Appendix One:

Background information on the development of screening criteria

DOH established screening criteria in 2009 mainly based on international research by Swartjes and Tromp in The Netherlands (2008).

The determination of asbestos in soil has some differences with chemical contaminants, such as:

- fibres are physical structures of various sizes and dimensions, rather than a chemical molecule
- the available analytical methods provide semi-quantitative (estimate of) concentrations and depend on adequate representative sampling and consideration of other supporting information to characterise contamination
- concentration in soil does not consider the potential for release of airborne fibres, and there is a poor correlation between the two;

Asbestos is a banned and controlled substance, and contaminated sites management must consider other legislation (see Section 2.1) that applies to the handling, removal and disposal of asbestos contaminated soils, e.g. restriction on sale and supply, notification, labelling. This is a consideration for any remediation objective. The basis for the screening criteria is two-fold.

1. For all asbestos types, the concentration of 100 mg/kg or 0.01% w/w asbestos in soil is expected to keep outdoor airborne fibre levels below 0.001 f/mL and probably around 0.0001 f/mL.

DOH applied this criterion to the less hazardous bonded ACM, depending on on-site use. These mirror the Assessment of Contaminated Sites (ASC) National Environmental Protection Measure (NEPM) (1999) site uses and associated default exposure ratios.

A lower criterion has been applied to both FA and AF as activity and disturbance may result in the suspension of smaller particles from FA and AF in air. The 100mg/kg was divided by a factor of 10 to account for greater dryness and dust-generating potential of local soils and the fact that current exposure standards (external site) treat the mineralogical forms of asbestos as equivalent.

Note: For low concentration exposures (cumulative exposure of less than 0.01 f/mL.yr), the risk of mesothelioma, the most applicable health outcome from crocidolite fibre (the most potent fibre), is low. There are generally accepted quantitative estimates of disease, extrapolated from dose-response relationships established for higher occupational exposures. These are those presented by WHO (2000) and Hodgson and Darnton (2000). The estimates suggest that asbestos exposure below 0.0002 f/mL.yr is likely to be less than the lifetime risk of 1×10^{-5} and possibly less than 1×10^{-6} (WHO 2000 and Hodgson and Darnton, 2000). These are lifetime cancer risks estimates that are broadly acceptable for environmental contaminant hazards.

Appendix Two:

Determining soil asbestos concentrations and interpreting results

The confidence in the calculation and extent of the application will vary based on site-specific information on the nature of the contamination, the quantity and distribution, the investigative method used, the sensitivity of the analytical method and calculation assumptions.

Estimating asbestos concentration in soil with a high level of confidence is difficult because of its discrete and heterogeneous occurrence and the different physical forms it can take. Sampling asbestos in soil provides an estimate of contamination that can assist in characterising the site.

Ultimately, a professional judgement that considers all relevant parameters is relied upon to determine if the screening criteria has been exceeded.

Asbestos concentrations can be calculated based on the weight of asbestos for a given weight of soil using the method described below. The asbestos weight portion of the bonded ACM can be estimated, such as by using manufacturing information or laboratory estimates of asbestos proportion.

Some important considerations for calculating asbestos concentration for site characterisation include:

- where more than one distinct stratum is impacted by asbestos, separate asbestos concentration estimates should be made for each stratum
- asbestos concentrations must be reported with reference to the sampled strata.
- weight by weight concentrations should be specific to the representative sampled material and should not be calculated for areas or sample volumes with distinctly different types and concentrations of asbestos contamination; however, the type, quantity and distribution of asbestos contamination through the observed impacted areas should be described as completely as possible
- the applied soil density should be confirmed to be applicable (with comment made within the report as to the suitability for using an assumed density for soil found at the site) or preferably use calibrated field scales to weigh the 10L sample and use a measured weight for calculations where practical to do so, and soil is dry.

Generally accepted assumptions:

- soil weight may be directly measured in the field or calculated. **Sandy soil** density (1.65 kg/L) may be used as a default in WA; therefore, a 10L soil sample can be estimated to weigh 16.5 kg
- the content of asbestos in bonded ACM from **asbestos cement sheeting** may be assumed to be 15%, but for any other products, the asbestos content must be decided based on **either manufacturing information for the specific product or suitable estimates of concentration provided by a NATA accredited (for bulk samples and soils) laboratory**.[6]

[6] While the NATA accreditation may not relate specifically to such work, the results can be provided in a non-NATA endorsed report.

- % FA will need to be estimated depending on the origin of the FA, manufacturing information about the original product and the degree of friability.

Confidence in the calculated results is improved using measured rather than assumed variables (e.g. soil weight, asbestos content); this is the preferred approach. Care should be taken in ensuring transparency for any methods adopted.

For AF, it is possible to estimate the mass of loose asbestos fibres observed under a low power stereo microscope using AS 4964 Section 8.2.3 (m). The ability of a laboratory to report a concentration of asbestos in soil will depend on the sample size, level of contamination, the representativeness and homogeneity of the sample, and sampling and analytical limitations.

It is important to remember that a sample result provides an estimate of contamination.

Whenever unquantifiable asbestos fibres are found in a laboratory sample (e.g. trace analysis results), the investigation report must interpret the results based on other site information, the data quality objectives and the site conceptual site model.

Interpretation of analytical data must be provided. Discussion on results should include information on the impact area represented by the sample and how the sample results relate to the assessment criteria. Similar to other contaminants, decision making against criteria should be based on all the information available from the site investigation rather than on individual sample results. In some cases, statistical interpretation of data in accordance with the ASC NEMP and DWER guidelines may be useful but should be well justified.

In the case of AF, a few low-level concentration detects may sometimes be construed as trivial, incidental or background, especially if contamination is not suggested by site history or the main contamination contributing to the source of fibre has been removed. The context and use of a conceptual site model that reflects the relevant exposure scenarios and the frequency and occurrence of other positive and negative results should be considered.

Some sites may contain combinations of different forms of asbestos contamination, each at significant levels. In those cases, or if in doubt, the respective investigation criteria and concentration calculation methods should be applied and, where applicable, combined.

The concentration of asbestos in soil may be calculated as below:

Equation 1:

$$\text{mg/kg} = \frac{\text{proportion of asbestos x weight of bonded ACM or AF or FA (mg)}}{\text{Soil weight (kg)}}$$

Equation 2:

$$\text{\% (w/w) asbestos} = \frac{\text{proportion (expressed as \%) of asbestos x weight of bonded ACM or AF or FA (kg)}}{\text{Soil weight (kg)}}$$

Note Equation 2 is simplified to remove conversion required for percent values and could otherwise be written as.

$$\text{\% (w/w) asbestos} = \frac{\text{(\%asbestos/100) in bonded ACM x weight of bonded ACM or AF or FA (kg)}}{\text{Soil weight (kg)}} \text{ x } 100$$

Table 13 Example calculations

Example calculations
Example 1 AF in Soil: A 2.5 g piece of asbestos cement and a 500 mg piece of woven textile material (assumed to be 100% asbestos content) have been found in 1kg of soil. $\text{mg/kg} = \frac{(0.15 \times 2500\text{mg}) + (1 \times 500\text{ mg})}{1\text{ kg}}$ mg/kg = 875 mg/kg asbestos **Example 2 Bonded ACM in soil:** Two fragments of asbestos cement sheeting have been found in a 10 L sample of soil. One fragment weighs 100 g and the other weighs 50 g. Total weight of asbestos cement fragments is 150 g (0.15kg). $\%\ (\text{w/w})\ \text{asbestos} = \frac{15\% \times 0.15\text{ kg}}{16\text{ kg}}$ = 0.14 % (kg/kg) asbestos

Appendix Three:

Site-specific clean up goals

This appendix should be read in conjunction with Section 3.9.2 and provides more detailed information on parameters that may be considered in the derivation of site-specific clean up goals.

Soil character and mineralogy

Soil character and mineralogy are considered together because they were combined to derive screening levels, namely:

- division of Dutch figures by a factor of 10 in consideration of the greater dryness and dust-generating potential of local WA soils
- equivalent toxicity applied to the different mineralogical forms of asbestos.

The basis for the soil character mitigating potential for asbestos fibre release is primarily related to moisture content and also the presence of clay or silt. When present at sufficient levels, clay and silt have been shown by Addison (1998) and separately by Tromp and Swartjes to reduce the fibre releasability by factors of 10 or more depending on their order of magnitude.

The Friability of a material relates to how easily it is broken up and how readily fibres will be released into the air. Generally speaking, the more friable the material is, the more likely it will release airborne fibres when handled or disturbed. However, in the soil, the same material may be wetted (depending on soil moisture content) and coated with the soil reducing the tendency to release asbestos fibres.

The sandy and often dry soils of many WA urban centres, especially on the coast, do not meet these conditions and hence the basis for applying an adjustment factor in the derivation of the screening criteria.

If it can be demonstrated that soil will maintain the moisture content of 10% or more into perpetuity and there is substantial clay/silt content for the area impacted by asbestos, then this soil mitigation feature will be considered to be met. A soil moisture probe capable of reporting within ± 5% would be sufficient. The moisture content may be difficult to prove in the longer term, especially with projected climate changes, but features such as substantial year-round rainfall or depth of contamination may be of assistance.

For clay/silt content, this feature will be deemed to be achieved if the impacted soil can be classified as Fine Grain Soils – Silts and Clays under the AS 1726:2019 (more than 35% of soil, excluding oversize fraction, is less than 0.075mm).

Regarding the mineral form of asbestos, amphiboles, particularly crocidolite, have been reported to have higher potency for mesothelioma. For many contaminated sites, mixed fibre types are found. The practicality of demonstrating that only chrysotile is present is likely to limit the usefulness of this modifying factor, hence why it was excluded in the derivation of screening levels.

For consideration of moisture content and soil type separately to asbestos type, contact DOH.

Moisture, clay content and asbestos type (predominantly chrysotile) may allow for adjusting the screening criteria by x10 where such conditions are a permanent feature of the site.

Contamination depth

If contamination is prevented from coming into contact with people, such as by surface barriers or depth, then it presents a decreased potential for exposure. However, the longevity of a surface barrier may be difficult to guarantee, and even buried contamination may result in exposure if subsequently disturbed.

Contamination from below 1 m is less likely to be disturbed and still more so with increasing depth. If such material is disturbed by deep digging or excavation, any associated exposure may be short-lived as an infrequent activity with the material being reinstated or taken off-site for disposal subject to waste disposal regulations. Also, the deeper the contamination, the greater the likelihood that dilution during excavation will reduce exposure potential. For instance, a contamination layer that begins 2 metres deep and is 0.6 m thick may be diluted by nearly fourfold by the time it was dug up, assuming no additional dilution by the lateral spread. However, consideration needs to be given to plausible future excavations at the site that may undermine assumptions regarding dilution.

Site-specific clean up goals may be able to apply a modifying factor for increasing contamination depth. Modifying factors can be applied in consultation with DOH.

Extent of Contamination

The extent of asbestos contamination as a proportion of the total used area represents a parameter for mitigating risk. Consideration for this factor is already included as part of the ASC NEPM.

The total quantity of the contamination may also be a mitigating condition but is less easy to use and may not offer sufficient conservatism where human activities may be difficult to predict and may occur within a hot spot area. In addition, for localised hot spots and other limited area contamination situations, it may be more feasible and expedient to remove and dispose of the contamination.

The location, size, concentration and spread of contamination can be considered against the likely disturbance through discrete tasks/activities, proximity to and time spent in the area of contamination during the task/activities.

An example of limited contamination where this parameter might apply is in relation to soil impacts limited to an undisturbed narrow drip line along an un-guttered residential asbestos roof.

Supporting sampling

Derivation of the site clean-up levels requires adequate data on the parameters being modified. As such, there would be a need for supporting sampling and analysis beyond the standard expectations.

For instance, location and concentration-related mitigating factors will require a higher sampling rate to be confident of the patterns being used as a basis for clean-up variation, e.g. lateral and vertical distribution and concentration range.

Separately, if soil parameters are being used, then specific sampling and analysis of soil properties, including moisture content, will need to be done and shown to be widespread to support the proposal.

Analytical methods

The derivation of the screening level for AF was fixed for all site uses because of the difficulty quantifying fine material (especially loose fibre and fibre bundle concentrations). In other words, accurate quantification between 0.01% and 0.001% asbestos (weight/weight) is not feasible.

Since the first publication of the Guidelines in 2009, international methodologies have emerged that offer greater sensitivity and have been accepted for use by DOH (See Chapter 5). If these or other sufficiently sensitive DOH accepted analytical methods are employed, it is feasible that the screening criteria for AF can be varied to reflect the type of site use (ASC NEPM (1999).

Where other mitigation factors for a particular site are being applied for AF, there may be greater scope for considering site use exposure ratios for site uses as the clean-up levels will start from a higher quantifiable concentration.

Other factors

Other factors that have not been used in deriving screening values but could be considered in developing sustainable remediation options or deriving site-specific clean-up goals, if they appear to mitigate risk, include:

- rainfall patterns and level
- wind erosion potential
- soil physical properties
- surface cover, noting that this may vary with time
- soil chemistry (which may be stabilising rather than conducive to bonding breakdown)
- exposure assessment with air sampling data
- the physical form of the asbestos
- asbestos fibre characteristics
- the total mass of asbestos
- site isolation.

In using such factors, it is important not to exclude other factors that might have more of a risk increasing role, such as the asbestos being present as pure crocidolite fibre.

It is also worth noting that the original basis for developing the screening criteria assumed a 70-year exposure, and the current ASC NEPM applies 30-35 years. The average time for the development of mesothelioma is 40 years, and so late-life exposure will not have an opportunity to manifest as this disease.

Appendix Four:

Laboratory analysis

The current *AS4964–2004 Method for the qualitative identification of asbestos in bulk samples* provides a staged approach to detecting asbestos in soil samples. The information below can be used to develop in house procedures consistent with these Guidelines and the staged approach in AS4964 for pre-analysis of AF samples and sample preparation for trace analysis.

A larger 500 ml sample is submitted to assist in the quantification of AF (all material less than 7 mm x 7 mm) found in the preliminary steps of analysis, which cannot be effectively observed in the field and which is best examined in a controlled environment by a NATA accredited laboratory (see Table 14).

Samples submitted for AF in soil analysis are intended to be representative samples and should not be diluted through improper sampling techniques. It is accepted that the larger sample may result in the less than 2 mm material being reduced before subsequent stages analysis. Where it is expected that the form of asbestos contamination is predominately less than 2 mm, submission of a smaller field collected representative sample may be more relevant. Any variations or advice regarding sample size can be discussed between the client and the laboratory.

It is important to note that the laboratory sees a very small sample of material where the origin of AF may be unknown to the analyst. As such, analysts do not have the information necessary, unless provided by the sampler, to determine whether the origin of any AF should be managed as friable or non-friable or minor contamination of dust and debris.

Bonded ACM and FA (>7 mm) may be described based on appearance. (e.g. fraying woven asbestos). The size of material or debris found in AF may be insufficient to accurately identify the potential source of the debris (i.e. the identity of the source commercial product). Therefore, the laboratory may only be able to provide a limited description.

The supporting site investigation information may sometimes be provided to the laboratory to assist describe the sources of AF in the soil sample.

The DOH has requested that for contaminated site assessments, the presence of all forms of asbestos is reported, even where it is below the detection limit and non-respirable, as this information provides supporting information to site assessments.

Where these Guidelines recommendations inadvertently conflict with Australian Standards or in-house NATA accreditation requirements, laboratories should approach DOH to discuss and help resolve these differences.

The limit of reporting is determined by the laboratory. Where the presence of asbestos is detected using AS 4964 the value of 0.001%w/w asbestos should be assumed to be exceeded.

Limitations of PLM should also be considered, such as for analysis of fibres that are:

- of small diameter
- occluded by interfering materials in the sample matrix
- of a fibre type not able to be identified by the method.

The use of alternate methods may be acceptable to DOH, following consultation on their suitability, that may provide supporting information regarding the presence and relative quantities/contribution of asbestos fibres in a sample in Tier 2 and 3 assessments. Examples of international methods are:

- ASTM D7521
- ISO methods
- Quantification of Asbestos in Soil: Methods for the Examination of Waters and Associated Materials (Standing Committee of Analysts, 2017, "Draft") or the IOM Technical Report: Release of dispersed fibres from soils (Addison et al., 1988).

Table 14 Examination of samples

Further information regarding examination soil samples by the laboratory (aligned with steps in AS 4964-2004, 8.2.3)

1. Record the dry weight of the submitted soil sample.
2. Screen the entire sample through a 10 mm sieve.
3. Examine the +10 mm matter by eye or magnifying glass/stereo microscope
4. Options for providing separate information on +7 mm material
    a. Screen the entire sample through a 7 mm sieve as an intermediate step
    b. Examine the -10 mm fraction and report the separated and weighed +7 mm suspect material found in Step 5 separately to the -7 mm material.
5. Separate and weigh all suspect material, including small fragments of bonded material and other fibrous matter, for identification by PLM and DS – note appearance, size and estimated asbestos content.
6. Screen through a 2 mm sieve.
7. Spread out and examine the entire, or a number of sub samples (to be determined by in-house procedures), of the - 2mm fraction using a combination of low and high power stereomicroscopy.
8. Extract any suspect -2mm material for later identification by PLM DS, noting appearance and dimensions (weigh if possible).
9. Conduct a trace analysis on (a reduced) -2mm fraction.

For split tube core samples, open tube and examine each layer and separate suspect layers for more detailed analysis, i.e. more time should be spent examining those layers[7]. Each layer may require separate treatment, including sieving through 10 and 2 mm sieves, in effect allowing for individual sample results for each strata layer.

AS 4964 requires all fibrous matter to be weighed or measured and allows for the estimate of weight to occur based on the appearance and dimension of the matter found or knowledge of the identified asbestos-containing product found and likely asbestos content (see AS 4964, Section 8.2.3 (m)). For small pieces of bonded materials with fibres still retained in the substrate, it may be possible to assign a portion of the weight as asbestos (e.g. 15% asbestos for an asbestos cement fragment).

[7] Use appropriate safety precautions.

The proportion of asbestos content attributed to fibrous matter should be conservatively determined. Where little of the parent bonding material remains, 100% of the weight of the material can be apportioned as asbestos fibre.

It is important, especially for Tier 2 assessment, for all the supporting information gathered during analysis to be provided (i.e. information on the appearance, size and asbestos content of materials identified as asbestos). If possible, such a detailed report should differentiate between empirical and estimated values, including weights and dimensions.

The laboratory can provide NATA accredited reports that include a description and results of identification by PLM-DS of the separated asbestos found in the soil sample. Results of trace analysis on a laboratory reduced soil (sub)sample can also be provided as per AS4964, being:

- no asbestos detected by polarized light microscopy, including dispersion staining
- trace [fibre type] asbestos detected by polarized light microscopy, including dispersion staining
- [fibre type] asbestos detected by polarized light microscopy, including dispersion staining.

For these Guidelines, laboratories may assist the client with a summary of findings that clarifies:

- the total dry weight of the submitted soil sample
- a description of each confirmed asbestos “fibrous matter” found in the sample, its dimensions and the measured or estimated weight, which can also be categorised into:
    - +7mm bonded ACM
    - +7mm FA material
    - -7mm AF
- the estimated asbestos weight of the fibrous matter in the sample can be expressed as a percentage of the total dry weight of the sample (% asbestos (w/w) in soil) separately for the above categories.

The “trace analysis” results provide useful information, especially for Tier 2 assessment, but are subject to interpretation prior to comparison with screening criteria.