SOCIETY OF BROWNFIELD RISK ASSESSMENT
SUMMER WORKSHOP REPORT 2013

ASBESTOS IN SOIL RISK ASSESSMENT

PUBLICATION

This report summarises the key technical issues relevant to the risk assessment of asbestos in soil as presented and discussed at a SoBRA (Society of Brownfield Risk Assessment) workshop in June 2013.

Whilst every effort has been made to ensure the report is an accurate account of the workshop proceedings, neither SoBRA nor the authors of the report accept any liability whatsoever for any loss or damage arising in any way from its use or interpretation, or from reliance on any views contained herein.

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PREFACE

The Society of Brownfield Risk Assessment (SoBRA) was established in December 2009 with the principal aim of promoting technical excellence in land contamination risk assessment in the United Kingdom (UK).

As part of achieving this aim, SoBRA have undertaken to host regular conferences and workshops on technical subjects of interest to UK risk assessors.

SoBRA's first Summer Workshop was held in June 2010 in York where the human health risk assessment of polycyclic aromatic hydrocarbons in soil was considered.

SoBRA's second Summer Workshop was held in June 2011 at the Mechanics Institute in Manchester. It addressed the assessment of the risks associated with lead contamination in soil.

SoBRA's third Summer Workshop was held in June 2012 at Armada House in Bristol. It addressed the assessment of risks associated with petroleum hydrocarbons in groundwater.

The current report describes the proceedings of SoBRA's fourth Summer Workshop, which considered the risk assessment of asbestos in soil. The event was held at the Priory Rooms in Birmingham on 27th June 2013. Rather than the usual thematic format established by previous events, the specific aim of the event was to support the Joint Industry Working Group (JIWG) risk assessment chapter. Therefore, the event focussed on the risk assessment aspects of asbestos throughout the CLR11 process. The three key themes were:

1. site investigation support;
2. exposure scenario – remediation and cross boundary issues; and
3. exposure scenario – existing/future land users decision algorithm.

Delegates received presentations from expert speakers on these three topics and participated in separate afternoon workshops on the same themes. During the morning proceedings, delegates also heard a presentation from Public Health England on the challenges of toxicology, and a lawyer's perspective on the application of the Control of Asbestos Regulations 2012 (CAR 2012) with respect to soil.

Eighty nine delegates, including expert speakers and SoBRA Executive Committee members, attended the 2013 Summer Workshop. Feedback provided by delegates after the event was extremely positive with more than 90% of responding delegates rating the event as "excellent" or "good", with similar high scores awarded to the speakers and more than 80% of responding delegates also highly rating the individual afternoon workshops. Overall, therefore, the 2013 Summer Workshop consolidated SoBRA's commitment to hosting high quality and stimulating meetings on technical topics of relevance to its members.

This report fulfils an undertaking given by SoBRA to produce a formal record of the proceedings of the workshop. It summarises the expert presentations given on the day, records current views on the main technical issues within each subject area and describes the challenges identified by risk assessors in dealing appropriately with asbestos in soil.

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Seamus LeFroy Brooks	LBH Wembley Geotechnical & Environmental	Speaker
John Parker	RSK	Speaker
Martin Stear	Workplace Environment Solutions Ltd	Speaker
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Finally, SoBRA wishes to acknowledge the contribution to the overall success of the event made by individual workshop delegates for attending and enthusiastically participating in the day's proceedings.

Workshop delegates are listed in Appendix 1 to this report.

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1 INTRODUCTION

1.1 Background

Asbestos is a naturally occurring mineral. It was recognised for use within the building industry owing to its flame retardant and insulating properties. It was imported and used extensively in the building industry primarily between the late nineteenth century and the late twentieth century but can be present in buildings constructed up to and including 1999 when it was prohibited. The asbestos was used in different forms: cement, spray coatings, textured coatings, lagging, bitumen and vinyl products and board. Uses included insulation, fire protection to steel work and in ducts, wall panels and partitions, rope, textiles, school notice boards, utility pipes, ceilings as tiles and as decorative plaster, roofing as cement and felt, gutters, water tanks, sinks, toilets and vinyl floor tiles. Consequently, asbestos is present in UK buildings and, as a result of redevelopment activities and below ground services, in the soil.

There are three main types of asbestos: crocidolite, amosite and chrysotile. These are often referred to as blue, brown and white respectively. There are a further three rarer types of asbestos: tremolite, actinolite and anthophyllite. There are two types of asbestos fibres: serpentine and amphiboles. Uncertainty exists regarding the potency of the different fibres, although it is commonly reported that amphibole fibres have a greater potency than serpentine fibres. Amosite and crocidolite are examples of amphibole fibres whilst chrysotile is the only serpentine fibre.

As a rule of thumb, lagging, insulating board and sprayed coatings are more likely to contain crocidolite and amosite asbestos. Insulation and lagging are most likely to give off fibres owing to the absence of a bonding material. Furthermore, these products can contain up to 85% asbestos. Hence, these forms of asbestos generally pose the greatest risk. By comparison, asbestos cement typically contains 10-15% asbestos and this is bound into the cement. Hence, fibres are only released if the cement is broken.

Exposure to asbestos fibres can lead to carcinogenic and non-carcinogenic health effects although these usually do not occur until 15 and 60 years later (HSE, 2012 (a)). Thus, challenges are faced with respect to exposure, which is cumulative over a lifetime. Therefore, the age at which a person is exposed becomes an important factor in the risk assessment. Another challenge is how the potency of the different asbestos types is incorporated into a risk assessment.

The Control of Asbestos Regulations, often referred to as CAR 2012, legislation came into force in April 2012. Under these regulations every employer has a duty to prevent or, where this is not reasonably practicable, to reduce spread and exposure of people to asbestos. Regulation 5 requires an employer to undertake a risk assessment before demolition, maintenance or any other work that might expose employees to asbestos at the premises. The Association of Geotechnical and Geoenvironmental Specialists (AGS, 2013) notes that CAR 2012 applies to land included in the premises rather than just the buildings. Guidance to support CAR 2012 with respect to asbestos in soil, however, was not published. Thus, uncertainty and inconsistency exists in the industry in terms of how to deal with asbestos in soil under CAR 2012.

At the time of the workshop, a CIRIA project was underway to improve the performance of practitioners and other professionals when undertaking risk assessments on sites that could be contaminated by asbestos. This project was subsequently published on 26th March 2014 (CIRIA, 2014).

Owing to inconsistent application of CAR 2012 regulations and the associated commercial and compliance risks, the JIWG was set up. JIWG comprises industry and government bodies, chaired by the Environmental Industries Commission (EIC) with Contaminated Land: Applications in Real Environments (CL:AIRE) acting as secretariat. The group aims to provide practical guidance in the form of a Code of Practice. This will be based on clear and consistent regulatory enforcement positions which will reduce uncertainty and the consequent commercial and compliance risks.

JIWG has six key issue focus groups:

- investigation and monitoring;
- laboratory analysis;
- waste management;
- CAR 2012 / Environmental Permitting Regulations (EPR) 2010;
- asbestos work categories; and
- human health risk assessment.

SoBRA is contributing to the human health risk assessment chapter. Hence, the Summer Workshop and asbestos sub-group was established to support development of this chapter.

1.2 Objective and aims

The objective of SoBRA's summer 2013 workshop was to inform the human health risk assessment chapter of the JIWG Code of Practice for asbestos in soils.

The aims of the workshop were to:

- provide high quality speakers who could outline the challenges faced for their topic area that affect the risk assessment process, including site investigation, laboratory analysis, the legal framework, toxicology, exposure modelling and remediation; and
- break out into workshop groups to discuss issues pertaining to a topic area in more detail and identify how such issues might be resolved. The three topic areas were:
    - site investigation support (data requirements and laboratory methods);
    - exposure scenarios that might be used to evaluate remediation, re-use and cross boundary issues; and
    - algorithms for existing/future land user exposure scenario for which there were two parallel groups.

Note, although toxicology is a key aspect of the risk assessment, it was considered that insufficient people with adequate toxicological knowledge would be attending the event and therefore a workshop on this topic would be impracticable.

1.3 Structure of the report

A specific goal of the workshop organisers was to produce a formal workshop output that summarised the proceedings, consolidated ideas and made recommendations on the work required to support risk assessment efforts in the future. Following this introduction, Section 2 of the report sets the scene for the workshop proceedings by providing accounts of the challenges faced by industry relating to the risk assessment of asbestos in soil. Sections 3 to 6 provide a factual account of the workshop discussion group outputs. The exposure scenario-existing / future land users topic was discussed by two groups with the intention that the proposed methods by both groups could be compared to help inform the work of the JIWG. Therefore there are two sections (Section 5 and Section 6) to describe the discussion outputs of the two groups.

Subsequent to the workshop, the SoBRA asbestos sub-group developed the tools used for exposure scenarios of existing and future land users. This work is presented in Section 7. Concluding remarks, including areas for further work to inform scientifically robust risk-based decision making, are provided in Section 8.

Reference documents used to support presentations and workshop discussions are shown as footnotes to the text, and are collated as a complete list in Section 9 of the report.

Appendix 1 gives details of the workshop groups including names of individual participants. Appendix 2 sets out a list of abbreviations used in the report.

2 EXPERT PRESENTATIONS

Six speakers kindly gave their time to prepare and give presentations. The presentations are summarised in the following sub-sections and comprised:

- site investigation and analysis of asbestos;
- legal aspects/case law and how this might influence risk assessment;
- remediation and re-use;
- asbestos: review of toxicology & options for human health risk assessment; and
- approaches to exposure assessment.

2.1 Site investigation and analysis of asbestos

The presentation outlined how the AGS sub-group on asbestos in soil has used the CAR 2012 to give practical advice on protecting site investigation and geotechnical laboratory staff from asbestos in soil.

By means of introduction, it was recognised that investigation is usually undertaken to determine geotechnical properties of the ground and/or to ascertain its suitability for use. Investigation is rarely undertaken purely to determine whether asbestos is present within soil. Subsequent to CAR 2012, it is necessary to assess the potential for people to be exposed to asbestos including at the investigation stage. Hence, AGS developed interim guidance to enable AGS members to be aware of their responsibilities and to offer practical measures to comply with CAR 2012.

The presentation highlighted that the first risk assessment must be done before anyone goes to site which poses challenges since although each Industry Profile refers to asbestos as a potential contaminant, its presence, form and quantity are uncertain. Key questions to be considered when undertaking a risk assessment are:

- Is there a risk of asbestos being present?
- Is there a risk of asbestos fibre release? and
- Is there a risk of the fibre release exceeding the control limit?

The presentation noted that notification to the Health and Safety Executive (HSE) was not required where:

- the exposure of employees to asbestos is sporadic and of low intensity;
- it is clear from the risk assessment that the exposure of any employee to asbestos will not exceed the control limit; and
- the work involves the collection and analysis of samples to ascertain whether a specific material contains asbestos.

The AGS sub-group considered whether there were any ‘safe’ levels for asbestos in soil. Given it is the inhalation of fibres that cause disease, the sub-group considered information would be needed to ascertain whether there is a relationship between:

- the amount of fibres in the air and the risk of disease; and
- the concentration of fibres in the air and the concentration of fibres in the soil.

The sub-group also considered that in order for indirect exposure to occur outdoors, free fibres must be present at the ground surface, and the fibres must become airborne. Fibres may become airborne through dry and windy conditions and/or vehicle and/or machinery movements.

For indirect exposure to occur indoors, wet and muddy conditions within the soil containing asbestos fibres would be required to permit mud being trodden back to the property. Two key parameters that affect fibres becoming airborne and thus exposure to people are: drying and airflow.

Asbestos poses a risk when fibres become airborne and are inhaled. The majority of people working in site investigation are not air specialists. Hence, it is necessary for our industry to engage with other specialist skill sets. This is recognised by the JIWG of which AGS is part. Further details of JIWG are provided in Section 1.1.

The presentation also documented the following data sources that affect our judgement on asbestos in soil. These include the importance of the:

- Supreme Court mesothelioma ruling (Sienkiewicz v Greif UK Ltd, Willmore v Knowsley Metropolitan Borough Council (2011)[1];
- Environment Agency (EA) position on waste as laid out in WM2 (Environment Agency 2013);
- HSE position on guidance[2];
- Enterprise and Regulatory Reform Act 2013, which prevents civil claims being made in respect of breaches of duties under health and safety legislation; and
- public awareness / perception.

2.2 Laboratory analysis

The second half of the first presentation focussed on laboratory techniques for asbestos identification. The presentation included:

- methods for bulk analysis of suspected asbestos- containing materials (ACM) including details of the equipment used;
- detection limits and quality control (QC) checks undertaken;
- uncertainty; and
- fibre in air analysis.

[1] The Supreme Court ruling upheld the original High Court ruling (Willmore v Knowsley Metropolitan Borough Council, (2009)) that made the decision that no burden of proof was required beyond showing minimal or "de minimis" exposure and a foreseeable health hazard, even though the defendants could show relatively minor or infrequent ("i.e. fleeting") exposure.

[2] At the time of publication, there is still no published HSE guidance that deals with asbestos in soils. It is expected that a revised draft version of HSG248, incorporating guidance on sampling and analysis of soils for the presence of asbestos will be available for consultation in 2015.

2.2.1 Bulk analysis

There are several stages to bulk analysis comprising:

- initial examination – sample examination by eye to describe the material and product type, see whether visible fibres are present and ascertain layers within heterogeneous products;
- stereoscopic examination – use of a low powered scope (X10-X30) to detect fibres, ascertain fibre colour, texture and tensile strength, lustre, tenacity and elasticity. These properties help identify asbestos since all fibres are flexible, all except chrysotile are elastic and, with the exception of chrysotile and crocidolite, all asbestos has a vitreous lustre. Chrysotile has a silky lustre and crocidolite a metallic lustre. Details of these properties for different asbestos products are recorded in Table 1;
- sample treatment – reagents are used to remove biological and chemical binding agents in order to release fibres from the sample. Heating/burning can be used but it can also affect the fibre integrity;
- polarised light microscopy (PLM) preparation – slides are prepared by placing a drop of appropriate refractive index liquid onto the slide, suspected asbestos fibre is then placed on the slide so it is immersed in the drop and a cover slip is placed over the top. The slide of suspected material can then be analysed and compared to accepted standards issued by the HSE within HSG248 ("the Analysts Guide") (2006); only those matching these standards may be declared as positive for the asbestos type identified. If suspected asbestos fibres are not discovered during the stereoscopic examination, then two slides of the sample material will still need to be analysed using PLM before the sample may be declared as negative for the presence of asbestos;
- PLM analysis – using polarised light, fibres are examined for the following properties: fibre morphology, colour and pleochroism colours, extinction, signs of elongation and birefringence[3]. Laboratory analysts use these properties to positively identify individual types(s) of asbestos within the sample. Table 2 records these properties for the different types of asbestos; and
- dispersion staining – colours and phase contrast are used together with known extinction and elongation properties of the different asbestos types to identify the asbestos type with utmost confidence.

[3] Birefringence is defined by the Collins Concise English Dictionary as the splitting of a ray of unpolarized light into two unequally refracted rays polarized in mutually perpendicular planes.

Table 1: Physical fibre properties observable under a stereoscope (HSG248, 2006)

Colour	Colourless/white	Colourless/white	Colourless/white	White – pale green	White - brown	Deep blue
Texture & appearance	Soft, curly bundles, flexible fibres, cling to tweezers	Straight fibres, bundles, relatively flexible fibres	Small fibres, breaks easily, loose can be very fine with low aspect ratio	Straight fibres	Straight fibres, needle- like	Straight brush-like fibres, barbs when pulled apart
Tensile strength	High	Medium	Low	Low	High	High
Suspected asbestos type	Chrysotile	Anthrophyllite	Tremolite	Actinolite	Amosite	Crocidolite
Required refractive index liquid	1.550	1.605	1.605	1.640	1.670	1.700

Table 2: Summary of asbestos properties recorded using PLM (HSG248, 2006)

Asbestos type	Chrysotile	Anthophyllite	Tremolite	Actinolite	Amosite	Crocidolite
Refractive index liquid	1.550	1.605	1.605	1.640	1.670	1.700
Morphology	Fibrous	Fibrous	Fibrous	Fibrous	Fibrous	Fibrous
Pleochroism-fibre perpendicular	None	None	None	Grey	None	Grey
Pleochroism-fibre parallel	None	None	None	Green	None	Blue
Birefringence	Low	Moderate	Moderate	Moderate	Moderate	Low-anomalous
Extinction	Complete or undulose with curved fibre; parallel	Complete; parallel	Complete; parallel or small angle	Complete; parallel or small angle	Complete; parallel	Complete; parallel

Asbestos type	Chrysotile	Anthophyllite	Tremolite	Actinolite	Amosite	Crocidolite
Sign of elongation	Usually positive (length slow)	Positive (length slow)	Positive (length slow)	Positive (length slow)	Positive (length slow)	Usually negative (length fast)
Dispersion staining-fibre perpendicular	Blue	Blue-red	Blue	Blue-purple	Purple	Blue
Dispersion staining fibre-parallel	Purple	Yellow-orange	Yellow	Yellow-brown	Yellow	Blue
Phase contrast Fibre perpendicular, fibre colour	Pale blue	Blue	Blue	Blue	Blue	Blue
Phase contrast, fibre halo	Orange	Orange-yellow	Orange	Orange	Orange	Red-brown
Phase contrast – fibre parallel, fibre colour	Pale blue	Dark grey	Dark grey	Dark grey	Grey	Blue
Phase contrast – fibre parallel, fibre-fibre halo	Orange	Orange	Yellow	Yellow	Yellow	Red-brown
Refractive index range-na[4]	1.537-1.554	1.596-1.654	1.599-1.620	1.599-1.658	1.670-1.675	1.680-1.692
Refractive index range-ny[5]	1.545-1.557	1.625-1.667	1.622-1.641	1.641-1.677	1.683-1.694	1.683-1.700

[4] Lower range
[5] Upper range

2.2.2 Detection limits and quality control

As with any laboratory technique, quality control is paramount. A single fibre can be found within a few mg of material. For a fibre measuring 100µm x 2µm, this implies a detection limit of 1ppm. Hence, cleanliness of all tools and work area is essential to minimise cross contamination.

Analysts undertaking bulk asbestos identification adhere to quality control schemes. Monthly, a number of samples are analysed by another analyst, with external quality control taking place quarterly through the Asbestos in Materials Scheme (AIMS). The scheme checks the performance of the laboratory as a whole rather than an individual analyst, although it should include checks of each person completing bulk analysis over time.

Internal quality schemes include re-analysis of samples, checks on individual analysts using blind testing of samples of previously known composition, microscope alignment and also examination of refractive index liquids for cross contamination or degradation. Individual analysts should also be audited every 12 months. On a daily basis analyst performance is affected by work quantity. Hence, a limit of 40 homogeneous or 20 heterogeneous samples applies and above these limits additional QC checks are required, e.g. 20% of all additional samples require re-analysis by another analyst. Note that asbestos in soil would count as a heterogeneous sample. Hence, after an analyst has analysed 20 soil samples in any 24 hour period, 20% of any excess samples will need to be rechecked by another suitably qualified analyst.

The United Kingdom Accreditation Service (UKAS), who operate the national independent quality assessment scheme recognised by government, perform yearly visits to laboratories to audit the quality procedures and laboratory personnel, and also advise on continual improvements of performance.

2.2.3 Sources of uncertainty

As with any laboratory method, areas of uncertainty exist and it is important these are understood by people using the laboratory data. Although the analysis methods described in Section 2.2.1 distinguish between asbestos and other common mineral fibres, difficulties can occur. For example, when distinguishing between fine fibres that are <1µm in width, confusion can occur between tremolite, actinolite and anthophyllite, asbestos fibres subjected to heat, and other fibrous materials. The use of a scanning electron microscope or infra-red spectroscopy can provide greater certainty in some instances. However, costs are greater owing to fewer samples being analysed per day. Table 3 notes some typical mineral fibres that are confused with asbestos fibres, particularly when samples are dirty such as those found within soil.

The prolonged effect of temperature in the region of 300-500^{o}C will cause increases in the refractive index, fibre colour, elongation and pleochroism of amosite and crocidolite. Similar changes are noted with chrysotile after being heated to approximately 600^{o}C, with fibres ultimately changing to a pale brown colour.

Uncertainty is also associated with the stage of analysis. For example phase contrast microscopy (PCM) analysis simply allows the counting of visible fibres that fall into a particular category; longer than 5 µm, average width <1µm, length to width ratio >3:1. Spider webs and man-made fibres can fall into this category giving false positives.

Table 3: Fibre confusion and remedies

Fibres	Remedy
Polyethylene (chrysotile substitute)	De-saturate the dispersion colour- the fibre subsequently has a higher birefringence than chrysotile. If polyethylene is suspected it can be burnt off.
Leather swarf fibres have low birefringence and dispersion staining similar to chrysotile	At magnification up to x100, leather swarf has a similar morphology to that of chrysotile and uniform fibrils. However, chrysotile fibrils are not visible at this magnification and if leather swarf fibres are suspected the sample can be ashed at 400^{o}C
Macerated aramid appears similar to chrysotile	Can be easily distinguished by high birefringence and high refractive index (1.640-2.400)
Spider webs & natural organic fibres have refractive index close to chrysotile & also similar dispersion staining	If organic fibres are suspected these can be ashed at 400^{o}C
Kinked talc fibres can have similar morphology to chrysotile	Talc has a higher refractive index (1.539-1.550 and 1.580-1.600) and consequently will have a blue-yellow dispersion colour

2.2.4 Asbestos in air sampling

Asbestos in air sampling is now undertaken on many remediation projects to demonstrate the works are compliant with CAR 2012, i.e. exposure to site personnel is being prevented and that the works are not spreading asbestos in so far as is reasonably practicable.

Air sampling uses a negative pressure pump to draw air through a cellulose acetate filter. The filter is dissolved onto a slide using hot acetone vapour, leaving airborne fibres on the slide. The fibres are fixed using chemicals and a cover slip placed over the slide. Analysis using PCM magnification to approximately x500 allows fibres down to 0.25µm to be visible and counted.

Air sampling detection limits vary depending upon the volume of air sampled and the number of graticules[6] counted. The clearance indicator threshold[7] of 0.01 fibres/ml of air is used by many asbestos surveyors as the detection limit. This detection limit necessitates a sample with a minimum volume of 480 litres air and the counting of 200 graticules. Lower detection limits require longer sampling and analysis times and hence incur additional costs per sample result. For example, a detection limit of 0.001fibres/ml air requires:

- air volume of 1600 litres with 600 graticules counted;
- air volume of 2000 litres with 480 graticules counted; or
- air volume of 3000 litres with 320 graticules counted.

In a similar way to bulk analysis there is a limit of to the number of graticules an analyst can count without re-analysis by another analyst being required. This limit is 2400 graticules in any 24 hour period.

[6] A graticule is a calibrated disc placed in a microscope eyepiece for asbestos fibre counting

[7] The clearance indicator threshold is used in asbestos removal works as the level at which reoccupation of the room is permitted without personal protective equipment (HSG 248, 2006)

2.3 Legal aspects / case law and how this might influence risk assessment

Four case law examples were discussed where people have developed mesothelioma. These are:

- Fairchild v Glenhaven Funeral Services Ltd (2002);
- Sienkiewicz v Greif UK Ltd, Knowsley MBC v Wilmore (2011);
- Williams v Birmingham University (2011); and
- Garner v Salford City Council and McGuiness and Co (2013).

In each case there must be a material risk (not de minimis, trivial or fanciful) proved on the balance of probabilities. In addition, for negligence to have occurred, there must have been a duty on the Defendant owed to the Claimant and a breach of this duty must have occurred, i.e. the Defendant fell short of what was expected.

Background exposure should be considered to ascertain whether a material risk has occurred. Background exposure examples are:

- <500 fibres/m^3 in buildings which contain asbestos in a good condition; and
- <1 to 100 fibres/m^3 outdoors.

Consideration then needs to be made of whether a material risk is present. Although this method negates the exposure to 1 fibre being material risk, questions remain as to what does constitute material risk. For example, is material risk more than background, double background or some other number?

Some example photographs were shown to illustrate a discussion of whether a breach of duty occurred historically, for example when used in fire protective baby suits, when used to simulate snow on film sets in the 1930s, or cutting through pipes containing asbestos in the late 1960s. It was highlighted that the breach of duty depends upon the standards that were expected at that time. There are 'Safe Working with Asbestos' posters, possibly dating from the 1970s, that recognise asbestos insulation board should be moistened before cutting and that cutting of asbestos cement should be undertaken in a controlled manner with dust collected. In 2013 the removal of vinyl floor tiles containing asbestos might involve moistening the tile, whilst wearing white suit and respiratory protection. The question was posed as to whether undertaking this same task without any protection in the late 1960s would have been a material breach of duty.

Under CAR 2012 people must be considered throughout brownfield development, for example risks to investigation and surveying teams, remediation workers, site neighbours and future occupants.

It is necessary to be clear in what the risk assessment seeks to achieve, for example, risk assessment or remediation to de minimis/trivial exposure, as low as reasonably practicable (ALARP) or compliance with CAR 2012. Whilst ALARP might aim to achieve background concentrations, consideration is required as to whether or not this is realistic and what the background concentration might be at specific locations.

Regulation 5 requires 'an employer shall not undertake work in demolition, maintenance, or any other work which exposes or is liable to expose his employees to asbestos…….unless either a suitable and sufficient assessment has been carried out or its presence is assumed ……..'

Regulation 6 requires the risk assessor to consider what the outcome of the assessment undertaken to satisfy Regulation 5 comprises. For example, in considering the risk the assessment should consider the site history, whether asbestos is likely to be extensive, its form and whether it is buried or at the surface. This assessment enables the appropriate working practices to be adopted.

Under CAR 2012 exposure and spread must be prevented, as discussed within Section 1. From this arises the requirement to consider adjacent users and the environment in the risk assessment in addition to on-site workers. Where exposure and spread cannot be prevented under Regulation 11, it is necessary to minimise the exposure and spread. To minimise spread, in line with Regulation 16, it is necessary to consider how the asbestos might be spread, e.g. air, personnel, equipment and waste, and then adopt suitable mitigation measures. These might include decontamination units, dampening of soil, disposal of personal protective equipment (PPE) appropriately, vehicle haulage routes and inspections.

A number of questions were raised around what is really meant when Regulation 16 notes that spread must be minimised. These included:

What is an acceptable amount of spreading?

Does the revised HSG248 ("The Analysts Guide") proposal (HSE, 2006) of <0.001fibres/ml for leak testing, which is double the background, meet the definition for as low as reasonably practicable?

How do we as an industry demonstrate that we are complying with Regulation 16; for instance what analytical detection limit should we require for perimeter monitoring and how should we deal with asbestos that might escape through vehicle tracking and waste receptacles?

Equally Regulation 17 requires the site to be kept "clean". This raises the question of "How clean is clean?", given that looking for an asbestos fibre within soil can be likened to looking for a needle in a haystack. Is it reasonable to assume that the clearance indicator threshold of <0.01fibres/ml, which is currently utilised, can be taken to mean "safe" for occupation?

In summary, all exposures to asbestos should be prevented or minimised, i.e. kept as low as reasonably practicable. This requires risk-based proportionate decision making during brownfield development. Whilst this may not eliminate the risk it will demonstrate compliance with CAR 2012, which is the compliance test that people need to be able to demonstrate adherence to in court.

2.4 Remediation and re-use

The key drivers to be considered in determining whether soil containing asbestos is suitable for re-use include: site proposals/sensitivity of proposed end use and site setting, re-use criteria, ability to segregate material, nature of asbestos present (fibres/cement/board), and client, regulatory and other stakeholder issues pertaining to ACM.

A series of case studies were presented demonstrating how these issues were overcome during Hydrock projects. These case studies included practical advice as to how UK legislation and guidance such as CAR 2012 and CL:AIRE Code of Practice for re-use of materials (CL:AIRE, 2011) were used in the remediation and development process, e.g. controlled and uncontrolled areas, soil segregation, notification to HSE and the use of baseline boundary and personal air monitoring data to support risk assessments.

2.5 Asbestos: review of toxicology & options for human health risk assessment

Asbestos is a trade name for a group of mineral silicates. The two main types of asbestos fibres are:

- amphiboles, comprising 5 main types of asbestos: amosite (brown asbestos), crocidolite (blue asbestos), tremolite, actinolite and anthophyllite
- serpentine asbestos, which is also known as chrysotile or white asbestos.

Chrysotile asbestos is formed as rolled cylindrical sheets which can be readily degraded in the body. The amphiboles exist as twin sheets formed into solid cylinders which are much more resistant to degradation in the body than chrysotile. The amphiboles tend to break up into smaller, thinner fibres rather than into fragments.

Asbestos containing materials are found commonly in buildings constructed up to the year 2000, including as floor and ceiling tiles, pipe lagging, insulating board, cement roofing materials, protective coatings and textured decorations. It was also widely used as brake linings. This has inevitably led to asbestos fibres being liberated into the air, e.g. from damaged and/or weathered surfaces, and there is generally a small amount of airborne asbestos present in the urban environment (see Table 4 below). The ambient background levels in urban air mean that over a lifetime we might inhale over 50 million fibres without any discernible or known asbestos exposure.

Table 4: Airborne levels of asbestos

Air concentration (Fibres/m^3)	Equivalent air concentration (Fibres/ml)	Meaning
100,000	0.1	HSE 4hr control limit (Control of Asbestos Regulations 2012)
10,000	0.01	HSE 'Clearance Indicator Level'
1000	0.001	WHO Air Quality Guideline (electron microscopy)
100 - 1000	0.001 - 0.0001	Ambient background levels

2.5.1 Health effects

The main non-carcinogenic health effects in humans associated with exposure to asbestos are diffuse pleural thickening (DPT), pleural plaques, asbestosis (fibrosis) and decrease in lung function (HPA, 2007).

In respect of carcinogenic effects, a recent International Agency for Research on Cancer (IARC) review (IARC 2012) has concluded that "*all forms of asbestos (chrysotile, crocidolite, amosite, tremolite, actinolite and anthophyllite) are carcinogenic to humans (Group 1)*" and that "*asbestos causes mesothelioma and cancer of the lung, larynx, and ovary*" In addition IARC concluded that *"positive associations have been observed between exposure to all forms of asbestos and cancer of the pharynx, stomach, and colorectum"*

The main factors determining the health effects of asbestos fibres are its form, type, size, surface chemistry, biopersistence and solubility in body fluids. Fibres need to be "*sufficiently long, thin and durable*" to exert pathogenic effects and this means meeting the World Health Organization (WHO) fibre definition, i.e. an aspect ratio≥ 3:1 ; length ≥ 5μm and diameter ≤3μm. Generally, the pathogenic potency increases with fibre length, but the smaller fibres still have a role to play in determining health effects. Other factors also play a part including whether or not trace contaminants are present, and the ability to translocate through body tissues.

2.5.2 Possible mechanisms of action

When inhaled asbestos fibres can be deposited in the lung, with the site of deposition dependent upon the aerodynamic diameter of the fibres, their geometry and density. Fibres meeting the WHO criteria are more likely to reach the alveoli. From there they can be translocated to the pleural mesothelium – the pathway is unknown but movement through the lymphatic system has been shown to occur with amosite in rats.

Usually, particulate matter is cleared from the deeper areas of the lung by being engulfed by macrophages and then removed from the respiratory tract by mucociliary clearance. However, some asbestos fibres are longer than the diameter of macrophages (14-25μm) and are not readily engulfed by them. This leads to a process named as "frustrated phagocytosis" which can result in macrophage death and allows fibres (in particular the amphiboles) to persist longer in the lung and allows them to be translocated to other tissues.

The recent IARC review (IARC, 2012) has postulated mechanisms for the induction of cancer by asbestos. These originate from "frustrated phagocytosis" resulting in either

- impaired clearance and translocation of fibres; and/or,
- "inflammasome activation" caused by oxidants and resulting in the release of IL-1β followed by inflammatory cell recruitment and activation.

Subsequently the following series of events is postulated:

- release of reactive oxygen species, reactive nitrogen species, cytokines, chemokines and growth factors;
- DNA damage and apoptosis;
- effects on cellular signalling pathways, leading to cell proliferation, and resulting in fibrosis; and
- impaired DNA repair, chromosomal and epigenetic alterations, oncogene activation etc., resulting eventually in cancer.

2.5.3 Health evidence – epidemiological studies

Human health risk assessment for asbestos is derived from epidemiological assessment of cohorts of occupationally exposed workers in a variety of activities, but mainly either during the mining of asbestos or involvement in its processing into useable materials. There are many scientific shortcomings in the quality of the evidence upon which dose-response relationships for the different forms of asbestos have been derived. Among these are:

- fibre measurement methods – was the right thing being measured? (i.e. inhaled asbestos fibres of the correct dimensions);
- exposure estimates – are assumptions about which types of asbestos were present in the working environment correct; are assumptions about work exposure levels and exposure durations accurate?;
- insufficient information on smoking habits and other confounders; and

- cancer ascertainment – as this comes mainly from death certificate information, there could be under-reporting for the existence of mesothelioma.

Some of the key models and risk estimates are listed below:

- Hodgson and Darnton (2000) on behalf of the Health and Safety Executive (HSE);
- Berman and Crump (2008) on behalf of the United States Environmental Protection Agency (USEPA);
- Health Council of Netherlands (2010) on behalf of the Dutch Ministry of Health;
- WHO Air Quality Guidelines for Europe (WHO 2000); and
- USEPA IRIS Database RfC and Slope Factors (USEPA 1993).

The Hodgson and Darnton model (2000) is the one favoured in the UK. The authors undertook separate analyses for lung and mesothelial cancer risk and associated these with cumulative fibre exposure estimates. The exposure metric used is the average fibre concentration in air multiplied by the number of years of exposure and expressed as "(fibres/ml).yr". This metric is an indicator of the total number of fibres inhaled at work over the relevant exposure period. Non-linear models were used to get best fit between cancer risk and the exposure metric and these identified a greater slope at very low exposure levels (fibres/ml.yr) than at higher levels. In their risk model, exposures were assumed to commence at age 30, continue for five years and the risk was assessed to age 80.

A key finding from this analysis was the relative potencies for mesothelioma for the different forms of asbestos was in the ratio 1:100:500 for chrysotile vs. amosite vs. crocidolite for occupational exposures. This ratio does not hold for very low environmental exposures; where the ratio approximates 1:20:100.

However, the risk estimates were derived from a small number of studies. The datasets were as follows: crocidolite - three cohorts; amosite - two cohorts; chrysotile - three selected cohorts.

The Netherlands analysis concluded that the available data only allowed analysis of exposures to chrysotile alone and analysis of exposures to mixed fibres (chrysotile and amosite). Of the 30 epidemiological studies reviewed, only six studies (two for mesothelioma and four for lung cancer) met the quality criteria standards set by the authors. The newer risk estimates were 40 times greater than those calculated previously in the Netherlands and were also greater than estimations made by Hodgson and Darnton (2000) and by Berman and Crump (2008), particularly in respect of chrysotile risk. The potency estimate was 1:50 for chrysotile vs. amphibole.

A comparison of risk estimates from these various studies, expressed as an air concentration of chrysotile resulting in a 1 in 100,000 excess lifetime mesothelioma risk is presented in Table 5. A wide range of risk estimates is apparent.

Table 5: Chrysotile and mesothelioma; 1 in 100,000 excess lifetime cancer risk

Organisation	Concentration (Fibres/ml)	Comments
IRIS USEPA (1993)	0.00004	Derived from Inhalation Unit Risk of 0.23 per fibres/ml for ALL fibre types
Dutch Health Council (2010)	0.0003	Mid way between the published MTR[8] (10^{-4} risk) and VR[9] (10^{-6} risk) values
WHO Air Quality Guideline (2000)	0.001	10^{-5} to 10^{-4} risk for mesothelioma and 10^{-6} to 10^{-5} for lung cancer risk in adults (30% smokers) - all fibre types
Hodgson & Darnton (2000)	0.001	Calculated from a cumulative exposure of 0.1fibres/ml.yr (WATCH 1 in 100,000 risk estimate) assuming 70 years exposure and adjusted for early life exposure
Berman & Crump (2008)	0.01	Calculated from 1 in 100,000 risk estimate of 1fibre/ml.yr assuming 70 years exposure adjusted for early life exposures

2.5.4 Environmental exposures

The risk model published by Hodgson and Darnton (2000) allows an estimate of cancer risk to be made at exposure levels which are lower than were experienced in the epidemiological studies where exposures were in the range of 100 to 1000 fibres/ml.yr. The Hodgson and Darnton risk estimates, extrapolated down to 0.1fibres/ml.yr are presented in Table 6 (after WATCH, 2011). It should be born in mind that these lower estimates are highly uncertain as these cumulative exposures are up to 100,000 times lower than those in the observable data range, from which the original risk estimates were obtained.

Table 6: Hodgson and Darnton risk estimates - mesothelioma risk per 100,000 (after WATCH 2011)

Fibres/ml.yr (best max/min**)	Crocidolite	Amosite	Chrysotile
10	5600 (3200-8400)	2300 (960-4000)	56 (23-340)
1	750 (250-1600)	180 (35-570)	6 (1-45)
0.1	120 (24-360)	21 (2-100)	1 (0.1-7)

**Risk calculated for five years exposure from age 30, calculated to age 80.

[8] Maximal toelaatbaar risiconiveau (Maximum Permissible Risk)
[9] Verwaarloosbaar risiconiveau (Negligible Risk Level)

Cumulative public exposures are likely to be less than 0.01fibres/ml.yr, These could arise from exposure to urban background levels of say, 0.0001fibres/ml which may be experienced for several decades. Alternatively, an exposure of 0.001fibres/ml.yr could arise from short-term elevated exposures, as might arise from a contamination incident where 0.1fibres/ml may be experienced for several hours over possibly one to a few days (equivalent to less than 0.01years). There is considerable uncertainty in the risk estimates as can be seen in the wider ranges given in brackets at the lower exposure levels in Table 6.

Some national authorities consider an excess lifetime cancer risk of 1 in 100,000 to be broadly acceptable, and this level of risk would equate to a level of 0.1fibres/ml.yr for chrysotile. Risks from the amphiboles at this exposure level may be substantially higher.

The HSE's advisory body the Working Group on Action to Control Chemicals (WATCH) reviewed the applicability of utilising Hodgson and Darnton risk estimates at a lower level than published in Table 6, and concluded (WATCH, 2011):

"…..the scientific judgement of WATCH is that there are risks of asbestos-induced cancer arising from work-related cumulative exposures below 0.1 fibres/ml.years.
…
The risk will be lower, the lower the exposure, but "safe" thresholds are not identifiable. ….
Where potential exposures to amphiboles, particularly crocidolite, are below 0.1 fibres/ml.years (for example, 0.01 fibres/ml.years), the available scientific evidence suggests no basis for complacency, but rather a basis for active risk management… "

2.5.6 Exposures in childhood

The risk model for mesothelioma (but not for lung cancer) is not simply based on cumulative exposure (fibres/ml.yr) but is also dependent on duration since first exposure. The risk calculations in Table 6 assume a 50 year period since first exposure for adults. Children exposed to asbestos have potentially longer to develop mesothelioma (perhaps an 80 year period since first exposure) and so are at greater risk for the same level of fibre exposure.

The important aspect of possible increased vulnerability of children has been considered by the UK Government's Advisory Committee on Carcinogenicity (CoC, 2013) who concluded:

"From the available data, it is not possible to say that children are intrinsically more susceptible to asbestos-related injury.

However, it is well recognised by this Committee that, due to the increased life expectancy of children compared to adults, there is an increased lifetime risk of mesothelioma as a result of the long latency period of the disease.

In reaching our conclusion and taking into consideration that there are a number of uncertainties and data gaps, we conclude that exposure of children to asbestos is likely to render them more vulnerable to developing mesothelioma than exposure of adults to an equivalent asbestos dose" (CoC 2013).

Table 7 provides some relative risk calculations for children compared to adults based on increased duration of exposure. Compared to an adult first exposed at age 30, a child with the same exposure, first exposed at age 5, carries a 5.3 times greater risk of mesothelioma. Risk estimates which involve early life exposures need to be multiplied by adjustment factors such as those given in Table 7 (abstracted from data provided in Howie, 2012).

Table 7 Age adjustment factors for mesothelioma risk dependent on the age at which exposure commences (Howie, 2012)

Age at start of exposure	Risk persisting until age 80
0	7.0
5	5.3
10	4.0
15	3.0
20	2.1
25	1.5
30	**1**
40	0.4

(Note: these factors make no adjustment for possible greater susceptibility of the young)

Moreover, in addition to the greater risk from an equivalent adult exposure, children might also be more susceptible to early age exposures to asbestos, potentially because of impaired clearance mechanisms, under-developed immune systems, greater exposures relative to body weight and presence of actively growing tissues etc.

This is an important factor that needs to be considered in public health risk assessments of environmental asbestos exposure.

2.5.7 A risk assessment approach to low level environmental exposures

The Hodgson and Darnton risk model and the caveats described by WATCH (2011) and CoC (2012) provide an approach which might be useful for evaluating low level asbestos exposures (e.g. prolonged low exposure from asbestos contaminated soils, short-term public exposure from asbestos fall-out as a result of a fire or from demolition work and discovery of asbestos in air at school premises etc.)

The approach first requires an assessment of:

- cumulative exposure in terms of fibres/ml.yr. In this context a year is taken to be 1920 hours (this is the duration of a working year on which the epidemiological evidence is based), not 8760 hours which is the number of hours in a year (365 days x 24 hours/day)
- once a cumulative exposure in terms of fibres/ml.yr is calculated, an adjustment may need to be made for early life exposures if relevant
- the HSE WATCH table (Table 6) can be consulted to give an indication of risk of the type of fibre involved in the assessment

If exposures are to chrysotile only and are well below 0.1fibres/ml.yr then risks are possibly so small as not to be significant. Exposures to other types of asbestos, including mixtures, greater than 0.1fibres/ml.yr may indicate that a more detailed risk assessment and/or mitigation measures may be required.

However, the following caveats must be considered and expressed in any risk assessment using this approach:

- be aware of the large uncertainties at very low fibres/ml.yr cumulative exposures risk estimates;

- WATCH risk estimates should not be taken as absolute measures of risk, but they may be useful for comparisons and for prioritisation of concerns as an aid to risk management; and
- even if the risks are considered to be very low, action may still need to be taken to ensure that any exposure is reduced to "as low as reasonably practicable", as there is no threshold established for asbestos exposures.

2.5.8 Summary

The health effects of asbestos are well documented and factors influencing the health effects are reasonably well understood, though the mechanism by which these effects arise is largely unknown. Risk estimates and dose-response relationships have been established from studies of highly exposed workers for induction of both lung cancer and mesothelioma. There is generally considered to be no threshold for the carcinogenic effects of all forms of asbestos.

With the absence of a threshold, public health risks may be present from low level environmental asbestos exposures. Models indicate that level of cancer risk is directly linked to the cumulative fibre exposure, and additionally for mesothelioma risk, also influenced by the age at first exposure.

Extrapolations from the Hodgson and Darnton (2000) risk estimates can allow an estimate of risk to be made of the environmental exposure in question. Placing these exposures into some context and using the risk estimates can aid the public communication, prioritisation and management in these incidents. The uncertainties underlying these risk estimates always need to be clearly identified.

2.6 Approaches to exposure assessment

This presentation explored the possible approaches to human exposure assessment for asbestos in soil. In particular it focussed on existing approaches for both asbestos and dust, and considered whether a large part of asbestos exposure assessment can be achieved using existing and more familiar approaches to dust.

The key question for exposure modelling is how much asbestos will become airborne. To understand that we need to understand the source – for example, whether there are dispersed asbestos fibres in soil and/or whether there are discrete fragments of ACM. We also need to understand the pathways by which airborne asbestos fibres might be generated – for example, wind erosion of the ground surface or mechanical disturbance of the ground.

In terms of possible assessment approaches, options include adopting:

- pure qualitative approaches;
- existing dust models;
- empirical data relationships for asbestos in soil;
- laboratory methods;
- site-specific field testing (Activity-Based Sampling or ABS); or
- a combination of any of the above.

Qualitative methods should focus on the ranking of the exposure scenario according to the airborne fibre generation potential, in addition to the exposure characteristics of the receptor (sensitivity, frequency and duration of exposure etc.). There are a number of existing algorithms for qualitative risk ranking. These include:

- HSG227 (HSE, 2002) and HSG264 (HSE, 2012 (b)) methods for assessing exposure in buildings;
- a qualitative approach developed by the Dutch research agency RIVM10 (Swartjes, Tromp and Wezenbeek, 2003); and
- a qualitative approach for dust developed by the Institute of Air Quality Management (IAQM, 2012).

There are distinct differences between these existing algorithms, but there remains the potential to select or combine different aspects of each algorithm to suit the specific exposure scenario being assessed.

The HSE algorithms focus on a material assessment – the ease with which fibres might be released – and a priority assessment – the likelihood of ACM disturbance. Fibre release is assessed on the basis of asbestos product type, extent of deterioration or damage, surface treatment and asbestos type. The likelihood of disturbance is assessed on the basis of the activity type (and hence degree of disturbance), the location and accessibility of the asbestos, and the frequency of exposure.

The RIVM algorithm is based on empirical field measurements and provides a qualitative estimate of possible asbestos fibre in air concentrations based on soil content and type of activity. A simple table is provided equating soil concentration and activity with differing ranges of possible airborne fibre concentrations.

The IAQM algorithm focusses on dust, not asbestos, from construction sites. It provides a flowchart (Figure 1) incorporating four assessment steps. The first step considers the distance to the receptor. If the receptor is a sufficient distance away the assessment process can stop. If not, an assessment of the risk of dust effects using the scale and nature of the works is made (Step 2), focussing on the dust emission potential and the proximity of the receptor(s). Steps 3 and 4 determine and assess the effectiveness of activity mitigation to control the adverse effects from the anticipated dust generation.

[10] Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health and the Environment)

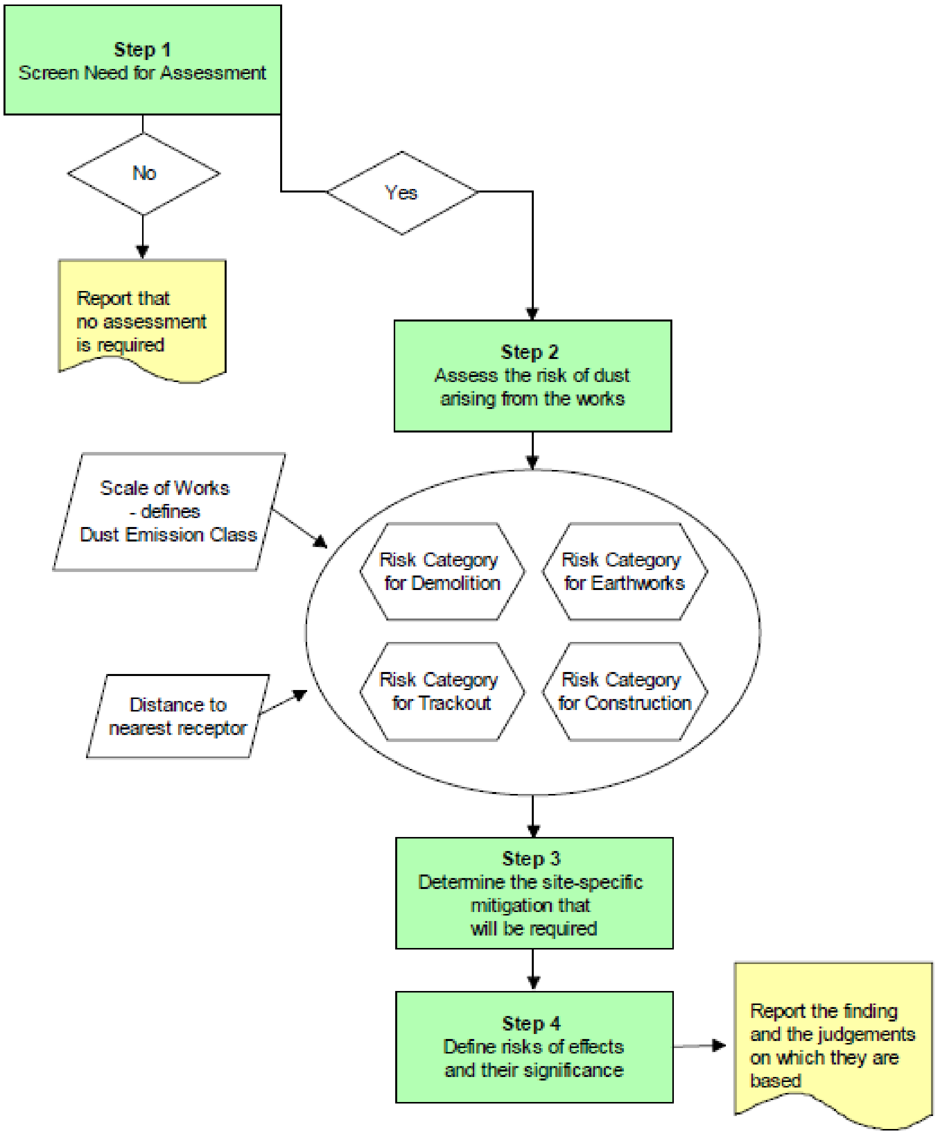

Figure 1: IAQM (2012) flowchart of steps to perform a dust assessment

Dust models can be used to calibrate qualitative scoring algorithms or can be used to provide generic and/or site-specific dust generation estimates that can then be used to provide information on potential asbestos fibre concentrations in air. One of the key questions is whether dust models are relevant to asbestos fibres. Do asbestos fibres behave like dust particles when it comes to airborne generation and dispersion?

Asbestos fibre sizes do not conform to typical dust particles in terms of size, shape or weight. Asbestos fibres are likely to be lighter, have greater aerodynamic resistance, potentially entrain in air more easily due to a lower threshold frictional velocity, and be carried greater distances in air. However, dust models do have a capacity to inform the relative fibre generation and dispersal risk from a particular activity, and there is also the potential to use correction factors for the dust estimates to apply to asbestos fibres.

In terms of available information for providing information on the relative dust generation capacity of different activities and scenarios, a number of good sources are available. These include:

- published generic dust levels for indoor and outdoor air and man-made disturbances based on empirical data;
- established dust models such as those developed by Cowherd et al. (1985) for wind erosion of surface soil, the collaborative Advanced REACH Tool (ART) model used to assist in REACH[11] assessments (Fransman et. al, 2013), and the USEPA AP42 dust emission factors; and
- existing air quality limits for dust, which if monitored for and complied with, for various activities, inform on the residual dust emission and associated risk with standard control measures applied.

Empirical studies provide a direct source of information on asbestos fibre release from soil, but also provide a means by which dust models can potentially be calibrated/adjusted for asbestos fibre release. There are two key published studies on asbestos fibre release from soil; that by Addison et al. in 1988, and that by RIVM in 2003 (Swartjes, Tromp and Wezenbeek, (2003) further published by Swartjes and Tromp in 2008).

The Addison et al. work, published by the Institute of Occupational Medicine (IOM) in 1988, establishes a series of relationships between asbestos fibre concentrations in air and soil which are based on experiments using two different types of dust boxes. The core data from those experiments is reproduced in Figure 2 below derived from the use of the IOM dust box. Of note is the data circled in red on which the Inter-Departmental Committee on the Redevelopment of Contaminated Land (ICRCL) guidance 64/85 published in 1990 was based. In terms of what the graph tells us; firstly the airborne dust levels generated varied slightly (between approximately 3 and 12 mg/m^3), and the respirable dust concentrations were slightly lower than the total dust concentrations (as might be expected). Secondly, the airborne asbestos fibre concentrations increased with soil concentration, but not linearly (note logarithmic axis). Thirdly, the measured airborne asbestos concentrations varied over approximately an order of magnitude at each tested soil concentration. If the data is split for the three different soil types, as shown in Figure 3, it can be seen that that order of magnitude variability lessens somewhat; as it also does if the three different fibre types are split out (see Figure 4).

[11] REACH is a European Union concerning the Registration, Evaluation, Authorisation & restriction of Chemicals.

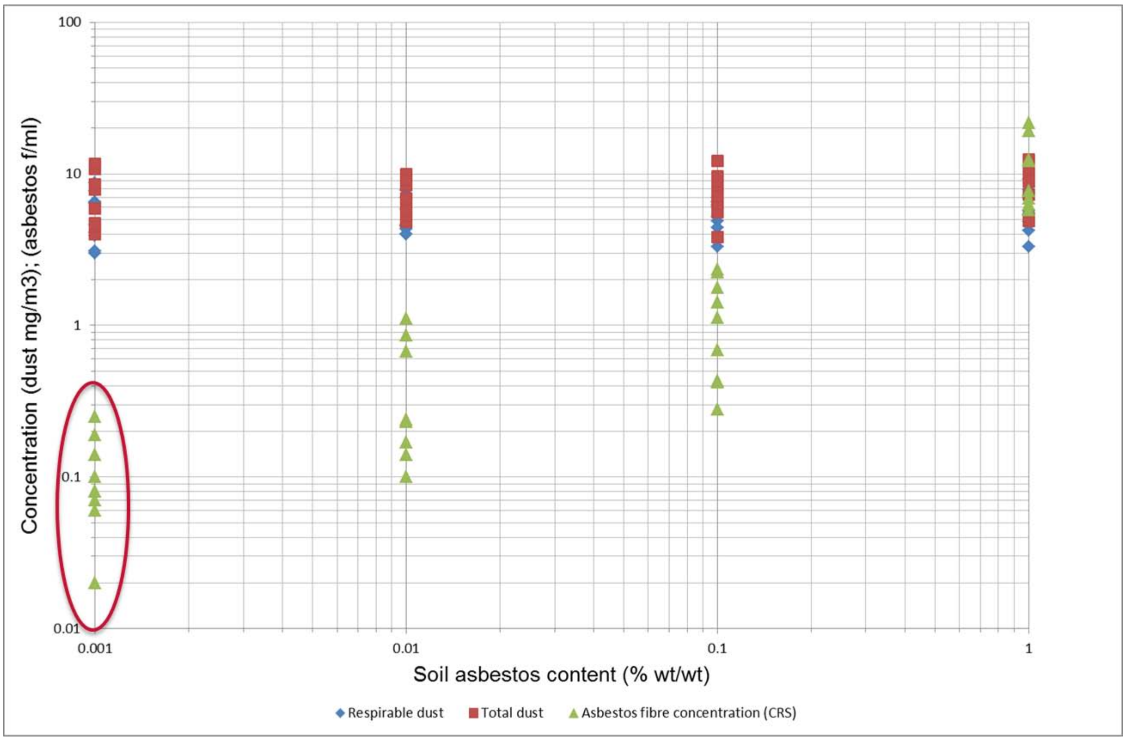

Figure 2: Addison et al. data

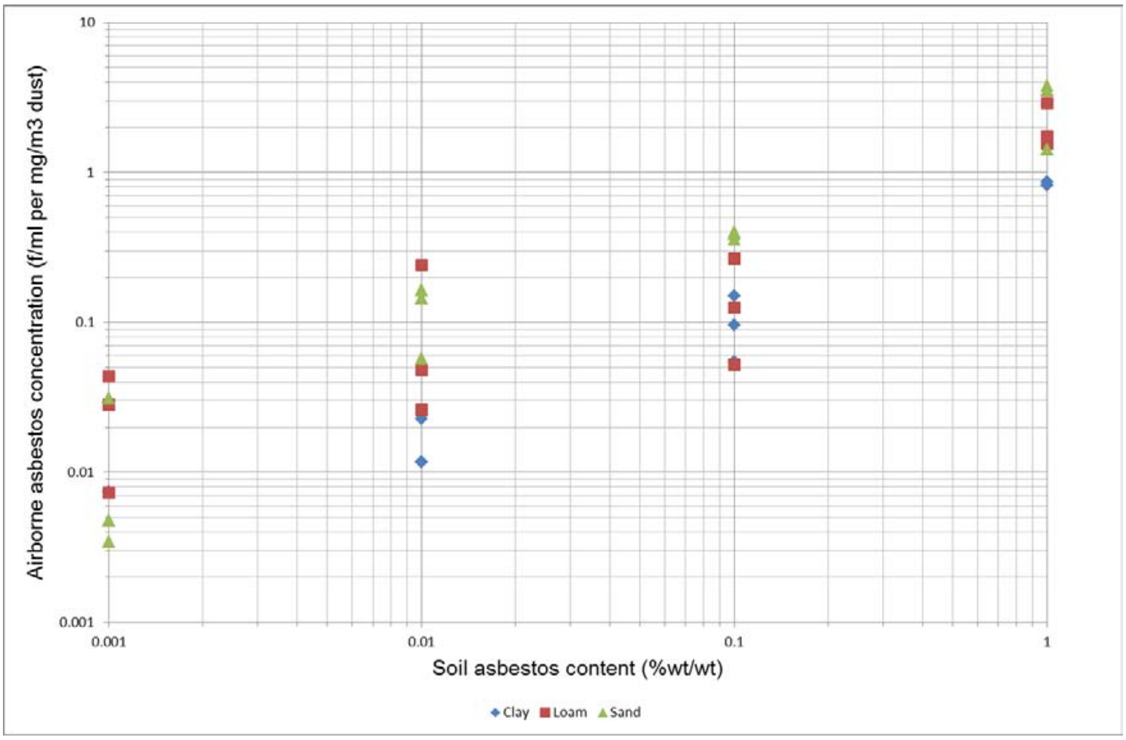

Figure 3: Addison et al. data split for soil type

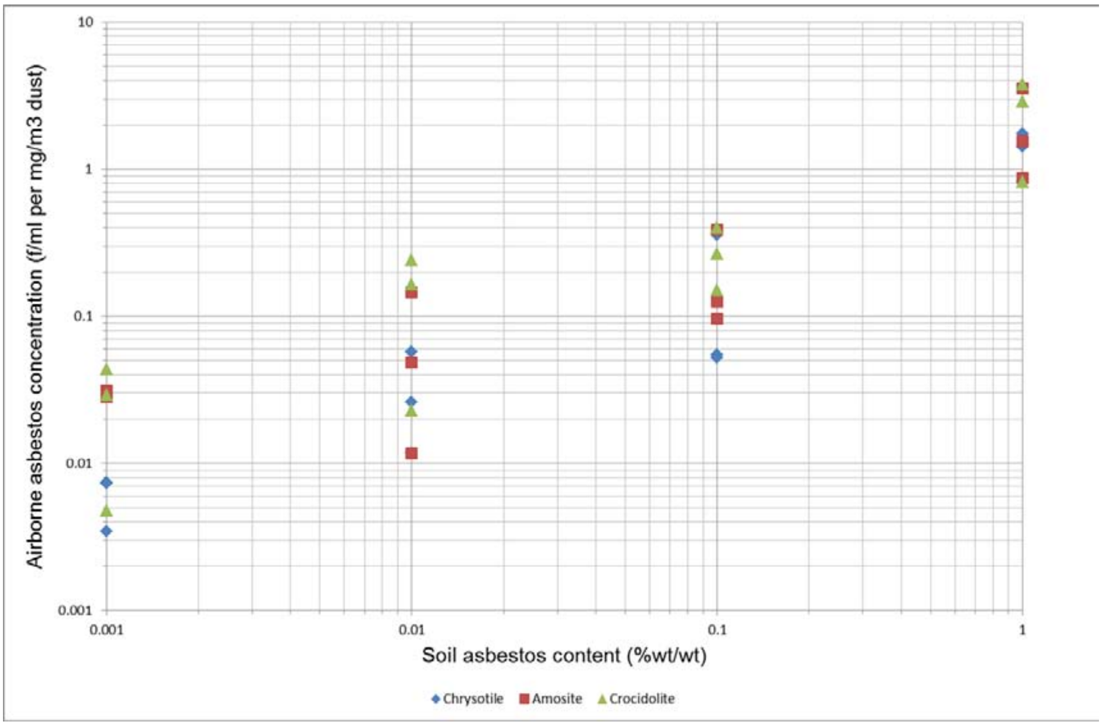

Figure 4: Addison et al. data split for fibre type

The variability in the Addison et al. data can be seen in Figure 5 below which shows the correlation between dust level and asbestos fibre concentration for the different soil concentrations tested. It is therefore clear that the adoption of an empirical relationship has to recognise the precision as well as the accuracy of that relationship.

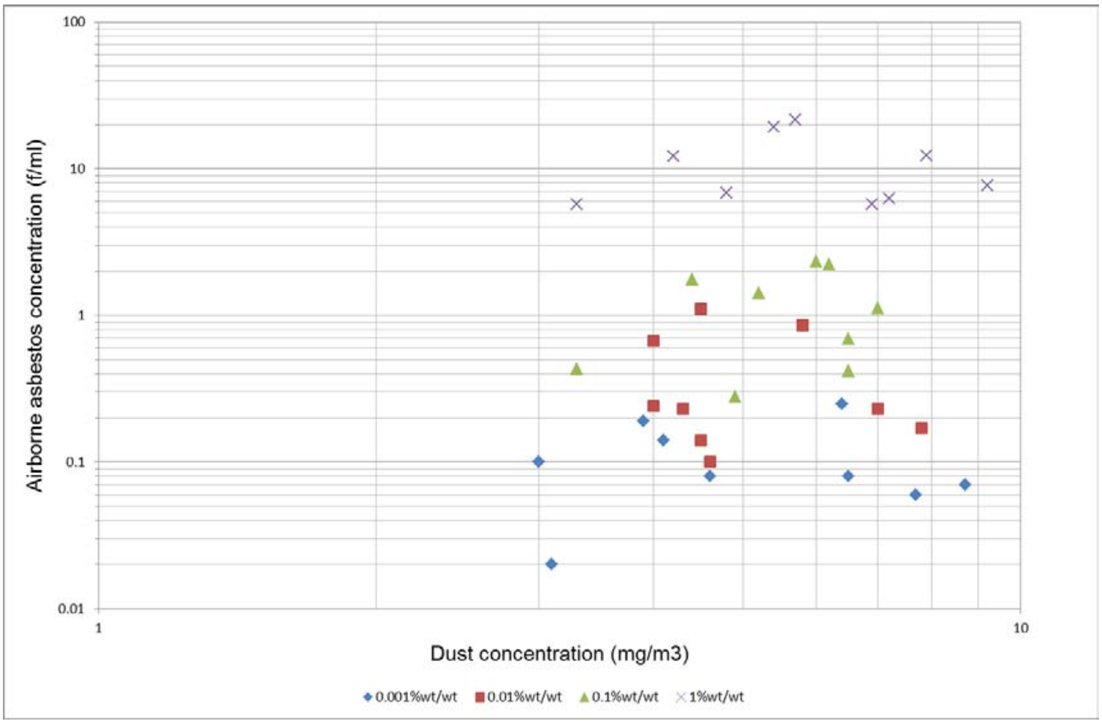

Figure 5: Addison et al. data airborne dust and fibre correlation

Importantly, the Addison et al. study also demonstrated the importance of soil moisture to fibre release. Using a different (GCT) dust box, the authors concluded that a 10-fold reduction in fibre release was observed at a soil moisture level of 5-10%, compared to the fibre release for dry soil, and further decrease in fibre release at higher moisture contents.

The second major empirical study is that reported by RIVM (Swartjes, Tromp and Wezenbeek, 2003). This study focuses on a meta-analysis of a large number of principally field measurements of airborne asbestos fibre concentrations. These resulted from a variety of activities being undertaken at sites where asbestos was present in the ground.

RIVM's study differentiated between bound and non-bound asbestos, and also evaluated the influence of soil moisture.

What is difficult to establish from the RIVM study are the environmental conditions under which the field activities were monitored. The assumption is that a large number of the measurements relate to damp conditions, which, for the majority of the UK, might represent a significant proportion of field conditions throughout a year.

In total RIVM compiled 350 field measurements for bound asbestos, and 200 measurements for unbound asbestos. The graphs from the RIVM publication indicate that for bound asbestos no dispersed fibres in air were detected except on one occasion relating to vehicle traffic on an unmetalled road with significant asbestos cement present in the road surface. Detection limits in air varied from approximately 100-1000 fibres/m^3. For unbound asbestos, dispersed fibres in air were detected from asbestos free fibre concentrations in soil >10mg/kg.

The data on which the Dutch Intervention Values are based comprise 85 positive (i.e. > method reporting limit) results for unbound asbestos in soil. This dataset includes a small number of laboratory simulations carried out by TNO in addition to a larger number of outdoor field measurements. The following points can be taken from the data presented by RIVM:

- airborne asbestos concentrations are approximately an order of magnitude higher in the laboratory simulations compared to the field measurements;
- field measurements vary by up to an order of magnitude for similar soil concentrations;
- the relationship between soil moisture and airborne fibre release appears to be exponential;
- the greatest influence of soil moisture appears to be associated with sandy soils. It is assumed that sandy soils provide the lowest level of fibre retention; and
- there is a factor of 100 decrease in airborne fibre release when soil moisture is increased from zero to 5-10%.

Figure 6 below provides a simplified comparison of the Addison et al. data (using CRS counting method) with the RIVM data (simulated and practical measurements). What can be seen is that the airborne fibre generation was much higher in the Addison et al. experiments. The hypothesis for the difference in the fibre concentrations reported for the various studies is that the fibre levels reflect the different dust levels generated by the simulations and field activities being measured. The RIVM report does not provide the corresponding dust levels for the reported asbestos in air concentrations, but, based on the qualitative information provided, it is assumed that the dust levels generated in the simulations were lower than those generated by Addison et al. Similarly the typically damp conditions under which the field measurements were taken is also likely to have resulted in lower dust levels being generated, and this is reflected in the differing asbestos in air concentrations reported in the studies.

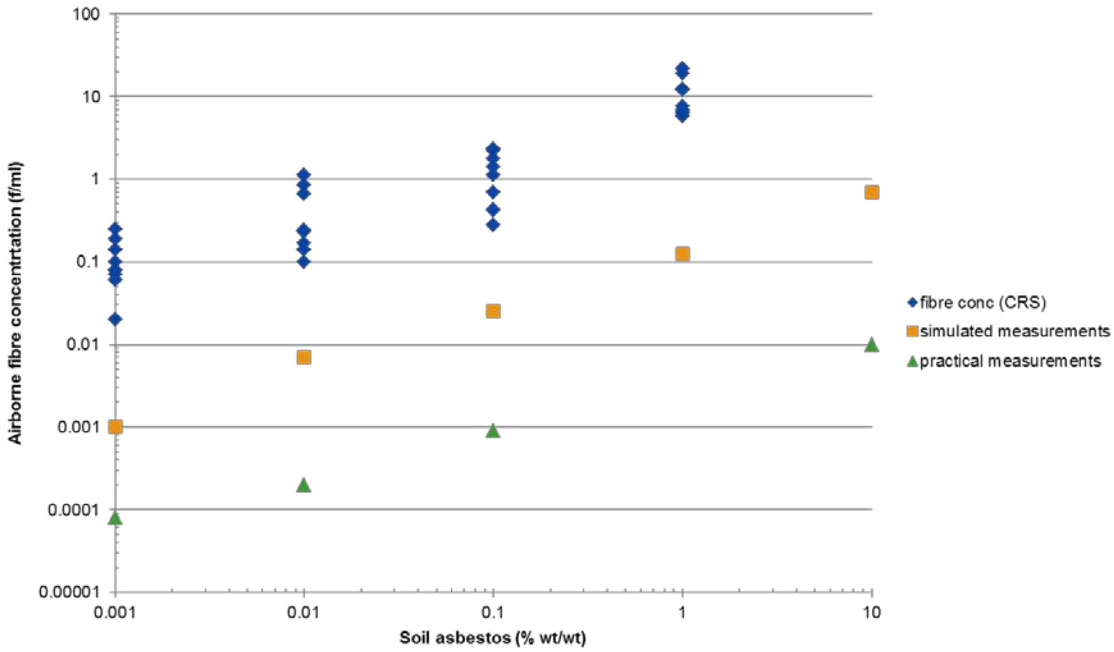

Figure 6: Comparison of Addison and RIVM data

The final approach covered by the presentation was activity based sampling (ABS). The USEPA guidance on assessing the risk from asbestos in soil (USEPA, 2008) recognises the limitations in the current scientific understanding on free fibre release from soil. It therefore advocates the use of ABS to assess the risk on a site-specific level at all sites where asbestos in soil is suspected. The guidance includes a staged assessment approach whereby generic ABS can be carried out first, followed by site-specific ABS if fibre concentration in air trigger levels are exceeded. The standard operating procedure which supports the guidance includes a wide range of activities- from children playing in the dirt to jogging, gardening and basketball.

The ABS guidance highlights a number of important considerations when interpreting the results from the ABS measurements, including the:

- potential differences in ABS results reflecting differences in time and space;
- range of possible soil disturbance activities;
- requirement for robust quality assurance and sampling plans;
- importance of health and safety in designing and undertaking the ABS;
- design of the ABS such that the determination of pathway-specific exposure point concentrations is possible; and
- adjustment of the results to account for possible future increase in the potential for fibre release.

One of the key considerations when evaluating the significance of asbestos fibre release into the air, and when looking to design air sampling methods, is the background concentration in air. A number of published summaries of background concentrations from the UK, Dutch and US studies were shown. It was noted that a large proportion of the data was relatively old. Where more recent studies were available, the data suggested a fall in background concentrations. It was suggested that this is consistent with the prohibition in use of asbestos products, and hence the gradual decline in the prevalence of the material in the built environment. It is not apparent that there are good data on what the current background concentrations are in the UK.

Finally the presentation posed the workshop delegates a number of questions that should be taken into the afternoon workshop sessions. These were:

- Is it possible to equate a qualitative scoring system to quantitative exposure estimates, and can a qualitative approach be sufficiently calibrated and adequately balanced to provide a robust risk ranking output and reliably inform risk management?
- Can we accept the lack of validation of dust models for asbestos fibre release?
- Can we accept the limitations in the current empirical studies, and are these empirical relationships adequate for use?
- Is activity-based sampling practicable, and in what circumstances?
- In developing a framework for asbestos in soil risk assessment in the UK can we understand, accept and work within the limitations of current science?

3 SITE INVESTIGATION SUPPORT

3.1 Introduction

The group comprised primarily chemical and geotechnical laboratory staff but also regulators and consultants. The site investigation support group attendees are listed in Appendix 1 and were led by the facilitator, Alan Jones, and rapporteur, Lindsay Pepperell.

3.2 Objective

The objective for this group was to identify and define key data requirements, methods and practices (site investigation and laboratory) needed to support a consistent decision making process.

3.3 Guidance published subsequent to the workshop

Subsequent to the workshop (held in summer 2013), guidance was published by CIRIA in March 2014, "Asbestos in soil and made ground: a guide to understanding and managing risks" (C733). The comments below reflect the discussion at the workshop and do not refer to the subsequent guidelines that are now available from CIRIA.

3.4 Key issues

3.4.1 Site investigation

Often fieldwork is undertaken by geoenvironmental staff that are not trained, and hence not proficient at, spotting/identifying asbestos – either as ACMs or fragments of ACMs, or as fibrous material. ACMs are hard to recognise after being in the ground and smeared in soil, and so can be easily missed. Trained asbestos surveyors may be experienced in building surveys but not necessarily under geoenvironmental 'field' conditions. In buildings, ACMs are used in particular types of locations and for particular purposes but expertise in knowing those locations does not necessarily aid finding ACM debris once mixed into soils.

When sampling suspected asbestos in soil there needs to be clarity as to whether a particular sample is taken either as being representative of average soil content or as a specific sample of suspect material. The percentage asbestos content may be much higher in a sample which is taken because it includes specific suspected ACMs.

If asbestos is present as dispersed fibres in soil, the fibres are often not visible to the naked eye during a site investigation.

Non-asbestos materials, such as mineral wool, glass-fibre, glass-reinforced plastic, fibreglass etc., can be mistaken for potential ACMs by field staff unfamiliar with ACM identification, due to their fibrous appearance. This can lead to false positives during site investigations (or at least until samples are tested and found to be non-asbestos). Such observations in the field may also distract the field staff from recognising actual ACMs.

When recording field notes and soil descriptions, it is important to record the type, fragment sizes and frequency of ACMs in soils – not just a note that it was 'suspected ACM' and was sampled. This is important if the field observation is followed by a laboratory result that just records the asbestos type such as 'chrysotile'. A good description of the find is important in subsequently assessing risks in relation to human health, CAR 2012 etc. A good photograph always helps (with a scale or metal ruler in it).

Therefore asbestos awareness and competence in recognising ACMs in soils is important and appreciation of the difficulty in doing this should lead to more appropriate and effective training of field staff in recognition of suspect materials during site investigations. Most current asbestos awareness courses are focussed on asbestos in buildings and do not include ACMs in soils. Asbestos awareness training, if it includes a section on asbestos in soils, may help to prepare someone for the task of spotting soil containing ACM fragments but practical experience and mentoring is still needed.

There may be instances where site investigation could usefully include taking soil samples, or recording observations to help assess soil moisture content and/or how soil moisture content may vary on the particular site with factors including weather conditions and depth. This is not common practice at present.

3.4.2 Laboratory analytical methods

Although laboratories generally work to the same basic method of analysing soil samples for asbestos, there are sometimes differences in their in-house detailed analytical methods. There is often a lack of awareness and transparency in this, as details of procedures may be held as commercially confidential and are not usually supplied in full with analysis results. These differences can be important when making assessments based on analytical reports.

Inter-laboratory comparisons of analysis of soil samples containing asbestos are at an early stage, but early results have shown that variation can be substantial. Subsequent inter-laboratory comparisons (since the SOBRA meeting) have shown better consistency.

The development of consistent detailed methods will be of value. This need for consistency in the details of methods is being taken forward with the Standing Committee of Analysts.

Determination of asbestos in soils usually involves analysis by PLM which provides a positive identification of fibre types, as per HSG248 (HSE, 2006). The analysis may, if the samples require counting of separate fibres, also involve counting fibres by PCM (as per HSG248 methods).

However, the PCM method does not provide a positive determination of the type of fibre. The overall count may also include non-asbestos fibres if they are present and conform to the specified dimensions for a 'countable' fibre. There are many non-asbestos fibres in soils or construction derived materials that could be of 'countable' dimensions, including mineral fragments, cellulose fibres and clay particles. PCM analysis usually relies on PLM determination of the type of asbestos being present. Laboratory reports should therefore be clear if any findings by PCM count are not supported by positive identification by PLM of those fibres.

There are some situations when laboratories record low concentrations of free fibres as counted by PCM, but where positive confirmation of asbestos presence and/or type by PLM is not possible. One possibility for dealing with this situation is to save filters (or halves of filters) to be used to determine fibres types if needed by SEM (Scanning Electron Microscopy). Alternatively, laboratories could recommend further re-analysis of the main soil sample to see if the result can be confirmed by SEM. This could avoid overly conservative assessments of risk based on PCM analysis alone, but where some, many or even all, of the fibres counted by PCM were not actually asbestos fibres.

3.4.3 Reporting of soil moisture by analytical laboratory

Soil moisture content is an important factor in assessing the risks of fibre release from soils. It would be therefore be good practice for laboratories to report the moisture content of all soil samples submitted for asbestos in soils quantification testing. Although laboratories dry such soils as part of the sample preparation, they do not routinely record or report the moisture content, unless this is specifically requested as a separate test (and this rarely happens).

3.4.4 Importance of routine analysis of asbestos for brownfield site soil samples

In the experience of one laboratory, 38% of soil samples containing building materials, were found to contain asbestos when tested. However, it was not specified whether this was as ACM fragments or as degraded ACMs such as fibre bundles or free fibre.

3.4.5 Additional information required from laboratory analytical reports

It was agreed that information is needed from the laboratories to assist in making assessments of potential exposure, e.g. types of materials containing asbestos, and the condition of such materials. It may be difficult for laboratories to identify the type of material in the samples supplied if these are only in small fragments. Thus the reports should provide clear descriptions of samples and the consequent uncertainties in the identification. However, an overall indication of the type of material containing the asbestos is still important and useful.

There may also be useful information on asbestos content within different size fractions of the soil samples. Laboratories should make it clear which fractions of soil a certain percentage asbestos content refers to. It should be possible to calculate the percentage of asbestos fibre in the fines fraction of soils, not the percentage of asbestos fibre in the total/all soil fractions combined. This is because free fibre in the fines fraction is where the short-term to medium-term risk of airborne fibre release primarily comes from – not, for example, from bits of asbestos cement in the coarse fraction.

3.3.6 Interpretation of measurements of asbestos in soil

The degradability of ACMs in soils was recognised as an important consideration. There is a difference between assessing current risks (from materials in their present state) and future risks (allowing for likely future degradation of ACMs in soils). There is currently no guidance on the degradability of different ACMs in soils and over what time periods this can or will occur. However, it would be expected that many friable ACMs (such as insulation, insulation board, etc.) will become degraded if left in soils, although the rates of degradation fibre release may vary between different ACM types. Rigid or non-friable materials (typically asbestos cement) may release fine dust and fibre if subject to crushing by construction traffic or by other mechanical processing, but are likely to degrade 'naturally' at a much slower rate than friable ACMs. Asbestos fibres are durable mineral fibres and are likely to remain after the ACM matrix degrades.

Moisture content of soils has a large effect on release of dust and asbestos fibres, if present, from soil. Interpretation of the significance of asbestos content should therefore take account of moisture as a major factor.

3.3.7 Measurements of asbestos in air

There was recognition that measurements of concentrations of asbestos fibres in air at sites where soil is disturbed would be valuable. However, the difficulties of air sampling and relating the results to conditions are substantial. Good descriptions of site conditions at the time of sampling are needed. There is likely to be monitoring data from various projects – but most will be to the 0.01fibres/ml Limit of Quantification and will be reported as total countable fibres, not asbestos fibres. The sample air volumes will need to be sufficient to achieve lower detection limits if intended to demonstrate that background environmental concentrations are not elevated (e.g. above the 0.0005 fibres/ml proposed by WHO (2000) in their "Air quality guidelines for Europe"). For future monitoring, halves of filter samples could be saved to be available for analysis by electron microscopy (e.g. SEM) to determine if fibres were asbestos fibres or not.

If air sampling is undertaken and it is known that the results are to potentially be used for chronic human health risk assessment (as distinct from current occupational health assessment) then the quantification limit of 0.01 fibres/ml may not be low enough for the assessment. Although an appropriate lower limit is being discussed and is yet to be agreed on, a prudent approach may be to lower the limit of quantification to achieve the WHO recommended limit of quantification of 0.0005 fibres/ml as noted above. This can be done by increasing the volume of air sampled, i.e. by sampling at the same rate but for longer, or by pooling samples, and then counting a higher number of graticule areas. Standard occupational hygiene sampling typically samples 480L of air (8L of air per minute for 1 hour) and an analyst then counts 200 graticule areas to achieve a quantification limit of 0.01fibres/ml. Increasing the volume sampled (8L of air per minute for 10 hours, or taking two pooled samples for 5 hours each) and counting 400 graticule areas (200 from each of the two pooled samples) would lower the quantification limit by a factor of 20 to 0.0005 fibres/ml using standard / existing equipment and analysts. If subsequent SEM analysis is required, it may be prudent to undertake this type of sampling in duplicate or halve filters and save one half for potential SEM analysis. It is always worth confirming with the laboratory undertaking the SEM analysis that the filter type and air volumes sampled are suitable for the SEM analysis and can achieve the same or lower quantification limits.

3.5 Conclusions

The group concluded that there are challenges around the identification of asbestos in soil, sampling and recording of asbestos frequency in the field and also in the laboratory. For example, field personnel are often not experienced with respect to identifying asbestos in soil where it is visible and, depending upon the laboratory method, not all the fibres counted may be asbestos. Transparency and consistency between laboratories was key, particularly with respect to sample preparation. More detailed analysis to ascertain the proportion of asbestos types relative to each other, and within different fractions of the soil matrices, was also identified as being helpful in the risk assessment process.

Further useful information for the risk assessment from laboratories could be provided if analysts made a judgement on the friability and degradability of the ACM. It is recognised that this would be outside the laboratory's accreditation and instead would be 'in the opinion of the analyst'.

Many challenges were raised around air sampling including detection limits suitable for chronic human health risk assessment rather than occupational health assessment.

3.6 Recommendations

No recommendations were specifically discussed during the workshop. From reviewing the text, recommendations can be made regarding the provision of asbestos in soil training, with a specific focus on recognising asbestos in soil, useful information to be included when describing the soil, both on-site and in the laboratory, explicitly recognising the limitations of analytical techniques and making improvements to these, such as saving half the filter for more detailed analysis if required.

4 EXPOSURE SCENARIO – REMEDIATION, RE-USE & CROSS BOUNDARY ISSUES

4.1 Introduction

Group attendees included representatives from local authority and asbestos, remediation and risk assessment specialists. The attendees of this group are listed in Appendix 1 and were led by the facilitator, Mike Higgins, and rapporteur, Gareth Wills.

4.2 Objective

The objective for this group was to identify and define key decision points, methods/practices/procedures and standards needed to implement asbestos remediation effectively, efficiently and safely.

4.3 Key issues

The group found the conceptual model and method of site investigation were key to planning remediation projects. Asbestos is not distributed throughout the soil matrix in a similar manner to other contaminants. Therefore, because, for example, trial pitting allows greater inspection of soil matrix in comparison to window sampling, more certainty might be placed in the assessment with respect to asbestos. Furthermore, trial trenches give further confidence to the likelihood of identification of asbestos in soil contamination. The importance of visual surveys by suitability qualified asbestos surveyors was also discussed.

The group identified two types of remediation projects with respect to issues with asbestos in soil:

1. Asbestos remediation projects – projects where asbestos in soil is the remediation-driving contaminant linkage.
2. Other remediation projects - where asbestos is uncovered at low levels during the remediation works.

The reason for identification of these two different types of projects was associated with the different controls and personnel that would be on-site.

An asbestos remediation project will fall under the duty of CAR 2012 and thus discussions are held with regard to whether the activity is notifiable licensed, non-licensed works or non-notifiable non-licensed works. Under these scenarios worker exposure is controlled by CAR 2012 and HSE guidance, as are risks to the environment.

As well as asbestos licensing issues, mobile plant permits and deployment forms are tailored to cover emissions across wider areas, i.e. the surrounding environment as well as the working environment. It was identified that key competencies of the project team, and particularly the site team, were key to delivering a safe project (as subsequently documented in CIRIA C733). Training of site investigation personnel is necessary so that they know what degraded asbestos looks like in soils and specific asbestos awareness training for all site staff likely to encounter asbestos is essential. The use of specialist surveyors is required for works in order to ensure that asbestos in the ground is identified. Having the right staff on-site that can spot degraded asbestos is very important (this need was subsequently published in Kwan, J., Higgins, M., and McFarlane, J 2014). The Material Management Plan is a critical document and, in particular, the materials tracking procedure. Cross boundary issues were also discussed with respect to the types of monitoring available and the communication of issues to adjacent land users and other stakeholders.

4.4 Conclusions

The group concluded there were two types of remediation project with respect to the risks from asbestos in soil:

1. Asbestos remediation projects – remediation projects where asbestos in soil is the remediation-driving contaminant.
2. Other remediation projects - where asbestos is uncovered during the remediation works and thus not specifically planned for.

The group concluded that in many ways the non-asbestos remediation projects were the more risky with respect to asbestos in soil since appropriately trained personnel may not be on-site to recognise asbestos and, if sufficient quantities were found, a supplementary project team might require mobilisation, with the additional associated time and economic costs.

4.5 Recommendations

The group did not have specific recommendations, other than noting that the CIRIA and JIWG guidance would set the way forward for these works and that the training of site personnel is necessary.

5 EXPOSURE SCENARIO – EXISTING / FUTURE LAND USERS DECISION ALGORITHM – GROUP 1

5.1 Introduction

The exposure scenario-existing/future land users topic was discussed by two groups with the intention that the proposed methods by both groups could be compared to help inform the work of the JIWG. This section summarises the discussions by the first group, whilst Section 6 summarises the discussions of the second group. The attendees of this group are listed in Appendix 1 and were led by the facilitator, Steve Forster, and facilitator/rapporteur, Simon Cole.

5.2 Objective

The objective for this group was to review existing decision algorithms, decide whether a UK algorithm should be qualitative, quantitative or a combination of both, and identify/suggest the key elements/components of that algorithm.

5.3 Key Issues

The group, comprising primarily consultants, focused on what factors should be included in a qualitative decision algorithm model, using the Derwentside Environmental Testing Services (DETS) draft algorithm as a starting point.

The DETS algorithm, entitled 'A common sense approach to the management of asbestos in soil' is an adaptation of the building material risk algorithms developed by the HSE and published in HSG227 and HSG264 (HSE, 2002, HSE 2012 (b)). It focusses on a 1-3 scoring matrix for a soil assessment that mirrors the material assessment algorithm developed by the HSE. Instead of scoring for product type, extent of damage, surface treatment and asbestos type, the soil assessment algorithm scores for soil type, mass percentage of asbestos in soil, respirable fibre index and asbestos type.

The group split into four sub-groups to discuss the DETS algorithm and identify what they considered to be necessary considerations when designing or employing a qualitative decision tool.

It was considered that the use of such an algorithm should be in conjunction with desk study information, site walkover data, intrusive site investigation data, and associated laboratory sample data.

Looking at the factors that should be considered by a qualitative algorithm, those highlighted included:

- asbestos type – whether chrysotile, amosite, crocidolite or a mixture of fibre types;
- product composition – whether bonded, unbonded, and whether in a poor or good condition;
- percentage asbestos content in the soil;
- the ACM matrix degradation rate – i.e. the potential release rate of asbestos fibres from the matrix;
- the respirable fibre index – a measure of the proportion of respirable fibres in the ACM, as opposed the total fibre count;

- the physical nature of the soil matrix in which the asbestos is present – whether soil types should be differentiated as sand, loam, silt, clay and aggregates;
- other physical characteristics of the ground, including:
  - moisture content;
  - depth to ACM in soil;
  - ground cover and propensity for surface wind erosion; and
  - heterogeneity of ground conditions – spatial scale of variation.
- the quality of the available data on which the assessment is being made; and
- the susceptibility of the receptor – characterised by:
  - age group;
  - exposure frequency;
  - exposure duration; and
  - activity level – associated with physical intensity of soil disturbance activity and propensity for dust generation.

It was agreed that a qualitative scoring system could form part of a decision flowchart that included the considerations above. The discussion then focussed on how to score these different factors, with consideration of the following questions:

- Would the 1-3 scoring system applied by the HSE work or should weighting be given differently if some factors are considered more important than others?
- Should fibre potency be scored differently, for example, given the orders of magnitude difference in mesothelioma risk associated with them?
- Alternatively, could a simple 1,2,3 scoring system be used, but the score allocation reflect a logarithmic scale, i.e. the scoring system would only recognise orders of magnitude difference in the factors being considered?

Discussion also focussed on how scores could be allocated reliably, and equally how the scoring system could be validated and demonstrated to be robust (i.e. so that the scores produced were reliable indicators of risk for a wide variety of activities/scenarios). For example, how could variability in site conditions, the uncertainty/difficulty in identifying ACM types in the field when the ACM is covered in mud, and data adequacy be reliably accounted for?

After some discussion it was considered that a robust scoring system was in the 'too difficult box'. However, it was agreed that a qualitative decision flowchart had merit. The flowchart should consider the factors listed above. It should also have exit points for activities/scenarios where it can be reliably ascertained that the exposure risk is likely to be minimal, and flag where additional data/information is required before a reliable decision can be taken. Such further information might include further sampling, further laboratory analysis of existing samples, better understanding of the likely activities being assessed, and/or quantitative risk assessment.

The final discussion briefly touched on the need to decide whether a value for soil or air is desirable, and how that might inform or be part of a decision flowchart. The group reached the conclusion that a value for soil is desirable, but questions remain as to what would it be, and whether the existing laboratory detection limit is low enough for this purpose.

5.4 Conclusions

The development of a qualitative decision flowchart for existing and future land users is a valid concept, as demonstrated by those published by Australian, Dutch and US authorities.

There are a number of important factors that the decision flowchart should consider, and these have been identified above.

It was agreed that a qualitative scoring algorithm would be a 'nice to have' if it might lead to consistent decision making and provide a robust mechanism for risk ranking activities or scenarios. However, it is not clear that a simple additive 1-3 scoring system for a combination of factors is feasible, or if it is feasible, what level of validation is required to demonstrate that it works for a wide variety of activities/scenarios and is relatively consistent between users.

There was a strong desire to ultimately incorporate one or a number of numerical soil criteria into the flowchart/algorithm to provide clear decision points. Alternatively it was also considered that decisions could be based on defined point of exposure concentrations in air if there was a consensus that the scientific understanding around the soil to air relationship was too fragile.

5.5 Recommendations

No recommendations were specifically discussed during the workshop. From reviewing the text, there appears to be a recommendation to develop a flowchart/algorithm to provide clear decision points.

6 EXPOSURE SCENARIO – EXISTING / FUTURE LAND USERS DECISION ALGORITHM – GROUP 2

6.1 Introduction

This section summarises discussions by the second group on the existing / future land users decision algorithm. The group attendees are listed in Appendix 1 and were led by facilitator, Simon Firth, and facilitator/rapporteur, James Clay.

6.2 Objective

The objective for this group was to review existing decision algorithms, decide whether a UK algorithm should be qualitative, quantitative or a combination of both, and identify/suggest the key elements/components of that algorithm.

6.3 Key issues

The issues discussed by the group have been summarised under the sub-headings below.

6.3.1 Dealing with large uncertainties in relation to evaluating risks from asbestos

Different types of sites/situations exist – e.g. Part 2A, planning, acquisitions, operational and ALARP. It was acknowledged that each of these situations has different requirements for standards and therefore entails a different approach. The objective of the decision framework developed by the JIWG work should be a decision matrix which allows the practitioner to exit at the earliest point to a reasonable conclusion, wherever possible. This would create a separation between those sites which can be addressed simply, as opposed to those which warrant detailed and complicated consideration.

It was also highlighted that there is the potential to develop something along the lines of what the HSE has done for risk ranking occupational activities associated with working with asbestos, i.e. describing situations that are unlikely to be of concern and others that are more likely to be of concern.

It was also mentioned that the various scenarios should ideally cover health and safety risks to employees undertaking work on soils containing asbestos.

6.3.2 Qualitative/quantitative approaches

It was discussed that a sensible way forward was to select the best aspects from other regimes but adhere to the CLR11 process (Preliminary Risk Assessment, Generic Quantitative Risk Assessment, Detailed Quantitative Risk Assessment) as far as possible, while recognising that asbestos requires some deviations in assessment methods to other contaminants. The difficulty with purely qualitative approaches is the perception issue – it is hard to prove that risk is not significant. The suggestion was made that effort should be focussed on what can be achieved at qualitative/screening level assessment, rather than the more complex and challenging risk modelling. For example, it would be advantageous to develop a decision tree/framework that points out the key factors that affect exposure/risk from asbestos in soils.

6.3.3 Acceptance criteria for asbestos for re-use of soils

It was widely considered that this is not a matter that needs much further consideration; an ALARP level is appropriate – in almost all likelihood a level of 0.001% which reflects both the practical limits of detection and also a level considered to be a low concentration (it would need to be recognised that in some circumstances this can still present a risk but in most conceptual scenarios this risk is likely to be low). The group felt it was important that the circumstances under which soil with low levels of asbestos can remain on-site and/or be re-used are clarified.

6.3.4 Consistency of approach

It was agreed that there is a need for consistency in how the industry assesses risks from asbestos, which is currently lacking. There needs to be a consensus view from people with practical experience of dealing with soils, and there needs to be recognition that there is a requirement for asbestos experts in soil. It is noted that a lack of consensus can lead to lack of confidence in the robustness of the risk assessment; this can have knock on effects, resulting in risk communication with the public on asbestos proving challenging.

6.3.5 Soil to air relationship

It was agreed that there is a requirement to consider multiple lines of evidence when considering the soil to air relationship. This should include amongst others: modelled estimates, empirical data relating soil to air concentrations, and dustiness tests.

6.3.6 Construction and demolition wastes

Construction and demolition wastes are increasingly an issue. It was considered that a standard testing protocol for the importation of soils would have considerable benefit in relation to ACM potentially entrained in recycled materials.

6.3.7 Acceptable Risk

It was agreed that what constitutes acceptable risk should be a policy decision.

6.3.8 Differentiation of asbestos form in the ground (i.e. ACM vs free fibres)

It was agreed that there would be merit in establishing re-use criteria for soil containing free fibres versus solid/bound materials. This is akin to the approach employed in the Netherlands.

6.3.9 Treatment of ACM degradation in soil

It was discussed that there are two contrasting perspectives to resolve, when considering the treatment of ACM degradation in soil. The first perspective is from the assumption that there will be the catastrophic failure of bound ACM in soil at some point in time. This would have the consequence that the ACM should be treated as if it is already friable. The other perspective considers the extremely slow disintegration of the ACM matrix, along with the potential degradation of the fibres also (specifically chrysotile) over a significant time period (hundreds of years).

6.3.10 Testing requirements for imported soil

A number of questions were considered regarding the testing regime relating to imported soil. These included:

- What is the minimum level of information required when importing soil to a site in relation to potential asbestos cross contamination?
- Should the reliability of the source count?
- What should be the minimum testing frequency per volume, and can this vary according to the sensitivity of the land use? (One example was given of a suggested one sample per 25m^3 for imported soil for residential land use, with lower frequencies for less sensitive land uses.)
- Is testing always required/sustainable?

6.3.11 Other issues

There was also a wide-ranging discussion around a number of other areas, some of them tangential to the discussion above, including the following:

- whether or not there might be potential merit in using the CLEA dust model (Environment Agency, 2009) for predicting the concentration of asbestos in air under ambient conditions[12];
- the balance between the focus of exposure models on exposure to surface soils (and hence importance of what asbestos is present at surface), versus the potential for excavation activities, whereby asbestos is worked from depth to the surface;
- the potential to use an asbestos register to facilitate leaving greater amounts of asbestos in the ground, in contrast to a residential development where there is little in the way of post development control;
- whether there should be a different approach when setting out a CLR11 approach to asbestos from that for other soil contaminants (it was suggested that there needs to be a recognition that it should be considered separately because the current default/generic exposure scenarios for other contaminants do not adequately cover the exposure scenarios for asbestos);
- alternative concentration thresholds – the potential to use control thresholds for air rather than use of acceptable soil concentrations; and
- how sampling requirements should adequately reflect the likely heterogeneity of asbestos contamination in soil.

6.4 Conclusions

Many issues were identified and it was agreed that the ALARP principle should be applied for asbestos in soil. The group concluded a framework aligned with the CLR11 approach would aid assessment. The framework could comprise:

1. Preliminary risk assessment (desk study, site walkover and conceptual model);
2. Site investigation and initial screening (conceptual model development and exclusion testing); and
3. Exclusion matrices for different scenarios – different land uses and different use of materials (e.g. topsoil, imported soil and capped soils).

It was recognised that legacy statements may be needed where risks from asbestos in soil are discounted.

Generic screening levels could be derived on the basis of the existing Australian or Dutch methodologies.

6.5 Recommendations

The group recommended that a qualitative framework should be further explored.

[12] There is an extensive discussion on the potential for using existing dust models, and their limitations with respect to asbestos in Section 2.6.

7 CONCLUDING REMARKS

7.1 Key Issues and Recommendations

The SoBRA Summer Workshop 2013 identified many challenges for the industry relating to asbestos in soil. With respect to risk assessment, these include gaining consistency and expertise in site conceptualisation and the identification of asbestos in soil, laboratory analysis methods and interpretation, practicable mitigation methods during investigation and remediation, and how to evaluate risks from asbestos in soil to land users throughout investigation, remediation, construction and post development.

The recommendations of the Summer Workshop were:

- the development of consistent details of laboratory methods will be of value. This need for consistency in details of methods is being taken forward with the Standing Committee of Analysts;
- laboratories should be clear if any findings by PCM count are not supported by positive identification as asbestos by PLM of those fibres;
- laboratories should retain filters/half filters in case further more detailed analysis to inform a risk assessment is required;
- good practice by laboratories would include "as received" moisture content of soil samples, since this is an important parameter to assess the risk of fibre release;
- further information should be sought from laboratories as to the type of material containing asbestos and the condition of such material. This can be difficult for small fragments and therefore analysis reports must contain clear descriptions of samples and associated uncertainty, along with the identification;
- laboratories should be clear whether the percentage asbestos in soil refers to a specific size fraction, i.e. within the fines, where the greatest short to medium term risk of airborne fibres comes from, or within the total soil mass;
- specific training for field staff relating to asbestos in soil recognition, sampling and recording practices and analytical limitations is required;
- good descriptions of site conditions at the time of air sampling are required and, if the results are to be used for chronic human health risk assessment, the limit of quantification needs to be reduced from the clearance limit of 0.01 fibres/ml used for occupational health. Discussions are ongoing as to what an appropriate lower limit of quantification might be;
- the development of a qualitative decision flowchart for existing and future land users that may incorporate numerical soil criteria and/or air concentrations at points of exposure would be valuable;
- a consistent approach is required to maintain confidence in the industry, particularly when engaging with stakeholders; and
- there should be a standard protocol for importation of soil, including the approach to recycled materials which may have ACM potentially entrained within them, with an imported soil testing frequency agreement needed as part of the protocol.

7.2 Delivering the Recommendations

In common with previous events, SoBRA's 2013 Summer workshop produced a number of recommendations that members believe would improve UK risk assessment practice for asbestos in soil.

Some of the recommendations potentially involve further research and the development of guidance; others are more concerned with promoting existing good practice guidance and ensuring that it is actually followed.

- Through its working groups, SoBRA has already demonstrated a capability for developing technical initiatives and delivering consensus-based solutions. Several of the recommendations outlined in this report may be amenable to this type of approach. For example, the asbestos in soil sub-group is currently supporting the JIWG risk assessment chapter by working on some of the recommendations from this workshop including the: development of qualitative guidance to support risk assessment supported by field data such as activity based sampling, dust sampling and asbestos concentrations in soil and air;
- interrogation of the Dutch data to further explore the data behind Figures 2 to 6;
- undertaking of site-specific monitoring;
- collation of UK data to facilitate preparation of a graph similar to that produced by RIVM but specific to UK soil; and
- preparation of a dust and asbestos sampling protocol.

Any member who wishes to take forward any recommendation using the 'SoBRA working group' mechanism is urged to contact the SoBRA Executive Committee.

As for recommendations on the need for greater compliance with existing good practice guidance, by publishing this report SoBRA is signalling its strong commitment to upholding the highest possible standards of risk assessment practice in the UK. It does so in the reasonable expectation that this will lend much needed support to practitioners, regulators and others who share the same, important objective.

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APPENDIX 1 - WORKSHOP GROUPS

WORKSHOP 1: Support for site investigation (minimum data requirements, understanding analysis options and risks to workforce)

Workshop facilitator

Alan Jones — IOM

Workshop rapporteur

Lyndsay Pepperell — ERM

Workshop members

Name	Company
Russell Corbyn	CMT Ltd
Gerry Davies	Tewkesbury Borough Council
Michael Davis	Ecologia Environmental Solutions
Rowan Devlin	East Riding of Yorkshire Council
David Hall	Golder Associates
Liz Hart	Environment Agency
Peter Hewitt	Laing O'Rourke
Rob Hyland	WSP
Darcy Kitson-Boyce	LBH Wembley Geotechnical & Environmental
Neil Moorby	Johnson Poole and Bloomer Limited
Lucy Thomas	RSK
Nik Reynolds	Coopers
Claire Stone	i2 Analytical
Christopher Swainston	Geotechnics Ltd
Jane Thrasher	Jacobs
Rhodri Williams	Alcontrol Laboratories
Martin Weil	Capita Symonds

WORKSHOP 2: Exposure scenario – remediation, re-use & cross boundary issues

Workshop facilitator

Mike Higgins	Hydrock

Workshop rapporteur

Gareth Wills	Parsons Brinckerhoff

Workshop members

Name	**Company**
Matthew Boot	Bolsover District Council
Jonathan Cundall	Cheshire East Borough Council
David Drury	Golder Associates (UK) Ltd
Mark Edwards	Lancaster City Council
David Hall	Golder Associates
Andrew Kent	RSK
Mark Knight	MDK Environmental
Matthew Lennard	Vertase FLI
James Lymer	Wardell Armstrong
Cathy Reynolds	Eden District Council
Elena Rovesti	Ecologia
Helen Smith	Leap Environmental Ltd
Jane Tierney	IOM
Sara Watson	Eden District Council
Geraint Williams	Alcontrol Laboratories

WORKSHOP 3: Exposure scenario – existing / future land users decision algorithm

Workshop facilitator

Simon Cole	URS

Workshop rapporteur

Steve Forster	IEG Technologies

Workshop members

Name	Company
Simon Burr	Campbell Reith
Roslyn Crocker	Ecologia Environmental Solutions
Will Prior	ASL
Andrew Fellows	Ramboll UK
Simon Firth	Firth Consultants
Paul Gribble	Alcontrol Laboratories
Liz Hamer	North Lincolnshire Council
Marian Markham	Halcrow Group Ltd
Phil Morgan	The Sirius Group
Kate Morgans	Parsons Brinckerhoff
James Mortimer	ESI Ltd
Mike Plimmer	Geotechnical & Environmental Assoc. Ltd
Paul Quimby	The LK Group
Rob Reuter	Wardell Armstrong
Megan Parker Seal	WSP Environmental Ltd
Keisha Smith	Card Geotechnics Limited
Adam Symonds	WorleyParsons
Philip Taylor	GEMCO

WORKSHOP 4: Exposure scenario – existing / future land users decision algorithm

Workshop facilitator

Simon Firth	Firth Consultants

Workshop rapporteur

James Clay	Campbell Reith

Workshop members

Name	Company
Richard Brinkworth	Leap Environmental Ltd
Stuart Day	Applied Geology Ltd
David Hall	Golder Associates
Simon Hay	Arcadis
Stacey Inglis	Wrexham Borough Council
Robert Ivens	Mole Valley District Council
George Kowalczyk	Public Health England
Joanne Kwan	CIRIA
Seamus LeFroy Brooks	LBH Wembley Geotechnical & Environmental
Javeed Malik	i2 Analytical Ltd
Megan P Seal	WSP Environmental
John Parker	RSK
James Rayner	Geosyntec Consultants Ltd
Ben Rees	Geotechnology
David Schofield	Environ UK Ltd
Andy Singleton	ESI Ltd
Philip Taylor	GEMCO
Ben Thomas	Smith Grant LLP
Becky Whiteley	Amec

APPENDIX 2 - ABBREVIATIONS

ABS	Activity-Based Sampling
ACM	Asbestos-Containing Material
AGS	Association of Geotechnical and Geoenvironmental Specialists
AIMS	Asbestos in Materials Scheme
ALARP	As Low As Reasonably Practicable
CAR 2012	Control of Asbestos Regulations 2012
CIRIA	Construction Industry Research and Information Association
CoC	Committee on Carcinogenicity
DETS	Derwentside Environmental Testing Services
DPT	Diffuse Pleural Thickening
EIC	Environmental Industries Commission
EA	Environment Agency
EPR	Environmental Permitting Regulations
HSE	Health and Safety Executive
IAQM	Institute of Air Quality Management
IARC	International Agency for Research on Cancer
IOM	Institute of Occupational Medicine
JIWG	Joint Industry Working Group
MTR	Maximal Toelaatbaar risiconiveau (Maximum Permissible Risk)
OPSI	Office of Public Sector Information
PCM	Phase Contrast Microscopy
PLM	Polarised Light Microscopy
PPE	Personal Protective Equipment
QC	Quality Control
REACH	Registration, Evaluation, Authorisation & restriction of Chemicals (EU Regulation)
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health and the Environment)
SEM	Scanning Electron Microscopy
UKAS	United Kingdom Accreditation Service
UK	United Kingdom
US	United States
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
VR	Verwaarloosbaar Risiconiveau (Negligible Risk Level)
WATCH	Working Group on Action to Control Chemicals