asbestos filter or filter cartridge through which air required by the wearer is drawn. The relatively high degree of filtration of these masks can only be achieved by proper use i.e. snug airtight fit and correct maintenance of the mask.

1.2.5.4 High efficiency positive pressure respirators

This type of mask is similar to High Efficiency Dust Respirators except a small battery operated pump and filter unit, which is worn on a belt, provides air to the wearer. The unit delivers air to the facepiece under pressure continuously until the battery requires recharging. The advantage of this type of respirator is that it provides a slight positive pressure underneath the mask so that air will tend to leak out of the mask and not inwards.

1.3 Air monitoring and analysis of airborne fibres

1.3.1 Air monitoring

This method requires drawing a measured volume of air using a constant-flow sampling pump. The air is drawn through a filter membrane, which is placed inside a cowl and attached the workers collar (placed within his breathing zone). After the sampling period, the filter membrane is then mounted on a microscope slide and rendered transparent. The particles of asbestos with a length to diameter ratio greater than 3:1, a length greater than five micrometers and diameter less than three micrometers (also known as Regulated Fibres), are counted by Phase Contrast Microscopy (PCM). The number of regulated fibres counted in relation to the volume of air sampled provides an airborne concentration in fibres per millilitre of air.

When considering the validity of PCM for the measurement of the dependant variable (airborne asbestos fibre concentrations), a literature review indicated that it is a widely used and internationally accepted measurement tool for occupational exposure to airborne asbestos (1). This methodology was utilised by Burdett, Nagar and Smith in 1994 in a similar study to this, involving the removal of asbestos insulation from difficult to access large diameter pipes (6).

1.3.2 Air monitoring limitations

The limitations of PCM and analytical protocol must be borne in mind. Fibres having widths < 0.2 μm may not be visible using this method (7). This means that the PCM count only represents a portion of the total number of fibres present. The count is therefore an index of the numerical concentration and not the absolute measure of the number of fibres on the filter. In addition, only regulated fibres are counted which are defined as particles with a length > 5 μm, diameter < 3μm and a length to width ratio > 3:1 (8). Fibre discrimination is therefore dependant on analytical techniques used and skills of the microscopist.

Due consideration must also be paid when small numbers of fibres are counted. Statistical considerations show that, for a mean density of 10 fibres per 100 graticule areas, a count of five or fewer fibres per 100 areas will be obtained on about five percent of occasions. Moreover there is some evidence that counters (microscopists) underestimate a blank count if they know it is a blank sample that they are counting (8).

The PCM method is not capable of identifying asbestos fibres. Millette, J.R. and Boltin, W.R. in 1994, highlight this limitation when they mention that for some work scenarios where the airborne concentration of non-asbestos fibres may be quite high, the PCM count may not reflect actual asbestos concentrations (over-estimate) (9).

In mixed dust situations, the presence of other fibres and particles may interfere with the accuracy of the results. In practice, the effects of chance superimposition on counts are small compared with subjective effects, and will not be important for the counting rules defined in this method (8).

When sampling fibres in atmospheres relatively free from interfering particulates, the density range for optimum accuracy should be from 100 – 1000 fibres per

mm^2. For densities above this, the results may be underestimates (but no attempts should be made to correct them) (10).

The smallest fibres observable by different microscopes may contribute to inter-laboratory differences between counts (8).

1.3.3 Summary

In general, counting asbestos fibres using PCM can result in systematic differences in counts produced by different microscopists and between different laboratories. However, these differences can be controlled by proper training and periodic quality checks.

The HSE (UK), OSHA (US) and OHSA (SA) have adopted similar methodologies incorporating PCM. These methodologies, the UK and South Africa being based on MDHS 39/4 and US on NIOSH Method 7400, are currently used as the primary tools for determining compliance with their respective legislated Occupational Exposure Limits.

1.4 Legal requirements (Exposure Limits)

In the USA, the EPA and Occupational Safety and Health Administration (OSHA) are the major federal agencies regulating work with asbestos in buildings. The EPA considers the environmental issues and OSHA, occupational exposure and protection issues. OSHA has established an eight-hour time-weighted average permissible exposure limit for employees of 0.1 fibers per cubic centimeter of air. They have also established a 30 minute excursion limit of 1.0 fiber per cubic centimeter (1 f/cc). The excursion limit is essentially a short-term exposure limit. Employees cannot be exposed to concentrations of asbestos exceeding 1 f/cc averaged over a 30 minute sampling period. Under the OSHA regulations, asbestos contractors are responsible for monitoring their own employees. Monitoring is undertaken by professional industrial hygienists that hold the appropriate certification (12).

Work involving asbestos in the UK is covered by the Control of Asbestos at Work Regulations, 2006 (13). The maximum permissible asbestos exposures at work is regulated by a single control limit of 0.1 fibres per centimeter of air for all types of asbestos, averaged over any continuous period of four hours. Guidance pertaining to work with asbestos insulation is also covered by an Approved Code of Practice published by the Health and Safety Executive entitled *HSE L143 Work with materials containing asbestos* (14). This code provides guidance for discharging various duties under the Regulations. Asbestos removal involving asbestos insulation and/or coating must be carried out by a removal contractor who holds a current license issued by the Health and Safety Executive under the Control of Asbestos at Work Regulations, 2006 (13).

In South Africa, the Asbestos Regulations, 2001, framed under the Occupational Health and Safety Act (Act No 85, 1993), regulates occupational exposures to asbestos and to a lesser extent environmental pollution (15). This regulation has established an OEL for employees of 0.2 regulated fibres per milliliter of air averaged over a four-hour working period, measured in accordance with MDHS 39/4 (8). They have also established a Short Term Exposure Limit (STEL) 10 minute (TWA) of 0.6 regulated fibres per milliliter of air (0.6 f/ml). Under the Asbestos Regulations, any person who intends to carry out demolition work must be registered as a Registered Asbestos Contractor with the Department of Labour. In addition, asbestos contractors must ensure that that a plan of work is submitted to an Approved Asbestos Inspection Authority for approval before commencing with the demolition work (15).

The AIA must be registered as such with the Department of Labour and the South African Institute of Occupational Hygienists (SAIOH) as certified occupational hygienists.

Under the previous South African government, the Department of Manpower published Guidance Notes entitled *The Safe Handling of Asbestos-containing Lagging or Insulation* (1988), for the safe handling of asbestos containing lagging or insulation that may be disturbed by the demolition of or structural alterations to buildings or structures (16). In March 2003, the Chief Directorate: Occupational Health and Safety, of the Department of labour, published Guidance Notes entitled *Demolition Work (Regulation 21 Asbestos Regulations)*(17). These provide for the safe handling of asbestos containing material that may be disturbed by demolition of or structural alterations to building and structures, and explains Regulation 21 of the Asbestos Regulations, 2001 promulgated under the Occupational Health and Safety Act, 1993.

1.5 Boiler de-lagging

Boiler de-lagging refers to the removal of asbestos and ACM's from boilers, associated pipe-work and equipment. Asbestos or ACM's have been extensively used to insulate boilers and associated heated pipe work throughout the world. During the lifetime of these facilities, occasional servicing, maintenance, repairs and even demolition will be required resulting in the removal of asbestos insulation. Managing human health risks posed by asbestos during the removal of lagging poses many challenges that result from the complexity of the problem and the unknown degree of exposure under various de-lagging scenarios.

Typical asbestos containing lagging comprises a rough asbestos mat 20 – 50 mm thick and held in place by a layer of wire mesh such as chicken wire. The wire mesh is coated with a 15 mm thick layer of asbestos containing cement known as the hardset, to ensure the integrity of the asbestos insulation. There are many variations to this form of lagging. These comprise different types and mixtures of asbestos, asbestos containing bricks as well as Man Made Mineral Fibres such as fibreglass coated with hardest that also contains asbestos fibres. A cross section of typical asbestos lagging has been illustrated in Figure 1.1.

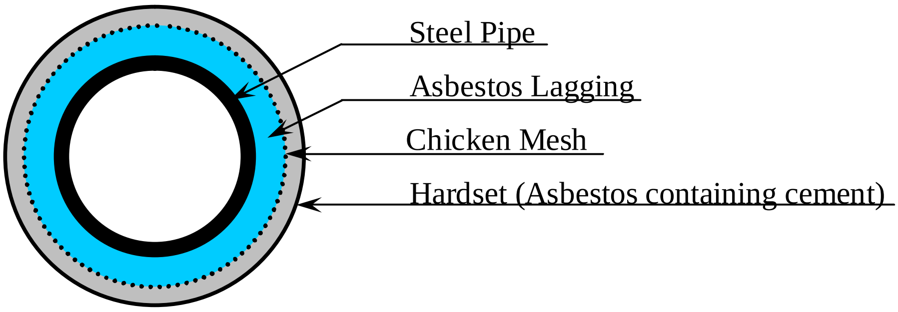

Figure 1.1: A cross section of typical asbestos containing pipe insulation

De-lagging of boiler surfaces, pipe work and associated equipment usually consists of four stages; (a) preparation of the area (b) preparation of the lagging to be removed (c) removal of the lagging and (d) bagging and cleanup. These have been discussed in more detail in the following chapters. Removal of lagging generally entails breaking through the hardset using any relatively sharp instruments such as sharpened metal bars, chisels and axes. This allows access to the wire mesh so that it can be cut with wire cutters or tin snips. Once the wire mesh has been removed, the asbestos lagging can be removed. Wire cutters can also be used to cut through the asbestos, wire mesh and hardset at the same time depending upon the nature of the lagging to be removed.

In most high-income countries there are stringent controls on asbestos removal and disposal, which are important for preventing environmental contamination and employee exposures to asbestos fibres. This extends to the careful decontamination of employees, work areas, tools and personal protective equipment. Many studies have been undertaken, particularly in the UK and US, providing a broad range of knowledge and experience pertaining to techniques for reducing occupational exposures (6)(9)(14). However, in a paper presented at a Workshop on Operations and Maintenance in Buildings Containing Asbestos, by Lippmann in 1994, the author concluded that although current Operations and Maintenance techniques are effective in keeping almost all occupational exposures well below 0.1 f/ml, the database is still quite limited and more investigations are needed to determine: (a) exposure in a wider range of building types, sizes, and inventories of ACM's; (b) means of extending Operations and Maintenance programmes to more buildings containing ACM's; and (c) optimal techniques in terms of costs and efficacy (18).

In a study undertaken within a large Washington DC office building, there appeared to be evidence of higher airborne fibre concentrations within specific jobs, particularly for the PCM data. This suggested that peak fibre concentrations did not necessarily occur in a random fashion over time. Instead, there may have been characteristics of individual jobs, which led to high airborne fibre levels. While insufficient documentation was available to investigate this issue further, such factors might include individual training and work practices, methods of control employed, and physical characteristics of the project and of the materials present. Because a better understanding of the factors that lead to jobs producing high concentrations could lead to improved control methods, these issues warrant careful attention in future studies (19).

Providing information from these experiences as well as observing the successes and failures of various asbestos work tasks and work practices, it is hoped that a greater awareness will be created within the South African asbestos contractor industry. The consequences of inexperience or ignorance are elucidated by Bailar III in 1994, who provides an example of catastrophic failure. The author explains that a single serious failure of control measures over a few hours or days would more than wipe out years of meticulous attention to protocol (20).

1.6 Importance of the study

A search for publications relating to airborne asbestos fibre concentrations associated with Work Tasks and / or Work Practices during boiler de-lagging, was undertaken of numerous Occupational and Environmental Hygiene journals found within libraries of both Wits and Nelson Mandela Medical Schools. An extensive internet search of relevant websites and CD ROM's was also conducted. The research found proved limited to American and British experiences. The author found none (of this type) that fell within the South African context.

It is hoped that this study will initiate dialog on the efficacy of work tasks and work practices within the Registered Asbestos Contractor industry. The data could be used to motivate for the provision of appropriate training and supervision of employees, not only for protecting themselves against airborne asbestos fibres, but removing asbestos lagging in a manner that results in the generation of the least amount of airborne fibres possible. Ultimately, with this and other contributions in this field of study, sufficient information will be available to compile a specific “Approved Code of Practice” for de-lagging asbestos containing materials using water as one of the primary forms of control.

The regulation of asbestos removal work in South Africa is still in its relative infancy with the introduction of the Asbestos Regulations, 2001. This means that by comparison to most high-income countries, there are limited published research data in South Africa on issues, which include;

a) the extent of occupational exposures occurring during de-lagging;
b) current techniques utilised by Asbestos Contractors for keeping occupational exposures below 0.2 f/ml (OEL);
c) the efficacy of these techniques;
d) the degree of compliance with legal requirements by Asbestos Contractors.

1.7 Aim of the study

The aim of this study is to link observed work tasks and work practices with measured airborne concentrations of fibres in order to identify those factors contributing to high airborne concentrations generated during a boiler de-lagging contract. This study will therefore provide valuable background knowledge and experience on asbestos dust control issues that may typically be experienced by Asbestos Contractors and AIA's during boiler de-lagging contracts.

1.8 Research objectives

1.8.1 First Objective

To confirm that the lagging material contained asbestos and to identify the type of asbestos present within the lagging of the four baggasse fired boilers and associated pipe-work under study.

1.8.2 Second Objective

To quantify airborne fibre concentrations for two work tasks i.e. Stripping (removing lagging) and Bagging (placing removed lagging into bags as well as cleaning spills).

1.8.3 Third Objective

To analyse data of recorded daily Work Tasks and Work Practices in order to demonstrate how they may influence airborne fibre concentrations.

CHAPTER TWO

2. MATERIALS AND METHODS

This chapter begins with an outline of the study setting and continues to describe the specific methodologies including sources of bias, limitations and quality control issues where relevant. Methodologies were described for the following:

i) Obtaining a definitive identification of the asbestos present.
ii) Deployment and analysis of air monitoring samplers.
iii) Recording daily observations of work tasks and practices.
iv) Statistical analysis of the data.

2.1 The study setting

This investigation was based on a study of two employees working for an asbestos removal contractor within the province of Kwa Zulu Natal in 2003. The study covered a single boiler de-lagging contract lasting twenty-one days. It was concerned with monitoring two employees undertaking two specific work tasks as well as taking a static sample approximately eight meter from the work face. The single static and two personal samples were taken on a daily basis, over the twenty-one day period. The primary form of asbestos dust control for the duration of the contract was the application of non-amended water.

Data of airborne fibre concentrations and observed daily work tasks and practices, were obtained. The researcher obtained this data personally with assistance from a Certified Occupational Hygienist employed by the AIA monitoring the contract.

The definitive identification of the type of asbestos present as well as daily measurements of airborne fibre concentrations were obtained and evaluated according to recommended methods (electron microscopy) and prescribed statutory standards (Asbestos Regulations, 2001 and MDHS 39/4), respectively. Two Certified Occupational Hygienists with a combined experience of 21 man-years compiled a Work Practice Checklist (Appendix 1) in order to describe three **work practices:**

i) the amount of wetting of lagging (for dust suppression),
ii) the manner in which asbestos was removed
iii) and manner in which asbestos was bagged.

The two **work tasks**, to which the Work Practice Checklist was applied, were:

i) stripping asbestos
ii) bagging asbestos.

2.2 Study population

The study population was taken as employees working for an asbestos removal contractor undertaking boiler de-lagging. The sample population for airborne asbestos monitoring comprised of each employee allocated to undertake one of the following tasks: (A) stripping (de-lagging) and (B) bagging of asbestos which included carrying bags and cleaning up spilt asbestos.

2.3 Data collection

2.3.1 Bulk Sample Analysis

The Phase Contract Microscopy method used for calculating airborne concentrations of asbestos, is not capable of identifying asbestos fibres. This method does not permit the determination of chemical composition or crystallographic structure of fibres, and therefore cannot be used on it's own to distinguish unambiguously between different fibre types (11). It was therefore necessary to establish whether or not the lagging did in fact comprise of asbestos. Bulk samples of three different materials identified within the lagging, were sealed in individual petri dishes and sent to the National Institute for Occupational Health (NIOH) in Johannesburg for analysis by SEM. The asbestos contractor was immediately informed as to the nature of the analytical results prior to commencement of the project.

2.3.2 Scanning Electron Microscopy

Each of the three samples was prepared for examination by SEM as follows:

Representative samples were teased out of each bulk sample and mounted on carbon discs.

i) The samples were then gold coated in a Polaron Sputter Coater™.
ii) The prepared samples were then placed under a Jeol Scanning Electron Microscope™.
iii) Chemical analysis was undertaken by Energy Dispersive Spectroscopy (EDS) using Noran Vantage Systems and Software™.

2.3.3 Airborne fibre monitoring

The question of this research report defines the main variable of measure as airborne asbestos fibre concentrations. In light of the requirements of the Asbestos

Regulations, 2001, PCM was selected as the primary measure of airborne asbestos fibres. The asbestos sampling strategy and subsequent analysis was therefore undertaken in accordance with the requirements of the MDHS 39/4 *Asbestos fibres in air, sampling and evaluation by PCM* (8).

2.3.3.1 Sampling Method

The sampling technique utilised is known as Compliance Sampling (8). This refers to the use of the approved method detailed in Appendix 1 of MDHS 39/4, and was reproduced as follows:

i) All air samples for assessment were taken by drawing a known volume of air, through a 25 mm cellulose ester membrane filter with a printed grid and of pore size 0.8 μm using battery operated pumps.

ii) The pumps used were Mine Safety Appliances, Escourt Elf® Constant Flow Sampling Pumps, which automatically provided a smooth flow.

iii) Open faced filter holders fitted with electrically conducting cylindrical cowls were used. The cowls extend 50 mm in front of the filters and exposed a circular area of the filter at least 20 mm in diameter.

iv) The cowls were pointed downwards when deployed.

v) All filter cowls were immediately sealed at the end of the sampling period and remained sealed until analysis.

vi) The pumps were carried by the worker on a belt pouch and attached to a loaded filter holder using flexible tubing.

vii) The pumps were set to run at 1**l**/min.

viii) For personal samples, the filter holders were fixed to the worker's clothing as close to the mouth and nose as possible, i.e. within the employees breathing zone.

2.3.3.2 Quality Control

i) The pumps were calibrated before and after each measurement using a Gilian® Gilibrator-2™ Primary Flow Calibrator, in order to ensure that the flow-rate was maintained within ±10% of the initial rate during the sampling period.

ii) Sampling times were measured to ensure that the pumps operated to within two percent of the required sample times.

iii) The filters were loaded into the holders, unloaded and analysed in an area free from asbestos contamination.

iv) Each cowl (sample) was uniquely numbered.

v) Four filters were selected from the box of 100 filters and sent for counting as Sample Media Blanks in order to check for any background fibres naturally occurring within the filter papers.

vi) During the study, three Field Blanks (unused filter loaded cowls) were obtained and subjected to the same treatment as normal samples except without having air drawn through them or being attached to a pump. The blanks were then sent for counting to check for possible unexpected contamination of the cowls. Three blanks were calculated as being greater than the required two percent of total samples taken.

vii) Two Laboratory Blanks (Control Filters) were obtained from the new batch of filters and investigated to ensure that fibre counts did not exceed 3 fibres per 100 fields. If any counts were higher than 3 fibres, the remainder of the batch would be investigated possibly rejecting the entire box if necessary.

viii) To minimize contamination, the filter holders and cowls were cleaned before use. The filters were loaded, unloaded and analysed in an area free from fibre contamination.

ix) Filters were handled carefully (on the edge of the filter) using flat tipped tweezers.

x) The filters were sealed at both ends (capped) when not in use.

xi) A Certified Occupational Hygienist (SAIOH) was used to verify the accuracy of asbestos monitoring procedures.

xii) The samples were counted every second day by an AIA (Approved for Asbestos), i.e. a person certified competent to do fibre counting.

xiii) The filters were placed on a stage vaporizer and cleared by immersion in acetone vapour. The samples were then treated with triacetin and covered with a glass cover slip.

xiv) The detection limit of the microscope was tested daily using an HSE/NPL phase contrast test slide Mark 2. The ridges of Block 5 and parts of Block 6 were observed.

xv) The Walton-Beckett graticule was checked on a weekly basis using a stage micrometer.

xvi) Either at least 100 fibres were counted or 100 graticule areas examined, however in any case, at least 20 graticule areas were examined.

xvii) Ten percent, eight slides (N=79) were re-counted by an independent laboratory in order to test for counting bias (21).

2.3.4 Work Practice Checklists

In order to obtain qualitative data on Work Tasks and Work Practices, an interview was arranged with the asbestos contractor to establish all Work Tasks likely to be undertaken during the project. The only two primary work tasks identified for this contract are described as follows:

1) Stripping – removing lagging from the boilers and associated pipe-work.
2) Bagging – placing removed lagging material into two polyethylene bags (one inside the other) as well as sweeping up and collecting spilt lagging material.

When considering Work Practices (i.e. asbestos dust control measures) the asbestos contractor informed us that wet removal methods utilising the application of non-amended water to the lagging material being removed, would be used to control for the release of asbestos containing dust.

2.3.4.1 Identification of independent variables

The assessment of all factors that may affect the dependent variable required the measurement of as many independent variables that resources would allow. However, caution was taken when selecting the number of independent variables to measure. This was due to the likelihood of the true value of one of the variables lying outside its confidence interval in the effect statistics.

To measure independent variables they first needed to be identified. This was achieved by interviewing both the asbestos contractor and the AIA. Information was obtained by drawing on past experiences of both companies on similar asbestos insulation removal projects where wet removal methods were implemented. The interviews identified three primary work practices, which were anticipated to be directly associated with the release of airborne asbestos fibres:

i) The extent of wetting of the lagging material before handling. This could range from being dry to totally saturated.

ii) The subsequent handling of the removed lagging material (stripping). Lagging can be removed in relatively small (manageable) pieces that will easily fit into the bags, or removed in large (unmanageable) pieces that require further folding, cutting and general handling.

iii) The bagging and cleaning up of spilt lagging material can generally be described by the degree of care (control) taken by employees whilst bagging and cleaning. This can also be observed by the speed at which they worked as well as the extent of spills onto the scaffold platform and floor.

The Work Practice Checklist was uniquely developed with the assistance of a Certified Occupational Hygienists (SAIOH) and the Asbestos Contractor (company owner). In a study by Stewart-Taylor A.J. and Cherrie J.W. (1998), the authors developed a peer-reviewed checklist to assess workers behaviour during asbestos remedial work (21). The checklist for this study was specifically designed to describe specified work practices that could be observed on a daily basis and that were anticipated to affect the dependant variable. A copy of the checklist has been provided under attached Appendix 1.

2.3.4.2 Analysis of the Work Practice Checklist

In order to provide an overall summary of Work Practices undertaken over the 21 days of observation, the overall "Work Practice Performance" was graded by adding the numerical values for each of the three categories assigned i.e. those shown under each Work Practice column of Table 3.3 in Chapter 3 (Results). For example, if the asbestos lagging was adequately saturated with water, removed in manageable pieces and bagged in a well controlled manner during the four hour monitoring period, then a Work Practice Performance score of three was applied for that day. Therefore for this particular study and subsequent Work Practices implemented, the ideal score to obtain would be a three. A Work Practice Performance score of nine would represent lagging removal undertaken in a potentially hazardous and undesirable manner.

2.3.4.3 Summary

The Work Practice Checklist was developed to assess those factors that may affect the dependant variable (airborne concentration of asbestos fibres). After interviews with the asbestos contractor and AIA, it was established that the degree of wetting of the lagging could be assessed with relative accuracy through observing water application as well as visual inspections of the sections of lagging as they are removed thereby providing ordinal data for the study.

The manner with which lagging is removed and bagged, were two work practices that could also be easily observed and categorised as nominal (manageable or unmanageable pieces) and ordinal data (well, semi or uncontrolled bagging) respectively, to facilitate subsequent statistical analysis of the independent variables.

2.3.5 Statistical analysis of the data

2.3.5.1 Statistical Methodology

Data were entered into an MS Excel spreadsheet and imported into SPSS version 13 (SPSS Inc., Chicago, Illinois, USA) for analysis. p values <0.05 are usually regarded as statistically significant (22).

Descriptive analysis and checking of distributional assumptions was done graphically using histograms and, box and whisker plots. Because the distribution was skewed, asbestos concentrations were transformed using $\log_{10}$ for subsequent analysis in order to normalize the distribution.

Compared to the arithmetic mean, the geometric mean is less sensitive to values in the upper tail of the distribution and therefore a useful measure of central tendency (23). However, for public health considerations, the arithmetic mean was also calculated because it is more directly associated with the health risk posed to humans, where the human respiratory system is assumed to accumulate fibres linearly with concentration (24)(25). Therefore, in attempting to better relate the data obtained from this study and provide the most amount of information for occupational health professionals, both geometric and arithmetic means are presented.

Inferential analysis entailed independent t-tests and ANOVA tests with Bonferroni post hoc tests at the bivariate level, and generalized linear modeling using a full factorial design at the multivariable level of analysis.

2.4 Ethical considerations

Written permission was obtained from the AIA to implement a daily Asbestos Work Practice Checklist in tandem with daily air monitoring of employees involved in the de-lagging process. Confidentiality and anonymity of the employees, contractor and owner of the company owning the boilers, was guaranteed. Ethical clearance was granted by the University of Witwatersrand – Committee For Research on Human Subjects (Medical), protocol number M 03-02-31 (see attached Appendix 2).

Although permission was sought verbally from employees to carry air-monitoring samplers, they were not informed of the study. It is in any case, a legal requirement for employees to carry air-monitoring equipment for this type of work (15). Prior to commencement of the project, the owner of the Registered Asbestos Contracting company was informed of the aims and requirements of the study as well as of the results of bulk sample analysis which confirmed the presence of Asbestos.

Both ethical and legal requirements required the work to be halted by the AIA on four occasions during the study as a result of airborne fibre concentrations exceeding the 0.2 f/ml OEL. Methods other than respiratory protective equipment were identified in order to reduce the airborne concentration to below the OEL (15).

CHAPTER THREE

3. RESULTS

In this chapter the results are presented in the following order:

1. Results from quality control tests.

2. Bulk sample analysis results are presented which was necessary in order to verify if indeed the insulating material (lagging) contained asbestos as well as provide a definitive identification as to the types of asbestos.
3. The Asbestos Work Practice Checklists were summarised to provide information relating to Work Practices undertaken as well as the development of any trends over the 21 days of observation.
4. A brief description of means and comparison with OEL's are presented for the asbestos fibre monitoring results as well as exploratory data analysis to show minimum and maximum values, ranges, distributions and measures of spread.
5. The chapter ends with the presentation of results from inferential statistical analysis of airborne fibre concentrations combined with data obtained from the Asbestos Work Practice Checklists. These results are summarised at the end of the chapter.

3.1 Quality control test results

3.1.1 Sample Media Blanks

No fibres were observed on the four Sample Media Blanks selected from the box of 100 filters. This provided a relative degree of confidence that there were no background fibres naturally occurring within the filter papers.

3.1.2 Field Blanks

No fibres were observed on any of the three Field Blanks (unused filter loaded cowls) that were sent for counting to check for possible unexpected contamination of the cowls.

3.1.3 Replicate analysis

According to NIOSH Method 7400, *Asbestos and other fibres by PCM,* differences will be observed between the first and second counts of the same filter paper. Most of these differences will be due to chance alone, that is, due to the random variability (precision) of the count method. Statistical recount criteria enables one to decide whether observed differences can be explained due to chance alone or are probably due to systematic differences between analysts, microscopes, or other biasing factors. The following recount criterion is for a pair of counts that estimate AC in fibers/ml. The criterion is given at the type-I error level. That is, there is five percent maximum risk that we will reject a pair of counts for the reason that one might be biased, when the large observed difference is really due to chance (26).

Reject a pair of counts if:

$$\sqrt{AC_2} - \sqrt{AC_1} > 2.78 \times (\sqrt{AC_{AVG}}) \times CV_{FB}$$

Where:

AC_1 = lower estimated airborne fiber concentration
AC_2 = higher estimated airborne fiber concentration
AC_{avg} = average of the two concentration estimates
CV_{FB} = CV for the average of the two concentration estimates

Four samples were randomly selected for re-counting from each Work Task category and then compared to the initial counts made on those samples. Coefficients of variation (CV's) for the calculation were obtained from Table 4 of MDHS 39/4 (8). Table 3.1 shows the initial and recount fibre concentration results. Table 3.2 shows results of the analysis along with the co-efficient of variation used for each pair. If A > B the pair of results is rejected. The calculations performed on all eight pairs of slides, (eight of the initial slides with eight of the replicate count) found all eight pairs to pass this statistical test for homogeneity.

Table 3.1: Replicate-counting results of 4 randomly selected Stripping and Bagging samples

Stripping		
Sample Number	**Initial count concentration in f/ml**	**Recount concentration in f/ml**
1	0.612	0.547
2	0.153	0.132
3	0.017	0.112
4	0.226	0.198
Bagging		
5	0.250	0.165
6	0.081	0.069
7	0.141	0.186
8	0.065	0.051

Table 3.2: Replicate analysis results using calculation listed in paragraph 3.1.3 above with the co-efficient of variation used for each pair

Sample Number	**A**		**B**	**Result**	**Expected CV_{FB}***
1	0.042	>	0.529	Accept	0.25
2	0.027	>	0.388	Accept	0.37
3	0.202	>	0.346	Accept	0.49
4	0.029	>	0.320	Accept	0.25
5	0.093	>	0.143	Accept	0.25

6	0.021 > 0.102	Accept	0.49
7	0.055 > 0.136	Accept	0.3
8	0.028 > 0.079	Accept	0.49

* Coefficients of variation (CV's) for the calculation were obtained from Table 4 of MDHS 39/4.

3.2 Bulk sample analysis results

Bulk samples of three different materials obtained from the boilers thermal insulation material (lagging) were analysed by SEM. Figures 3.1 and 3.2 below illustrate sections of boiler and pipe-work lagging with the outer hardset partially removed exposing the asbestos insulating material. Bulk Sample Nº 1 was obtained of insulating material, which comprised of the bulk portion of insulating material present on all four boilers and associated pipe-work. Bulk Sample Nº 2 was obtained from insulating material, which made up approximately 25 % of the total insulating material used and was mainly found on pipe-work. Sample Nº 3 was deliberately obtained from a portion of hardset material which had recently (within the last two years) been applied to a valve and portion of pipe-work which had undergone repair work and from which the original insulating material had been previously removed. It was estimated that this newer form of hardset comprised of less than five percent of the total insulating material removed during the study.

Figure 3.1: Removed hardset from a boiler's outer casing exposing asbestos insulating material beneath

Figure 3.2: Removed hardset from pipe-work exposing asbestos insulating material beneath

3.2.1 Bulk Sample 1

The sample was initially studied under Stereo Light Microscopy (SLM). Straight fibres with a faint yellow / brown colour were noted. Using SEM, the fibres in this sample had the appearance of amphibole asbestos. EDS showed the presence of Silicon, Iron and Magnesium, confirming the presence of Amosite. A manganese peak was not seen. The micrograph and chemical analysis printout has been provided on attached Appendix 3.

3.2.2 Bulk Sample 2

Under SLM, white fibres were noted, which had a serpentine appearance. Using SEM, the fibres displayed the morphology of Chrysotile asbestos. EDS displayed the presence of Silicon and Magnesium, confirming Chrysotile asbestos. The micrograph and chemical analysis printout has been provided on attached Appendix 4.

3.2.3 Bulk Sample 3

Using SLM, transparent, curved fibres were seen attached to a matrix. When observed under SEM, the fibres did not have the morphology of asbestos. EDS showed the presence Silicon and Aluminium. Asbestos was not identified in this sample. The elemental composition suggested an Aluminium Silicate however, the morphology was not typical of fibre glass. The micrograph and chemical analysis printout has been provided on attached Appendix 5.

3.2.4 Summary of Results

From the bulk sample analysis results it was confirmed that the insulating material to be removed was indeed asbestos. In addition, Bulk Sample No 1 represents the bulk of the insulating material present. This was definitively identified as Amosite commonly known as brown asbestos. Bulk Sample No 2 was also confirmed as asbestos. This sample was definitively identified as Chrysotile, commonly known as white asbestos.

It was therefore estimated that of the total insulating material removed during the study, approximately 95 percent comprised asbestos and five percent non-asbestos materials.

3.3 Asbestos Work Practice Checklists results

3.3.1 Findings of the Asbestos Work Practice Checklist

The Work Practice table, Table 3.3 below, displays numerical values assigned for each Work Practice. These values represent and describe the closest estimation of observed Work Practices undertaken during the daily four-hour sample period.

Table 3.3: Summary of observed daily Work Practices

Day	**Wetting***			**Stripping****		**Bagging*****			**Work Practice Score#**
	1	2	3	1	2	1	2	3	
DAY 1		2			2			3	7
DAY 2		2			2			3	7
DAY 3		2			2			3	7

DAY 4		2		1			2		5
DAY 5	1			1			2		4
DAY 6	1			1			2		4
DAY 7	1			1			2		4
DAY 8	1			1		1			3
DAY 9		2		1			2		5
DAY 10		2			2		2		6
DAY 11	1			1			2		4
DAY 12	1			1		1			3
DAY 13	1			1			2		4
DAY 14	1			1		1			3
DAY 15	1			1		1			3
DAY 16		2		1			2		5
DAY 17	1			1		1			3
DAY 18		2		1			2		5
DAY 19	1			1			2		4
DAY 20			3	1			2		6
DAY 21	1			1			2		4

Footnotes: # The sum of Wetting, Stripping and Bagging score for each day.

***Wetting:** 1 = Saturated
2 = Partially Wet
3 = Dry

****Stripping:** 1 = Manageable Pieces
2 = Unmanageable Pieces

*****Bagging:** 1 = Well Controlled
2 = Semi Controlled
3 = Uncontrolled

Definitions have been provided for Wetting, Stripping and Bagging, see attached Appendix 1 (Work Practice Checklist).

3.3.2 Summary of Work Practice results

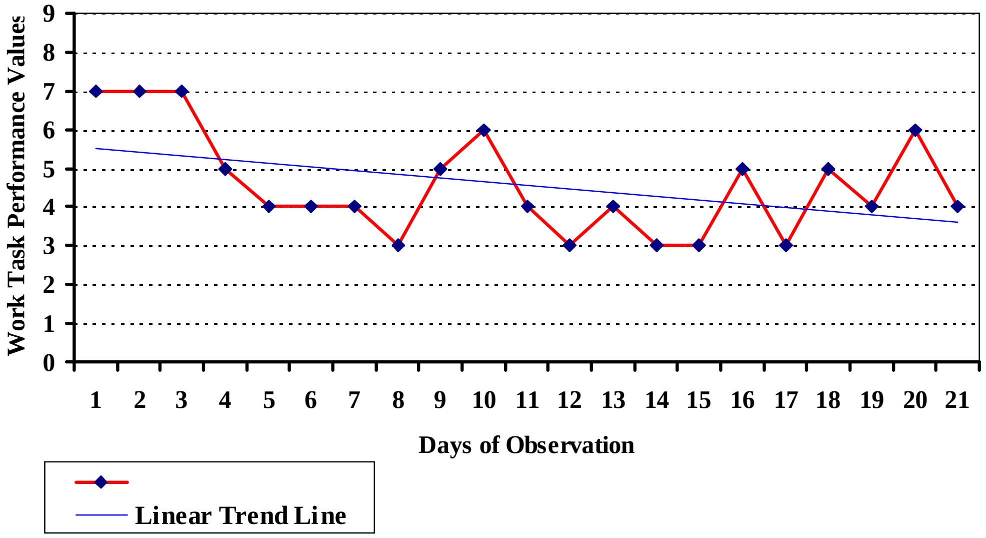

Figure 3.3: Trend analysis for all Work Practice Performance Values for the 21 days of observation

The assessment of the total daily Work Practices (Wetting, Stripping and Bagging) illustrated in Figure 3.3 above, shows that the optimal work practices theoretically prescribed for generating the least amount of airborne asbestos fibres possible i.e. Work Task Performance Values of 3, were only achieved on five of the 21 days of observation. Furthermore, Wetting, Stripping and Bagging of asbestos undertaken in a relatively uncontrolled manner was observed during the first three days of the contract. This was attributed to contractor employees not being suitably trained or even familiar with acceptable de-lagging practices. The contract was subsequently halted by the AIA on three occasions during the first three days and once thereafter due to airborne concentrations exceeding the OEL of 0.2 f/ml, as required by Regulation 11. (1)(b) Control of Exposure to Asbestos, Asbestos Regulations, 2001.

The trend line shows a gradual improvement in Work Practice Performance for the duration of the contract. This was primarily attributed to the intervention of the AIA who instructed the employees to work in a less reckless manner, remove manageable pieces of asbestos at a time and to apply more water when necessary.

3.4 Airborne fibre monitoring results

Airborne concentrations were calculated to four decimal places however, since the methodology is not as precise as four decimal places may suggest, airborne concentrations for this study were reported to three decimal places. The concentrations were based upon the number of fibres counted and volume of air sampled. All airborne concentrations provided in this study represent counts of regulated fibres only i.e. with a length > 5 µm, diameter < 3µm and a length to width ratio > 3:1, see attached Appendix 6.

3.4.1 Arithmetic means and comparison with OEL's

The arithmetic and geometric means were determined for sample concentrations. The geometric mean was a useful measure of central tendency for the data since it was highly skewed to the right (positively skewed). However, for public health purposes the **arithmetic mean** was also considered because it provides some idea of health risk where the human respiratory system is assumed to accumulate fibres linearly with concentration (23).

The mean personal sample concentration for Stripping (0.262 f/ml) was greater than mean personal Bagging sample concentration (0.135 f/ml) by almost two times. The highest value was measured during Stripping, which was 1.664 f/ml, approximately eight times greater than the S.A. legislated Occupational Exposure Limit (OEL) of 0.2 f/ml. The highest Bagging sample (0.631 f/ml) was approximately three times greater than the OEL.

None of the static samples exceeded the OEL with the highest being 0.133 f/ml. The overall mean fibre concentration was approximately five times greater for personal samples (0.198 f/ml) than for the concurrent static samples (0.039 f/ml).

3.4.2 Exploratory data analysis

Table 3.4: Airborne asbestos fibre concentrations by Work Task

Airborne asbestos fibre concentrations in f/ml.						
Work Task	N	Median	Maximum Concentration	25^{th} Percentile	75^{th} Percentile	IQR*
Stripper	24	0.138	1.664	0.087	0.203	0.115
Bagger	34	0.092	0.631	0.065	0.154	0.089
Static	21	0.028	0.133	0.021	0.046	0.025

* IQR = Interquartile range (75^{th} Percentile – 25^{th} Percentile)

A total of 79 airborne asbestos fibre samples were counted for the boiler de-lagging contract. The medians for the two Work Tasks; Stripping and Bagging were 0.138 f/ml and 0.092 f/ml respectively. Both values were below the OEL of 0.2 f/ml for asbestos. From the Stripping data set (n = 24), six samples (25 %) exceeded the OEL. Five samples (15 %) from the Bagging data set (n=34) exceeded the OEL. None of the Static samples, which were taken approximately eight meters from the workface each day, exceeded the OEL.

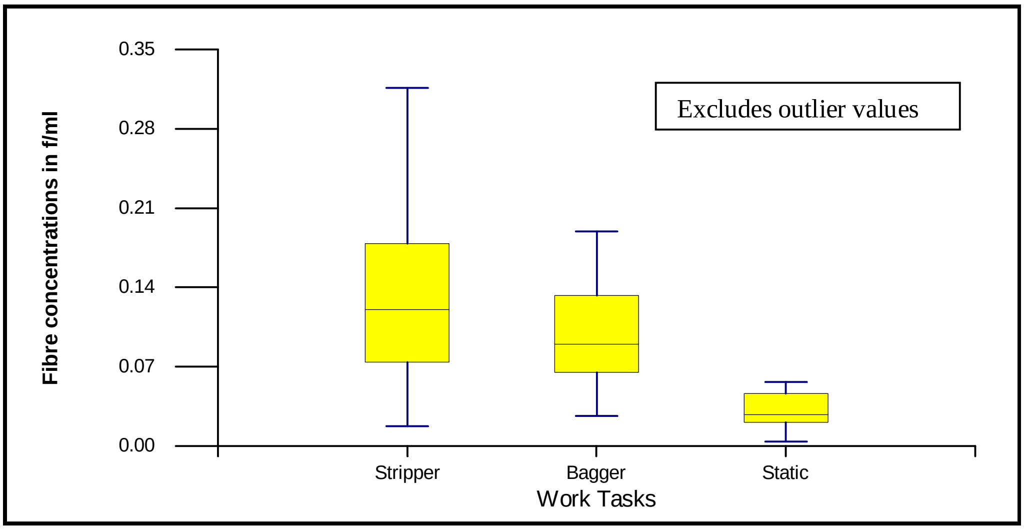

Figure 3.4: Box Plot of airborne fibre concentrations for each Work Task excluding outliers

Figure 3.4 shows box plots of airborne fibre concentrations for Stripping and Bagging Work Task. Static samples have been included as a supplementary data set. The length of the box is the Interquartile range (IQR), with the top and bottom horizontal lines of each box denoting the 75th and 25th percentiles respectively. The line inside the box indicates the sample median. The upper whisker represents the largest observations that is less than or equal to the 75th percentile plus 1.5 times the IQR. The lower whisker represents the smallest observation that is greater than or equal to the 25th percentile minus 1.5 times the IQR.

The Stripping Work Task had the greatest spread of data therefore the largest variability of airborne fiber concentrations. This task also had three outliers, 0.612 f/ml, 1.236 f/ml and the highest being 1.664 f/ml. The Bagging Work Task had two outliers, 0.439 f/ml and 0.631 f/ml. For this study, these outliers were not anticipated to be measurement errors. Outliers were considered as valid measurements because they were considerably larger than preceding values however their exclusion from exploratory data analysis was to prevent distortion of summary data.

3.5 Statistical analysis

3.5.1 Log transformation of data

Asbestos concentration in fibers/ml was highly skewed to the right (positively skewed). Table 3.5 and Figure 3.5 show this skewness. Consequently, a $\log_{10}$ transformation was applied to this variable to normalize the distribution. Figure 3.6 shows the distribution after the log transformation.

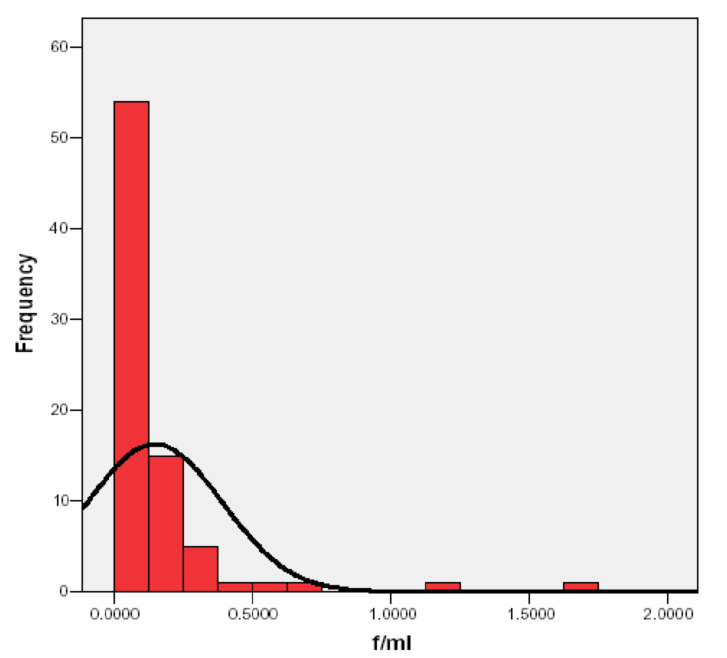

Figure 3.5: Histogram of asbestos concentration in fibres/ml

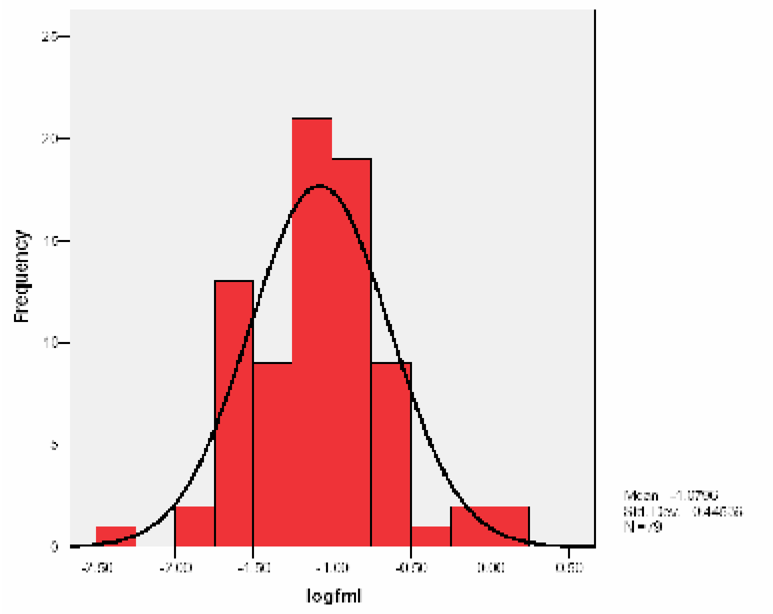

Figure 3.6: Histogram of asbestos concentration in $\log_{10}$ fibres/ml

Table 3.5: Descriptive statistics for asbestos concentration in $\log_{10}$ fibres/ml

N	Valid	79
	Missing	9*
Mean		0.148643
Skewness		4.574
Std. Error of Skewness		0.271
Minimum		0.0039
Maximum		1.6646
Percentiles	25	0.042800
	50	0.086800
	75	0.153300

* Missing values refer to those samples, which could not be counted (no result obtained) due to overloading of filter or ingress of water onto the filter

3.5.2 Bivariate Analysis

i) Analytical objective 1:

To compare the airborne asbestos concentrations between the work tasks (Stripping and Bagging) and the static samples.

Mean log asbestos concentration was compared between the tasks. Table 3.6(a) shows that there was an overall highly significant difference between the tasks (ANOVA, $p<0.001$), while Table 3.6(b) shows that the difference lay between the static samples and the Baggers ($p<0.001$) and the static samples and the Strippers ($p<0.001$). There was no difference between the Baggers and the Strippers ($p=0.480$). Figure 3.7 below shows that the concentrations for the Baggers and Strippers were similar, but the static samples had much lower concentrations.

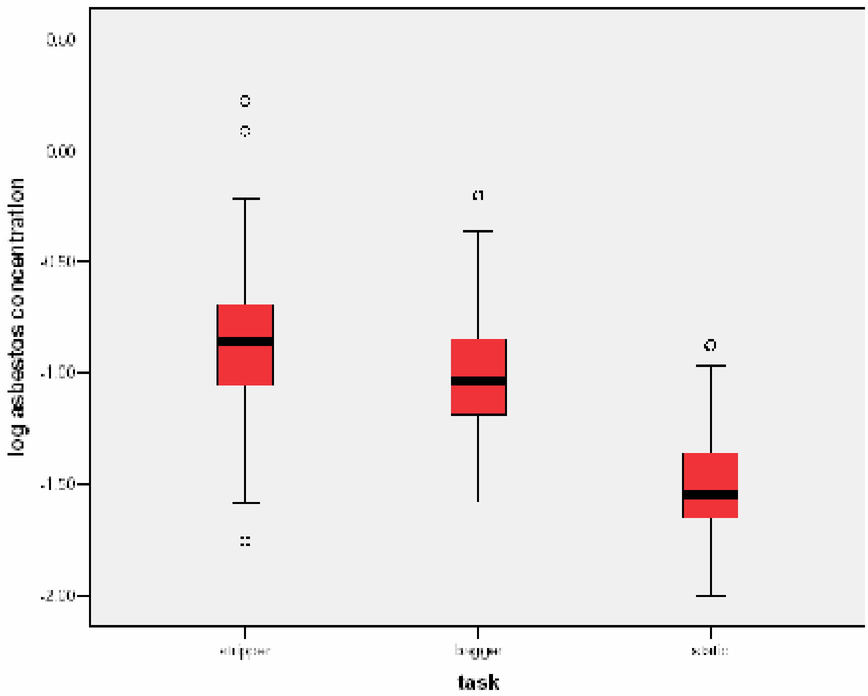

Figure 3.7: Box and whisker plot of the distributions of log asbestos concentration by task

Tables 3.6 (a) and (b): ANOVA test with Bonferroni post-hoc comparisons for mean $\log_{10}$ asbestos concentration between the task groups

Table 3.6(a):

	Sum of Squares	df	Mean Square	F	p value
Between Groups	5.269	2	2.634	21.573	<0.001
Within Groups	9.280	76	.122		
Total	14.549	78			

Table 3.6(b): Multiple Comparisons.

(I) task	(J) task	Mean Difference (I-J)	Std. Error	p value	95% Confidence Interval	
					lower	upper
stripper	bagger	.13219	.09316	0.480	-.0959	.3603
	static	.64826(*)	.10442	<0.001	.3926	.9039
bagger	stripper	-.13219	.09316	0.480	-.3603	.0959
	static	.51607(*)	.09699	<0.001	.2786	.7535
static	stripper	-.64826(*)	.10442	<0.001	-.9039	-.3926
	bagger	-.51607(*)	.09699	<0.001	-.7535	-.2786

* The mean difference is significant at the 0.05 level.

ii) Analytical objective 2:

To determine if the degree of wetting asbestos reduced asbestos concentrations.

There was a significant difference in asbestos concentration between the groups, which were saturated, partially wet and dry (p=0.005 – Table 3.7(a)). However, Table 3.7(b) shows that it was the partially wet group, which had the highest concentrations. There was only a significant difference between saturated and partially wet, and there was no difference between dry and either saturated or partially wet. One possible explanation for this was only five dry samples were obtained.

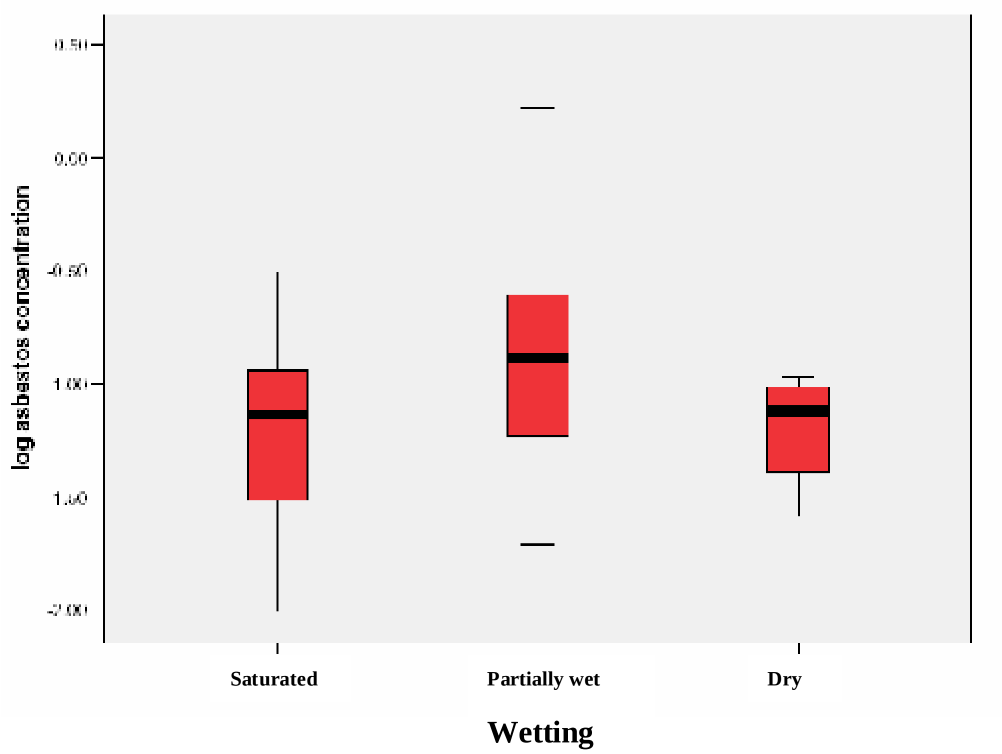

Figure 3.8: Box and whisker plot of the distributions of $\log_{10}$ asbestos concentration by wetness

Tables 3.7 (a) and (b): ANOVA test with Bonferroni post-hoc comparisons for mean $\log_{10}$ asbestos concentration by wetness

Table 3.7 (a)

	Sum of Squares	df	Mean Square	F	p value
Between Groups	1.862	2	.931	5.578	0.005
Within Groups	12.686	76	.167		
Total	14.549	78			

Table 3.7 (b)

(I) Wetting	(J) Wetting	Mean Difference (I-J)	Std. Error	p value	95% Confidence Interval	
Saturated	Partially	-.31818(*)	.09688	0.005	-.5553	-.0810
	Dry	.00431	.21298	1.000	-.5171	.5257
Partially	Saturated	.31818(*)	.09688	0.005	.0810	.5553
	Dry	.32249	.21792	0.429	-.2110	.8560
Dry	Saturated	-.00431	.21298	1.000	-.5257	.5171
	Partially	-.32249	.21792	0.429	-.8560	.2110

* The mean $\log_{10}$ difference for regulated fibres is significant at the 0.05 level.

iii) Analytical objective 3:

To determine if the removal methods (Stripping) influenced airborne asbestos concentrations.

There was a highly significant difference in asbestos concentration between the two different ways of Stripping the asbestos ($p<0.001$). Handling manageable pieces resulted in much lower airborne asbestos concentrations than unmanageable pieces. This is shown in Figure 3.9.

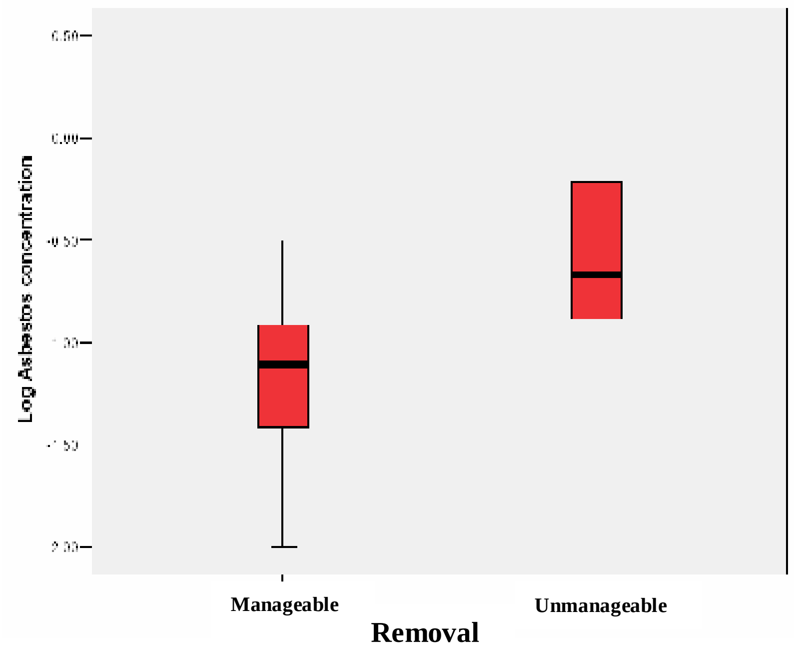

Figure 3.9: Box and whisker plot of the distributions of log asbestos concentration by removal method (Stripping)

Table 3.8: T-test for comparison of mean $\log_{10}$asbestos concentration by method of Stripping

	Removal	N	Mean	Std Deviation	Std Error Mean	t value	p value
Asbestos Concentration	Manageable	65	-1.1725	.34957	.04336	-4.967	<0.001
	Unmanageable	14	-.6190	.49598	.13255		

iv) Analytical objective 4:

To determine whether Bagging methods influenced airborne asbestos concentrations.

Overall there was a highly significant difference in mean asbestos concentration between the well controlled, semi controlled and uncontrolled Bagging techniques ($p<0.001$). The differences lay between the uncontrolled technique and the well controlled ($p<0.001$) and between the uncontrolled and the semi-controlled technique ($p<0.001$), but not between the well and semi controlled techniques ($p=1.000$). Figure 3.10 below shows that the uncontrolled method produced the highest asbestos concentrations. The well and semi controlled methods did not differ.

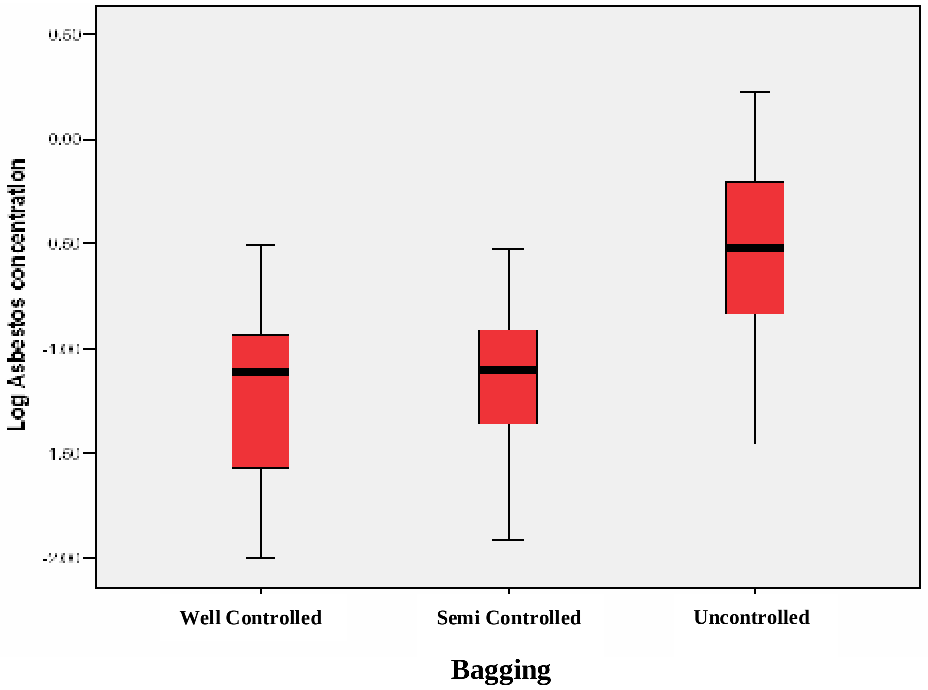

Figure 3.10: Box and whisker plot of the distributions of log asbestos concentration by Bagging method.

Tables 3.9 (a) and (b): ANOVA test with Bonferroni post hoc comparisons for mean $\log_{10}$ asbestos concentration by Bagging method

Table 3.9 (a)

	Sum of Squares	df	Mean Square	F	p value
Between Groups	4.112	2	2.056	14.974	<0.001
Within Groups	10.436	76	.137		
Total	14.549	78			

Table 3.9 (b)

(I) Bagging	(J) Bagging	Mean Difference (I-J)	Std. Error	p value	95% Confidence Interval	
Well Controlled	semi controlled	-.09539	.10186	1.000	-.3448	.1540
	uncontrolled	-.71946(*)	.14182	<0.001	-1.0666	-.3723
Semi Controlled	well controlled	.09539	.10186	1.000	-.1540	.3448
	uncontrolled	-.62407(*)	.12341	<0.001	-.9262	-.3219
Uncontrolled	well controlled	.71946(*)	.14182	<0.001	.3723	1.0666
	semi controlled	.62407(*)	.12341	<0.001	.3219	.9262

* The mean difference is significant at the 0.05 level.

v) Analytical objective 5:

To determine whether combinations of poor wetting, stripping and bagging result in higher asbestos concentrations.

A score was generated whereby the higher the score, the worse the practice. This score ranged from seven (worst) to three (least). Since this score consisted of five discrete categories, it was treated categorically. This score was highly significantly associated with asbestos concentrations ($p<0.001$). Tables 3.10 (a) and (b) shows that only a score of seven had significantly higher concentrations than the other scores. Therefore only those samples, which had a combination of partially wet, removed in unmanageable pieces and bagged in an uncontrolled manner, resulted in significantly higher concentrations than all other combinations. Figure 3.11 shows this graphically.

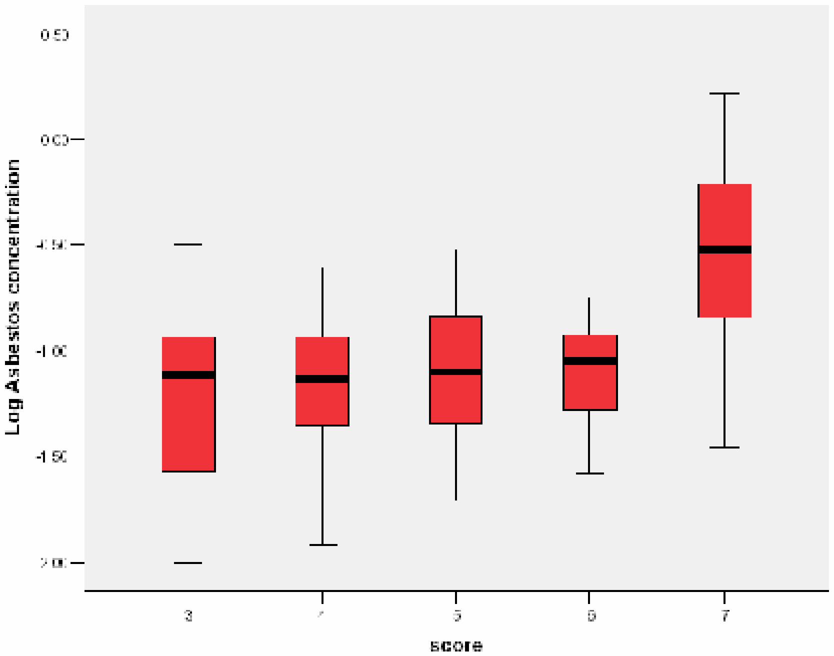

Figure 3.11: Box and whisker plot of the distributions of log asbestos concentration by score

Tables 3.10 (a) and (b): ANOVA test with Bonferroni post-hoc comparisons for mean $\log_{10}$ asbestos concentration by score

Table 3.10 (a)

	Sum of Squares	df	Mean Square	F	p value
Between Groups	4.147	4	1.037	7.375	<0.001
Within Groups	10.402	74	.141		
Total	14.549	78			

Table 3.10 (b)

(I) score	(J) score	Mean Difference (I-J)	Std. Error	p value	95% Confidence Interval	
3	4	-.07223	.11327	1.000	-.4000	.2555
	5	-.12520	.13108	1.000	-.5045	.2541
	6	-.12414	.16701	1.000	-.6074	.3591
	7	-.71946(*)	.14349	<0.001	-1.1347	-.3043
4	3	.07223	.11327	1.000	-.2555	.4000
	5	-.05297	.11997	1.000	-.4001	.2942
	6	-.05191	.15844	1.000	-.5104	.4065
	7	-.64723(*)	.13341	<0.001	-1.0333	-.2612
5	3 4	.12520 .05297	.13108 .11997	1.000 1.000	-.2541 -.2942	.5045 .4001
	6	.00106	.17162	1.000	-.4955	.4977
	7	-.59426(*)	.14883	0.002	-1.0249	-.1636
6	3	.12414	.16701	1.000	-.3591	.6074
	4	.05191	.15844	1.000	-.4065	.5104
	5	-.00106	.17162	1.000	-.4977	.4955
	7	-.59532(*)	.18128	0.016	-1.1199	-.0708
7	3	.71946(*)	.14349	<0.001	.3043	1.1347
	4	.64723(*)	.13341	<0.001	.2612	1.0333
	5	.59426(*)	.14883	0.002	.1636	1.0249
	6	.59532(*)	.18128	0.016	.0708	1.1199

* The mean difference is significant at the 0.05 level.

3.5.3 Multivariable Analysis

A generalized linear model was used to examine the independent and combined effects of task and score on asbestos concentration. A significant interaction between score and task was found (p=0.004), in conjunction with significant main effects of score and task (p<0.001).

Table 3.11: Asbestos concentration adjusting for score and task

Tests of Between-Subjects Effects.

Dependent Variable: Log Asbestos concentration.

Source	Type III Sum of Squares	df	Mean Square	F	p value
Corrected Model	10.463(a)	14	.747	11.705	<0.001
Intercept	57.446	1	57.446	899.761	<0.001
Score	3.260	4	.815	12.765	<0.001
Task	3.685	2	1.843	28.859	<0.001
score * task	1.615	8	.202	3.163	0.004
Error	4.086	64	.064		
Total	105.749	79			
Corrected Total	14.549	78			

a R Squared = 0 .719 (Adjusted R Squared = 0.658)

3.6 Summary of analytical objective results

3.6.1 Analytical objective 1:

Although airborne fibre concentrations were found to be similar for Stripping and Bagging work tasks, they were significantly higher than the static samples ($p < 0.001$).

3.6.2 Analytical objective 2:

The partially wet daily observations had the highest airborne fibre concentrations, which were significantly different from the saturated observations ($p < 0.005$). There was no difference between the dry and saturated or dry and partially wet observations.

3.6.3 Analytical objective 3:

The difference between Stripping asbestos in either small manageable pieces or larger unmanageable pieces, was highly significant ($p < 0.001$). Stripping (removing) asbestos in smaller manageable pieces resulted in much lower airborne fibre concentrations.

3.6.4 Analytical objective 4:

There was no difference between Bagging asbestos in either a controlled or semi-controlled manner. There was however a highly significant difference between both these manners and the uncontrolled manner ($p < 0.001$).

3.6.5 Analytical objective 5:

The observations recorded in the daily Work Practice Checklist were allocated a Work Performance Score between three and seven and compared to the daily airborne fibre concentrations. This Score was highly significantly associated with airborne fibre concentrations ($p < 0.001$). A Score of seven had significantly higher airborne fibre concentrations ($p < 0.02$) than any other Scores.

CHAPTER FOUR

4. DISCUSSION

This chapter begins by re-stating the aim of the study. A brief summary of the major findings are also stated which is followed by a presentation of the limitations to the study. The major findings are then discussed in greater detail starting with arithmetic means since they serve as a better summary value for occupational epidemiological studies. This is followed by an explanation of the significance of Work Practices observed on the first three days of the project. The chapter ends with a discussion on several strong tendencies revealed by the log-transformed data.

4.1 Aim of the study

The aim of this study was to link observed work tasks (Stripping and Bagging) and work practices (degree of wetting, manner in which asbestos was removed and the manner in which asbestos was bagged), with measured airborne concentrations of fibres in order to identify those factors contributing to high airborne concentrations generated during boiler de-lagging.

4.2 Summary of major findings

The main findings of this study indicate that Stripping asbestos, when partially wet, in unmanageable pieces and then Bagging in an uncontrolled (rushed or reckless) manner, resulted in the highest concentrations of airborne asbestos fibres. Based upon levels of significance, the data suggest that the manner with which the asbestos is handled i.e. size of pieces removed and the way that they were subsequently handled, were both important determinants of daily airborne fibre concentrations produced ($p < 0.001$). Surprisingly, the degree of wetting was not as important as expected: working dry did not generate significantly more fibres than working with saturated insulation but did generate significantly more fibres ($p < 0.005$) than working with partially wet insulation (which lead to the highest concentrations).

4.3 Limitations of the study

Several limitations of this data set as a whole will need to be borne in mind when interpreting the results.

i) Due to the analytical limitations of PCM, airborne fibre concentrations could not be specifically identified as being either asbestos or non-asbestos fibres. This meant that if the airborne concentration of non-asbestos fibres was quite high, the PCM count may not reflect actual asbestos concentrations (over-estimate) (9). The fact that this study included the de-lagging of bagasse fired boilers meant that bagasse dust / fibres may have been present in the counts. Whether or not this had a significant effect on the counts could not be accurately determined however, the microscopist performing the counts did confirm that in most cases he could visually distinguish between regulated fibres of “suspected asbestos” and bagasse dust (27).

ii) Daily work practices were only observed during the four hour air monitoring periods and, as with the airborne asbestos concentrations, were taken as representing work practices observed for that particular day. This meant that for an event, such as removing dry lagging, the degree of wetting, manner with which it was handled and the time periods that it was handled in that manner, can only be estimated as an average representing the four hour observation period. The observed work practices are also subjective and open to interpretation by the observer. To eliminate bias, which would have been evident between different observers, the same hygienist was used for the duration of the project. In addition, to provide a greater degree of consistency for the variables observed, definitions were provided for each observation criteria listed on the Work Practice Checklist.

iii) The limitation to interpreting the Wetting work practice in particular was the low number of samples taken within the dry category (n = 5). In general, the project had to be halted when dry stripping or stripping with insufficient water application was identified by the AIA. This may have resulted in the work being stopped for some of the partially wet observations or some of the partially wet observations being recorded as dry. This ultimately questions the validity of this particular work practice observation (Wetting).

For de-lagging projects incorporating the application of water as a form of dust control, AIA's are likely to halt the work when it is suspected that either no or an insufficient amount of water has been applied to the asbestos. This in turn questions the validity of collecting ordinal data to describe this particular Work Process i.e. dry, partially wet and saturated. Inferential analysis of the data showed the partially wet daily observations to have the highest airborne fibre concentrations, which were significantly different from the saturated observations ($p < 0.005$). However, there was no difference between the dry and partially wet samples (which was described under item (ii) above), or between the dry and saturated samples. Interventions by the AIA, tends to create difficulty in accurately describing the degree of wetness of asbestos for one representative period of time. Although the issue of utilising ordinal data will need to be tested statistically, these results infer that the collection of nominal data such as either insufficient wetting or sufficient wetting, would be a more valid method of describing this type of observation.

iv) Nine airborne fibre samples, designated as NONE in the attached air monitoring results sheet, (Appendix 6) of the total number of samples deployed, could not be counted. This was attributed to the following two reasons. Either the sample filter was overloaded with dust, which did not allow for an acceptable level of counting accuracy (8), or the excessive and uncontrolled use of water resulting in water spray entering the filter cowl and interfering with fibre deposition on the filter papers.

4.4 Major findings

4.4.1 Research objective 1 (Bulk samples)

Bulk sample analysis was found to be critical to the study since it confirmed the presence of both chrysotile and amosite asbestos lagging. This provided greater confidence in the airborne regulated fibre monitoring results being representative of airborne asbestos fibre concentrations. In addition the material suspected as being non-asbestos was identified as such, allowing for greater confidence and accuracy in estimating the percentage of non-asbestos material stripped and bagged during the study. It was estimated that less than five percent of the total insulating material removed during the study was non-asbestos containing material.

4.4.2 Research objective 2 (Airborne fibre monitoring)

Since the arithmetic mean may serve as a better summary value for occupational epidemiological studies, these will be discussed first. The overall mean fibre concentration was approximately five times greater for personal samples (0.198 f/ml) than for the concurrent static samples (0.039 f/ml). A similar relative difference between means for personal and area sampling (6 times greater) was discovered by Shaikh et al, in 1994 of their analysis of airborne fibre levels in a hospital operations and maintenance program (23).

The Stripping Work Task had the greatest spread of data therefore the largest variability of airborne fiber concentrations. Stripping had three outliers and Bagging two outliers. When outlier values were excluded from the arithmetic mean calculations (Figure 3.4), the personal sample concentration remained larger than the static sample concentration. This rank order remained the same, as compared when using all data and also when the data were log transformed. Previous studies reported the same finding when evaluating the relationship between personal samples and matched area (static) samples (19), (23), (24), (28). Lange et al, (1996), describe the importance of data evaluation of outliers. They warn that failure to isolate outliers, using unadjusted concentration results can lead to a fallacious interpretation of data, as seen in their own initial observations of personal and area sample relationships (25).

The difference in mean sample concentrations between personal and static samples (taken approximately eight meters from the work face) for this study demonstrates the importance of spatial and temporal proximity as a determinant for airborne fibre concentrations.

4.4.3 Research objective 3 (Analysis of Work Tasks, Work Practices and Airborne fibre concentrations).

Wetting, Stripping and Bagging of asbestos was undertaken in a relatively uncontrolled manner during the first three days of the project resulting in average airborne fibre concentrations of 1.171 f/ml for the Stripper and 0.315 f/ml for the Bagger. These means were 4.5 times and 2.3 times respectively, greater than the means calculated for the entire project duration. In a study by Stewart-Taylor A.J. and Cherrie J.W. (1998), the authors found that careful Bagging was shown to reduce exposures by approximately half, which is very similar to the effect of careful Bagging observed in this study (21). These initial high airborne concentrations were attributed to inadequate training and information provided to employees. Intervention by the AIA, comprised of instructions on how to remove asbestos (Work Practices) as well as specifying the location and quantity of water to apply. Airborne fibre concentrations were subsequently significantly reduced to levels below the OEL for the remaining 18 days (n = 49 personal samples), except for four samples, which exceeded the OEL. In the context of this project, these findings demonstrate the utmost importance of providing the appropriate training and supervision of employees, not only for protecting themselves against airborne asbestos fibres, but removing asbestos in manner that results in the generation of the least amount of airborne fibres possible.

The analysis of log transformed data revealed several strong tendencies of airborne fibre concentrations when related to Work Tasks and Work Practices. The difference between stripping asbestos in small manageable as opposed to larger unmanageable pieces was highly significant ($p < 0.001$). Smaller manageable pieces resulted in much lower concentrations. This was attributed to employees having difficulty in reaching all exposed dry areas with water when stripping larger sections. Further, these sections often broke apart or were folded in order to fit into the bags. This additional handling resulted in exposing more surface area of the asbestos, which had not been appropriately wet. Smaller pieces seemed to be easier to wet particularly around the edges and were also easier to remove and bag in a careful manner. The manner with which asbestos was bagged was also highly significant ($p < 0.001$). Bagging in an uncontrolled manner resulted in much higher airborne concentrations and was attributed to:

1) Attempts to complete the project earlier.
2) Ignorance of the fact that rushed and reckless handling of asbestos generated high airborne fibre levels.
3) Employees' general ignorance of the health risk associated with increasing airborne fibre concentrations.

The Work Performance Score derived from the daily Work Practice Checklist was highly significantly associated with airborne fibre concentrations ($p < 0.001$). This supports the validity of the checklist to describe the Work Practices for this project in relation to corresponding airborne asbestos concentrations.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

This study showed airborne asbestos fibre concentrations associated with two Work Tasks: Stripping and Bagging, as a result of daily Work Practices. Stripping asbestos lagging (a) without applying the correct amount of water in an appropriate manner, (b) removing large difficult to handle sections (c) undertaken in an uncontrolled manner i.e. rushed or reckless, produced the highest levels of airborne asbestos fibres. Bagging asbestos under the same inappropriate Work Practices did not produce as high levels but were still higher than the matched static samples. There was clear association between what can be described as rushed, reckless Work Practices, and resulting high levels (exceeding the OEL) of airborne fibre concentrations.

The application of water was the primary control technique for this project and was applied by garden hose from a municipal tap. When considering recommendations, previous research has shown that the use of water amended with a surfactant as a spray generally reduced airborne fibre levels by at least one order of magnitude (5). Furthermore, dry areas of the asbestos insulation can be more easily spotted if a dye is added to the wetting agent (6). However, whatever method is chosen to control asbestos fibres, it must be evaluated and implemented by an experienced AIA and Registered Asbestos Contractor.

Airborne fibre concentrations were significantly reduced to levels below the OEL after the provision of training by the AIA, which focused on specific wetting and removal techniques. In the context of this project, these findings demonstrate the utmost importance of providing the appropriate training and supervision of employees. With sufficient information obtained from these and similar studies, specific guidelines for de-lagging asbestos containing materials using water as one of the primary forms of control, could be added to the existing Guide to Demolition Work No OHC 6 (17). This document will be based on actual South African working conditions and current legislation as well as lessons learned from the many revisions to guidance documents introduced by other international agencies.

Implementing basic occupational hygiene principles, the potential to maintain fibre levels below the OEL during boiler de-lagging can be achieved. Preventing or minimizing the release of asbestos fibres into the air will significantly decrease the risk of asbestos-related diseases. Therefore further research in this regard is warranted.

It is hoped that the shared experience of this study will serve as a basis for useful dialog on how to best train Registered Asbestos Contractors in order reduce occupational and public health risks as a result of boiler de-lagging projects. The focus of training should be on maximizing appropriate specific Work Practices ultimately preventing the unnecessary release of high levels of asbestos fibres into the work environment.

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Appendix 1: Work Practice Checklist

Date of observation:__________________

Tick the box, which most accurately describes work practices undertaken during the 4-hour sample period.

1. WETTING:

1.1 Saturated ☐

The area of asbestos being worked (removed) was saturated with water with no airborne dust observed on either employees protective suits, in the air, or on plant and machinery.

1.2 Partially Wet ☐

The area of asbestos being worked (removed) was partially wet i.e. pockets of dry asbestos with small amounts of visible dust observed on either employees protective suits, in the air or on plant and machinery.

1.3 Dry ☐

The area of asbestos being worked (removed) was dry with large amounts of visible dust observed on either employees protective suits, in the air, or on plant and machinery.

---

2. REMOVAL OF ASBESTOS:

2.1 Manageable pieces ☐

The asbestos was removed mainly in sections that were small enough to fit easily into the bags without further folding, cutting or handling.

2.2 Unmanageable pieces ☐

The asbestos was removed mainly in sections that were too large to fit easily into the bags and therefore required further folding, cutting or handling.

---

3. BAGGING OF ASBESTOS:

3.1 Well controlled ☐

The bagging of asbestos was undertaken in a careful manner with no spills.

3.2 Semi Controlled ☐

The bagging of asbestos was undertaken in a relatively careful manner with only a few spills i.e. < 10% of the total volume of asbestos contained in the bag falling onto the floor or scaffold platform.

3.3 Uncontrolled ☐

The bagging of asbestos was undertaken in a rushed or reckless manner with many spills i.e. > 10% of the total volume of asbestos contained in the bag, falling or dropped onto the floor or scaffold platform.

Appendix 2: Ethical Clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)
Ref: R14/49 Randolph

CLEARANCE CERTIFICATE PROTOCOL NUMBER M03-02-31

PROJECT A Task Based Exposure Assessment of airborne Asbestos Fibres During Boiler De-Lagging

INVESTIGATORS Mr RW Randolph

DEPARTMENT School of Public Health, Wits Medical School

DATE CONSIDERED 03-02-28

DECISION OF THE COMMITTEE Approved unconditionally

Unles otherwise specified the ethical clearance is valid for 5 years but may be renewed upon application
This ethical clearance will expire on 1 January 2008.

DATE 03-04-17 CHAIRMAN .... (Professor P E Cleaton-Jones)

* Guidelines for written "informed consent" attached where applicable.

c c Supervisor: Prof D Rees
Dept of School of Public Health, Wits Medical School
Works2\lain0015\HumEth97.wdb\M 03-02-31

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10001, 10th Floor, Senate House, University

I/we fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress form. I/we agree to inform the Committee once the study is completed.

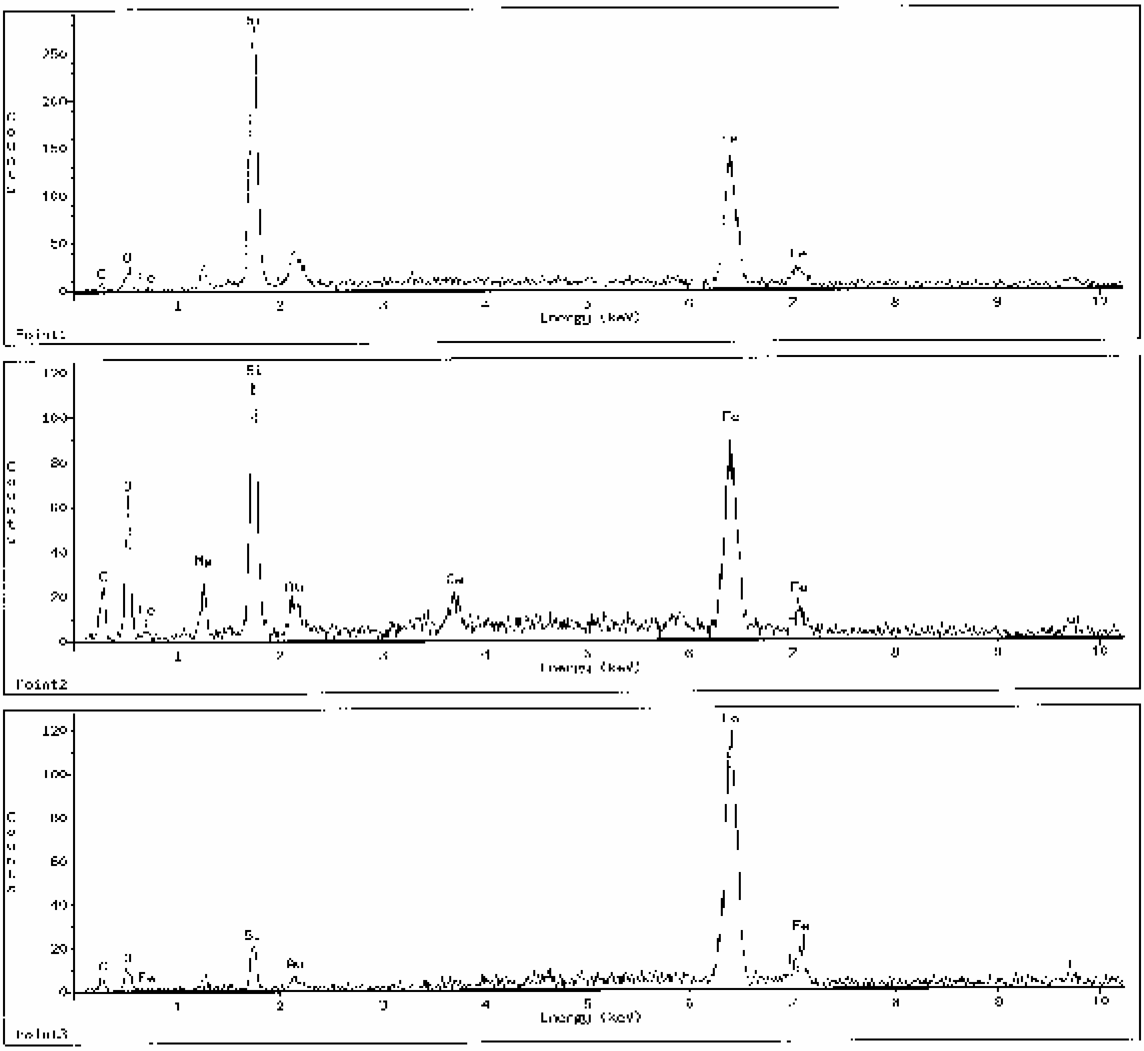
DATE 7th May 2003 SIGNATURE ....

PLEASE QUOTE THE PROTOCOL NO IN ALL QUERIES .: M 03-02-31

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

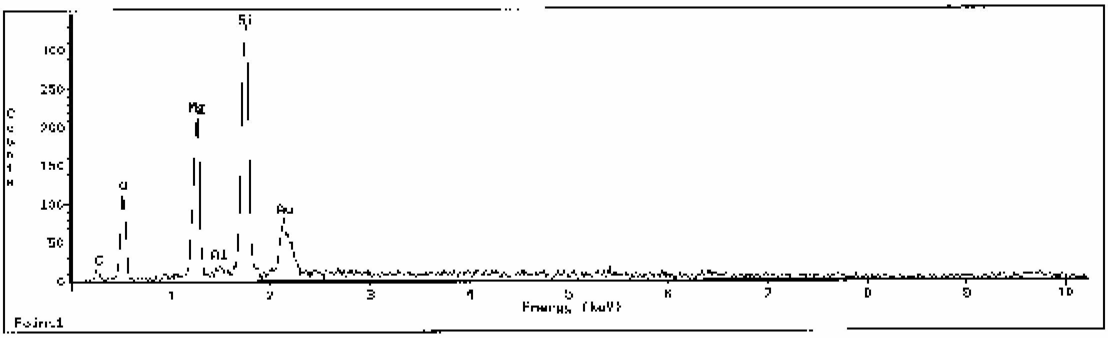
Appendix 3: SEM of Bulk Sample No 1, Amosite (brown asbestos).

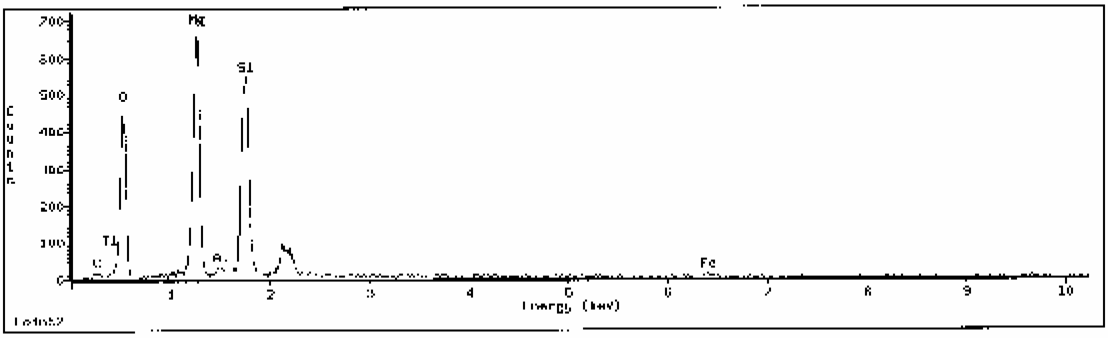
Sample ID	: 293/03
Area ID	: Robert Randolph
Label	: Bulk analysis Prof Rees
Date/Time:	: 2003/09/29 10:14

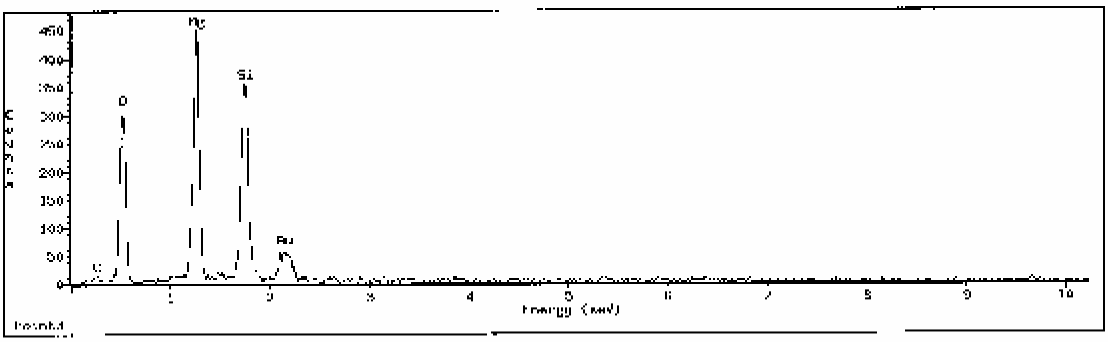


Appendix 4: SEM of Bulk Sample No 2, Chrysotile (white asbestos).

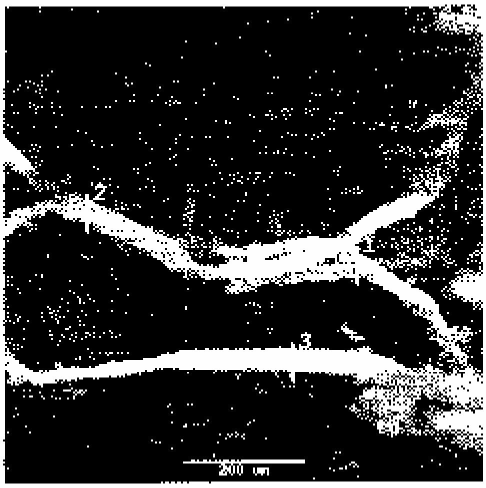
Sample ID : 294/03
Area ID : Robert Randolph AMA 2
Label : Bulk analysis Prof Rees
Date/Time: : 2003/09/29 10:48



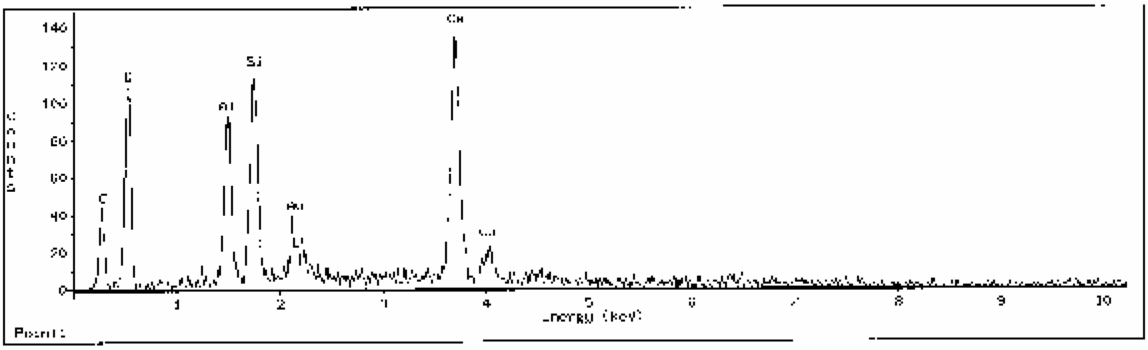


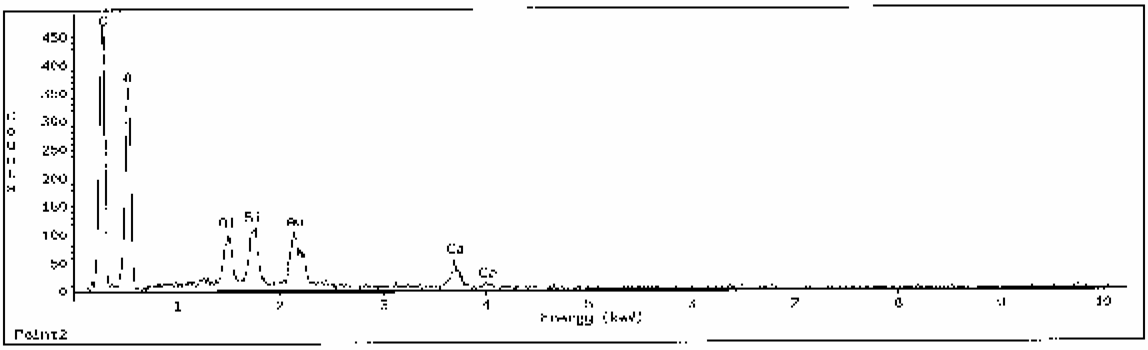


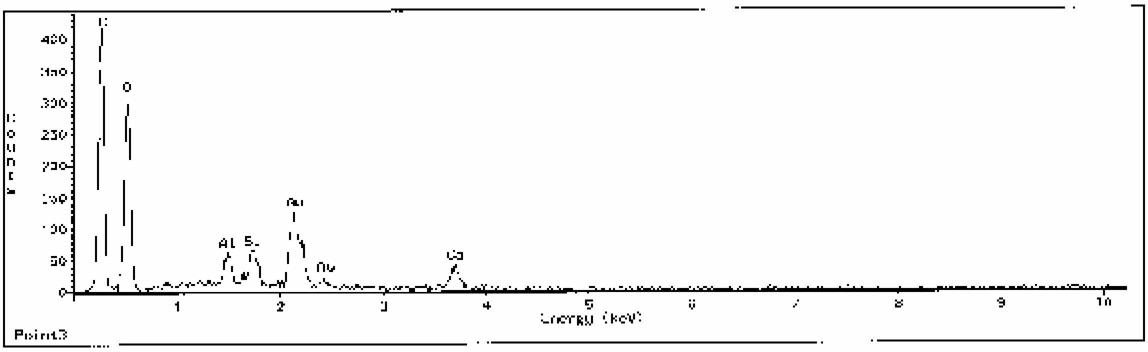
Appendix 5: SEM of Bulk Sample No 3, Non asbestos containing hardset.



Sample ID	:	295/03
Area ID	:	Robert Randolph AMA 3
Label	:	Bulk analysis Prof Rees
Date/Time:	:	2003/09/29 11:28







Appendix 6: Airborne fibre monitoring results.

Airborne Fibre Monitoring Results							
DAY	f/ml Stripper	DAY	f/ml Bagger	DAY	f/ml Static		f/ml Clearance Monitoring
1	1.2366	1	0.6314	1	0.0351		0.0192
2	1.6646	1	0.1072	2	0.1333		0.0161
3	0.6125	2	0.4398	3	NONE		0.0091
4	0.1797	2	0.2504	4	0.0222		0.0121
4	0.1772	3	0.3044	5	NONE		0.0088
5	NONE	3	0.1594	6	0.0222		0.0095
6	0.0985	4	NONE	7	0.0121		0.0110
6	0.0551	5	0.251	8	0.0279		
6	0.1533	5	0.1894	9	0.0440		
7	0.0699	5	0.0815	10	0.0428	**SUM**	**0.0858**
7	0.0780	6	0.0907	11	0.0310	**MEAN**	**0.0122**
8	0.3160	7	0.0637	12	0.0190	**RANGE**	**0.0091 - 0.0192**
9	0.1211	8	0.0941	12	0.0269		
9	0.1232	9	0.0796	12	0.0287		
10	0.1803	10	0.1312	13	0.0282		
11	0.0973	11	0.1226	14	0.0039		
12	NONE	11	0.0868	15	0.0855		
13	0.0383	12	NONE	16	0.0237		
13	0.0260	13	0.0525	17	0.0197		
14	0.0978	14	0.0712	18	0.0197		
14	0.1162	15	0.1412	19	0.0565		
15	0.0175	15	0.0678	20	0.1074		
16	0.2996	16	0.0467	21	0.0483		
17	0.1598	16	0.0595				
17	0.1604	17	0.0827				
18	0.2262	18	0.1068	**SUM**	**0.8381**		
19	NONE	18	0.0650	**MEAN**	**0.0399**		
20	NONE	19	0.1642	**RANGE**	**0.0039 - 0.1333**		
21	NONE	19	0.1333				
		19	0.1326				
		20	0.0653				
SUM	**6.3051**	20	0.0897				
MEAN	**0.2627125**	20	0.0263				
RANGE	**0.0175 - 1.6646**	21	0.0408				
		21	0.1109				
		21	0.0599				
		SUM	**4.5996**				
		MEAN	**0.13528235**				
		RANGE	**0.0263 - 0.6314**				

Appendix 7: Letter of consent.

ENVIRONMENTAL MONITORING UNIT C.C. TRADING AS

POLYCON

APPROVED INSPECTION AUTHORITY

11th April 2003

Mr R.W. Randolph
107 St. Anton
35 Beach Road
Doonside
4125

Re: **Consent for the use of airborne asbestos monitoring and observational data for research purposes – MPH (Occupational Hygiene)**

Dear Mr. Randolph

We would like to inform you that your request to utilise data obtained from airborne asbestos monitoring as well as from observations made during the predetermined contract period (May 2003) has hereby been granted.

Yours sincerely

Mr. S. J. Chester
Member

PO BOX 2079 • AMANZIMTOTI • 4125 • TEL/FAX (031) 9141004

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