NSW GOVERNMENT | Chief Scientist & Engineer

Management of asbestos in recovered fines and recovered materials for beneficial reuse in NSW

Final Report

December 2024

Acknowledgement of Country

The Office of the NSW Chief Scientist & Engineer acknowledges the Traditional Custodians of the lands where we work and live. We celebrate the diversity of Aboriginal peoples and their ongoing cultures and connections to the lands and waters of NSW.

We pay our respects to Elders past, present and emerging and acknowledge the Aboriginal and Torres Strait Islander people that contributed to the development of this Report.

Management of asbestos in recovered fines and recovered materials for beneficial reuse in NSW
Final Report
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The Hon Penny Sharpe MLC
Minister for the Climate Change, Energy, the Environment and Heritage

52 Martin Place
SYDNEY NSW 2000

December 2024

Advice on the management of asbestos in recovered fines and recovered materials for beneficial reuse in NSW

Dear Minister

In December 2022, the previous Minister for the Environment asked that I provide advice on the management of asbestos in recovered fines and materials for beneficial reuse.

In preparing this advice, an Expert Panel chaired by Dr Darren Saunders (Deputy Chief Scientist & Engineer) was convened, consisting of Linda Apthorpe (University of Wollongong), Prof. Timothy McCarthy (University of Wollongong), Pierina Otness (Western Australia, Department of Health) and Dr Liyaning Maggie Tang (University of Newcastle). The Office of the Chief Scientist & Engineer (OCSE) provided Secretariat support and report drafting was provided by OCSE.

To assist with informing the advice, a discussion paper was publicly released in June 2024 seeking feedback from stakeholders on aspects of the Terms of Reference associated with the advice. OCSE also undertook a number of site visit to gain a better understanding of the management of waste and asbestos.

The widespread and historical use of asbestos in NSW comes with a legacy of risks to human health and has already impacted many families. Given that significant investment is required to effectively remove, isolate and/or eradicate asbestos, it is necessary to take a pragmatic approach to management. This means ensuring risk to human health is managed while safety removing asbestos from its source, predominantly within the building environment. The findings and recommendations in this report look to balance risk with promoting safe removal and more effective management.

Finally, I thank the Expert Panel members for their expertise and insights, and the stakeholders who provided invaluable input in developing this advice.

Yours sincerely

H. Durrant-Whyte.

Professor Hugh Durrant-Whyte
NSW Chief Scientist & Engineer

Contents

Acronyms

AC	Asbestos cement
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	Asbestos-containing material
ADP	Asbestos Disposal Points
ASEA	Asbestos Safety and Eradication Agency
ASSEA	Asbestos and Silica Safety and Eradication Agency[1]
BRII	Business Research Innovation Initiative
C&D	Construction and demolition
CBA	Cost-benefit analysis
CLM Act	*Contaminated Land Management Act 1997* (NSW)
Codes SEPP	*State Environmental Planning Policy (Exempt and Complying Development Codes 2008* (NSW)
DA	Development Application
DRWDD	Dunmore Recycling & Waste Disposal Depot
EC	European Commission
EoW	End of Waste
EPA	Environment Protection Authority
EU	European Union
f/mL	Fibres/mL
HADS	Householders' Asbestos Disposal Scheme
HSL	Health Screening Level
IOM	Institute of Occupational Medicine
IARC	International Agency for Research on Cancer
IWTS	Integrated Waste Tracking System
LGAs	Local government areas
LOD	Limit of detection
LOR	Limit of reporting
MASP	Materials Acceptance and Sampling Plan
MFM	Membrane filter method
NACC	NSW Asbestos Coordination Committee
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measures
NIOSH	National Institute for Occupational Safety and Health
NOA	Naturally occurring asbestos
NOHSC	*National Code of Practice for the Control of Workplace Hazardous Substances*
NSSN	NSW Smart Sensing Network
OCSE	Office of the NSW Chief Scientist & Engineer
OHS	Occupational health and safety
PCBU	Person conducting a business or undertaking
PFAS	Per- and polyfluoroalkyl substances

[1] In December 2023, ASEA's functions were expanded to include silica and the agency's name changed to ASSEA.

PLM	Polarised light microscopy
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
POPs	Persistent Organic Pollutants
RCRA	Resource Conservation and Recovery Act (US EPA)
REL	Recommendation Exposure Limit
RPE	Respiratory protective equipment
RRE	Resource recovery exemption
RtR	WA Roads to Reuse
SCM	Swiss Cheese Model
SEM	Scanning electron microscopy
TEM	Transmission electron microscopy
TOR	Terms of Reference
TWA	Eight-hour time weighted average
UCL	Upper Confidence Limit
VAEA	Victorian Asbestos Eradication Agency
WA DOH	Western Australian Department of Health
WA DWER	Western Australian Department of Water and Environmental Regulation
WA Waste Guideline	Western Australia's *Guideline: Managing asbestos at construction and demolition waste recycling facilities*
WA Soil Guidelines	Western Australian Department of Health's *Guidelines for the Assessment, Remediation and Management of Asbestos Contaminated Sites*
Waste Regulation	*Protection of the Environment Operations (Waste) Regulation 2014* (NSW)
WEL	Workplace exposure limit
WES	Workplace exposure standard
WHO	World Health Organization
WHS	Work health and safety
WSRADS	Western Sydney Regional Asbestos Disposal Scheme
WSROC	Western Sydney Regional Organisation of Councils
XRD	X-ray diffraction

Executive summary

In December 2022, the Office of the NSW Chief Scientist & Engineer (OCSE) was requested by the then Minister for the Environment to provide independent advice into the safe and effective management of asbestos in recovered fines and materials for beneficial reuse in NSW. It should be emphasised that this is not a review of policy or legislation, but a review of evidence that may support changes to policy and/or legislation.

OCSE established an expert panel, commissioned three independent papers (national and international standards and guidelines; sampling and analysis of asbestos; and emerging technologies for asbestos detection in waste), visited recycling facilities, testing facilities and local council depots, and developed a Discussion Paper aimed at seeking feedback, comments and information from stakeholders.

Currently in NSW, any waste (including construction and demolition waste) containing asbestos must be sent to landfill. This applies to all waste containing any form of asbestos at any concentration. This also means that waste cannot be processed, screened or segregated to remove any asbestos. This approach is not sustainable in the context of very limited landfill capacity and does not support circular economy principles. Mixed construction and demolition waste is likely to contain asbestos in small or trace amounts and the current zero tolerance approach to the management, sampling and analysis of waste and material for reuse in NSW is unable to rule out the presence of asbestos. Further, there is a need for more evidence relating the risk tolerance, health and environmental impacts, technologies and cost-effective management methods relating to asbestos in recovered fines and recovered materials/waste intended for beneficial reuse. This information will inform future improvements to the safe and effective management of asbestos in NSW.

The findings and recommendations of the review reflect a need to address the problem with a through-chain risk-based approach. A focus on reducing and eliminating asbestos at all stages, including through source separation, will likely provide better outcomes for managing asbestos in recovered fines and materials. It is important to highlight that dilution is never the intention of this approach and will not be supported.

Findings

Chapter 2: Thresholds

- Varying definitions for asbestos, asbestos material and asbestos waste in different legislation result in a level of confusion when managing asbestos.
- In respect to environmental management, only a few national and international jurisdictions have established asbestos thresholds (or limits) in waste for recycling. Thresholds have been used a part of a broader risk-based approach to managing asbestos in waste.
- The context of any threshold needs to be clearly understood. Where thresholds have been established by environmental agencies, they are based on the NEPM's HSL values, the limit of detection for a specified method of analysis or based on experimental estimates of potential respirable fibre count.
- Studies that correlate concentration of asbestos in waste to asbestos-related disease levels were not identified in any literature.
- Health-related evidence to support thresholds is generally based on predicted disease risk rather than a link between asbestos concentration and asbestos-related disease.
- Within Australia, thresholds (or limits) are utilised within WHS requirements, although these cannot be interpreted as an acceptable level of exposure, and more accurately reflect a maximum upper exposure limit.
- The workplace exposure standard for airborne fibre concentration is 0.1 f/mL over an eight-hour period, five-day week.
- WHS limits are supported by other requirements to manage risk and minimise exposure, noting different requirements are set for DIY home renovators in NSW.

- In general, risk is considered based on a correlation between asbestos concentration in material and concentration of respirable fibres measured in air (similar to Swartjes and Tromp (2008)).
- Experimental estimates of fibre release from soil found that 'activities involving soil with friable asbestos concentrations of 100mg/kg of soil were unlikely to result in airborne fibre levels above 'Negligible Risk' level of 1000 fibre equivalents/m^3 (0.001 f/mL).'
- Asbestos soil concentrations below 0.01% are unlikely to generate airborne fibres above 0.01 f/mL.
- Additional safety factors may need to be considered when establishing thresholds for waste and recovered materials.

Chapter 3: Sampling and Analysis

- There are a limited number of guides for sampling and analysis of asbestos in waste (i.e. recycled end product). Soil sampling guides are widely understood and available for asbestos sampling and analysis.
- It is challenging to obtain a representative sample for analysis with high confidence due to the heterogeneity of the materials and non-uniform distribution of asbestos (i.e. hotspots).
- Visual identification of ACMs remains the first key step in detecting asbestos, whether at the demolition site, the receiving/tipping point at recycling facilities, or during analysis procedures in the field or laboratory.
- Current methods using NEPM gravimetric and AS 4964 (now superseded by AS 5370) laboratory analysis are sufficient to detect and estimate asbestos content in recovered materials; however, their limitations and applications to end product must be understood.
- Appropriate training and internal/external quality assurance through accreditation of those undertaking asbestos sampling and analysis are critical to ensure the competency of the analysts and minimise variability in reporting results.
- Sampling in WA Waste Guideline focuses on assessment of the end product by targeting areas with visible suspect asbestos materials. The samples are analysed using gravimetric method and AS 4964 to estimate the total asbestos content.
- Interpretation of sampling and analysis results in WA Waste Guideline applies a multiple-lines-of-evidence approach to deciding whether the stockpile meets the product specification of 0.001% w/w asbestos.
- In the case of exceedances in a stockpile, investigation of the cause must be carried out and preventative measures must be taken to prevent a future occurrence. Any actions taken on the stockpile must be recorded.
- A generic sampling and analysis plan for asbestos in recovered fines and materials is unlikely to provide a high level of confidence. The sampling and analysis of end products need to consider the sampling objectives, sampling strategies in the field, the limitations and applicability of selected analysis method and data quality assessment.

Chapter 4: Risk-Based Approach

- The current approach to managing asbestos in C&D waste in NSW does reflect a partial risk-based approach at specific stages, but it does not follow through the chain to the end use of recycled materials.
- The current controls in asbestos management in NSW include a requirement for safe handling and disposal of asbestos, tracking of asbestos waste, visual inspection of incoming waste and end-use control of recycled products.
- Lack of knowledge/awareness of asbestos presence, lack of practical skills to identify and handle ACMs, avoidance of disposal costs, and inadequate surveillance activities contribute to risks in asbestos management.
- There is general support for a through-chain risk-based approach focusing on source separation for effective asbestos management, although reservations on the approach's implementation and practicality remain.

- Early intervention through asbestos identification and removal at the source can more effectively prevent asbestos contamination downstream, where it becomes dispersed and harder to detect and remove.
- The mapping of asbestos management in the recycled waste value chain suggests that having multiple barriers through the chain can minimise the risk of asbestos contamination and exposure; this can be done by implementing a combination of process controls and supporting programs and policies at every stage.
- Conceptual design and elements of the through-chain risk-based approach for asbestos management in C&D waste can be drawn from case studies from other states in Australia and overseas.
- The WA Waste Guideline has a comprehensive risk-based approach to managing asbestos in waste for re-use that incorporates pre-acceptance procedures, a material risk classification matrix during acceptance procedures, waste processing controls, and sampling and analysis of the end products to validate the effectiveness of quality assurance and quality control processes.

Recommendations

Recommendation 1:

NSW Government implement a coordinated, through-chain risk-based approach to managing asbestos in recovered materials, incorporating a suite of specific recommendations on the application of thresholds, sampling and analysis designed to ensure that potential risks are understood and mitigated at each step in the value chain. Individual recommendations should not be considered in isolation.

Recommendation 2:

NSW Government considers implementing a threshold for asbestos in recovered fines and materials for beneficial reuse. The threshold should:

- Be based on the current criteria of 0.001% w/w (asbestos in any form) as described in the Western Australia “Guideline: Managing asbestos at construction and demolition waste recycling facilities” and meet all the requirements below:
    - no visible ACM,
    - below 10 mg/kg weight of total asbestos/weight of product (i.e. 0.001 % w/w) and
    - asbestos not detected using AS 5370.
- Support a through-chain risk-based approach to managing asbestos in recovered fines and materials for beneficial reuse
- Apply to the end product, ready for reuse in non-contact scenarios, although the threshold could also be used as an in-process standard to verify the efficacy of processing steps.

Recommendation 3:

NSW EPA develops material acceptance, inspection, sampling and analysis guidelines for asbestos in recovered materials to assess product quality against the set threshold in consultation with industry stakeholders. The sampling and analysis guidelines should:

- Support a through-chain risk-based approach to managing asbestos in recovered fines and materials for beneficial reuse
- Consider the nature of different materials and processing chains
- Be validated by the results from a staged pilot program.

Recommendation 4:

NSW EPA updates Standards for managing construction waste in NSW to include a through-chain risk-based approach by adopting WA Waste Guideline: Managing asbestos at construction and demolition waste recycling facilities.

Recommendation 5:

NSW Government considers a staged pilot program of a through-chain risk-based approach to design, test and validate findings and recommendations from this report.

Recommendation 6:

NSW Government engages with other jurisdictions to work towards a consistent approach and outcomes (including legislation) in managing asbestos in recovered fines and materials for beneficial reuse.

Recommendations 7:

NSW Government considers stronger support for better source separation at demolition sites, including residential premises, through the identification of industry best practice with clear and consistent guidance, training and competency around robust asbestos identification and handling for all workers handling asbestos prior to disposal.

NSW Government evaluates the delivery of small grants funding for council-run programs to date to inform the design of a more systematic funding model.

NSW Government improves and standardises data collection, collation and analysis procedures to better inform and adapt management as part of a through-chain approach.

Recommendations 8:

NSW Government remains aware of emerging technologies that can assist with asbestos detection, and considers supporting the development and trialling of technologies that have high potential through a new NSW business research challenge program.

Recommendations 9:

NSW Government facilitate development of national competency-based training for waste industry.

NSW Government liaise with industry professional bodies to develop competency-based training for laboratory analysts, asbestos assessors/environmental auditors/occupational hygienists who consult or work with the waste industry.

1. Introduction

1.1 Overview

In December 2022, the Office of the NSW Chief Scientist & Engineer (OCSE) was requested by the then Minister for the Environment to provide independent advice into the safe and effective management of asbestos in recovered fines and materials for beneficial reuse. The scope for this OCSE review (the Review) is detailed in the Terms of Reference (TOR - see Appendix 1) and includes:

- reviewing national and international approaches to managing asbestos in recovered fines and materials, including where tolerable threshold levels for asbestos have been established and the basis behind these approaches
- considering the use of tolerable threshold levels for asbestos in waste intended for beneficial use including the robustness of evidence supporting the levels and circumstances under which they can be implemented
- potential approaches to sampling and analysis of asbestos in recovered materials
- the applicability of existing tolerable threshold levels in asbestos-contaminated soils
- other potential approaches to managing asbestos in recovered materials
- the scientific and risk assessment principles that should be considered when setting thresholds.

OCSE was asked to consider any scientific or other evidence that would support alternative approaches to managing asbestos in recovered fines and materials, particularly the potential adoption of thresholds as opposed to the current zero tolerance approach. The Review is not an examination or assessment of the current policy or alternative policy approaches, a review of asbestos-related legislation, nor an investigation of previous compliance issues. However, information from this Review could be considered in any future review of policies and legislation.

1.2 The need for effective asbestos control in construction and demolition waste recycling

1.2.1 Landfills are reaching capacity

In 2022-23, the most recent complete year of data, the generation of 22.4 million total tonnes of waste across all streams in NSW represented one-third of Australia's total waste and was above the five-year average of 21.9 million tonnes of total waste for NSW (NSW DPIE, 2021; NSW EPA, 2023). This was due in part to increased generation of construction and demolition (C&D) waste, which is the major category of waste in NSW. Currently, NSW produces the highest volume of C&D waste of any Australian state. Approximately 12.7 million tonnes, or 56.7%, of overall waste generated in NSW in 2022/23 was C&D waste (NSW EPA, 2023). This equates to 1.52 tonnes per capita of C&D waste generation in 2022/23, an increase back to pre-pandemic levels (NSW EPA, 2023).

The large volumes of waste generated in NSW put considerable pressure on the existing landfill infrastructure. Over the next 20 years, NSW waste volumes are projected to grow to nearly 37 million tonnes in 2041 (NSW DPIE, 2021) from the current 22.4 million tonnes (in 2022/23). Recent assessment on Greater Sydney's future landfill capacity shows that there will be a shortfall in landfill capacity for non-putrescible waste (including inert C&D waste) from 2032 (Foy, 2024). The availability of landfills accepting asbestos waste is expected to be even more limited. One of the challenges identified in the NSW Waste and Sustainable Materials Strategy 2041 (NSW DPIE, 2021) is the need to 'manage this material so that we can avoid the worst of its impacts… we need strategies to reduce the volume of waste we generate; reuse, repair, and recycle what we can't avoid; and make sure that we have enough capacity to safely dispose of the material we cannot recycle'. With landfills nearing capacity, including facilities that can accept contaminated waste, the management of asbestos in the context of resource recovery is a pressing issue.

1.2.2 Asbestos can contaminate C&D waste recycling streams

C&D waste accounts for the largest proportion of waste recycled in NSW. The 2022/23 recycling rate for C&D waste in tonnes was 78%, which is above the overall recycling rate for NSW of 66%. The current recycling rate of C&D waste has decreased from 80% in 2021/22, while waste generation has increased (NSW EPA, 2023). In 2022/23, approximately 22% of all C&D waste (or 2.8 million tonnes) was sent to landfill. Figure 1 contains a breakdown of the C&D waste generated, recycled, and landfilled in NSW from 2019/20 to 2022/23, using C&D data from the NSW Waste and Resource Recovery Portal (NSW EPA, 2023).

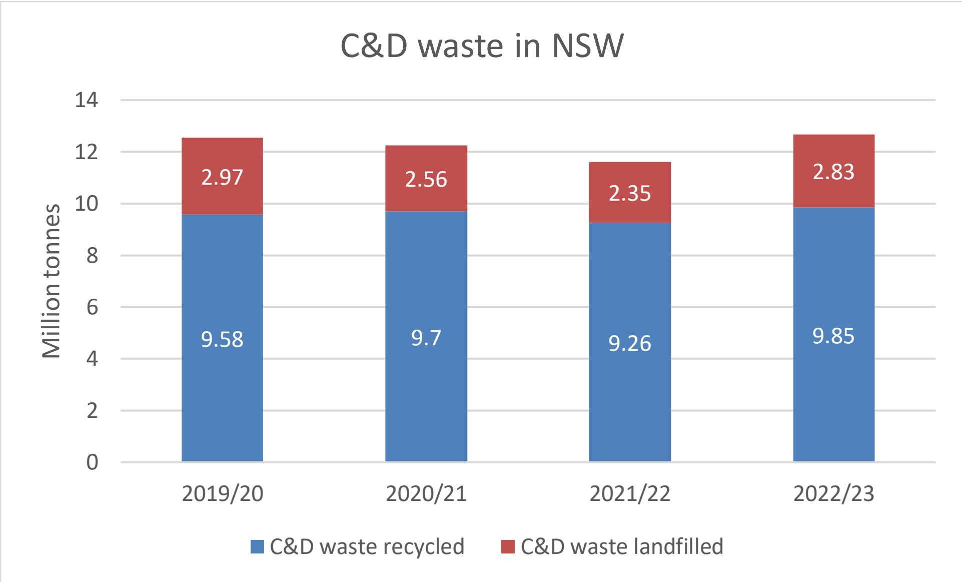

Figure 1: Generation and fate of C&D waste in NSW from 2019/20 to 2022/23.

NSW generates the highest volume of asbestos waste of any Australian state. In 2019/2020, 899,534 tonnes of asbestos waste (including asbestos-contaminated soil) made up 37% of all estimated NSW hazardous waste 'arisings', with arisings defined as the delivery of waste to processing, storage, treatment, or disposal facilities (NSW EPA, 2021). Figure 2 displays asbestos waste amounts generated in NSW from 2020/21 to 2022/23, drawn from the Asbestos Safety and Eradication Agency's (ASEA) yearly asbestos waste estimates using data from tracking systems for hazardous waste and/or reports from licensed landfill operators (ASEA, 2021; ASEA, 2023a; ASSEA, 2024a)[2]. In Figure 2, 'wrapped asbestos' or asbestos that has been double-wrapped and sealed in polythene sheeting for transport, is most likely to be from planned and licensed asbestos removal work where asbestos has been separated from other waste. Waste or soil contaminated with asbestos can be non-asbestos waste contaminated with asbestos, largely made up of other C&D waste or soil with any level of asbestos material identified. Problematically, there is a real possibility of the presence of asbestos at C&D recycling sites and in C&D products for beneficial reuse, including recovered fines.

[2] In December 2023, ASEA's functions were expanded to include silica and the agency's name changed to the Asbestos and Silica Safety and Eradication Agency (ASSEA).

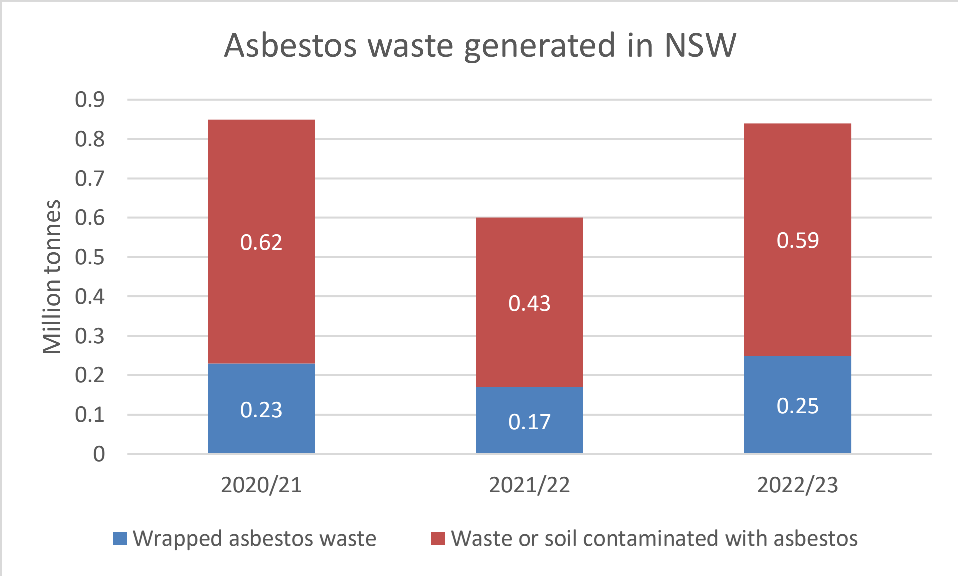

Figure 2: Volume of different asbestos waste types reported in NSW from 2020/21 to 2022/23. Note that data for asbestos 'arisings' in 2019/20 mentioned above (0.9 million tonnes total) is derived from tracking data or estimated using alternative data, adjustments, and assumptions, and is therefore not displayed here (NSW EPA, 2021).

With the recycling of C&D waste comes the risk of asbestos contamination in the end product (SafeWork NSW, 2010). While there are procedures in place to keep asbestos out of the C&D waste stream by identifying and removing asbestos from buildings prior to demolition, there remains a small risk that asbestos is present in C&D waste directed to recycling facilities. Through the mechanical processing and screening of C&D waste, asbestos can end up in recycled end products and become a threat to users that encounter the recycled product (WA DWER, 2021). End products include road aggregate made from crushed concrete, brick, and excavated rock, and fine materials generated from mixed skip-bin waste that can be used as soil or sand substitutes in landscaping products, sporting fields, and residential developments (Edge Environment Pty Ltd, 2011; NSW EPA, 2022b). In 2019/20, nine million tonnes of material were recycled under EPA resource recovery orders from C&D waste (Figure 3) (NSW EPA, 2022c).

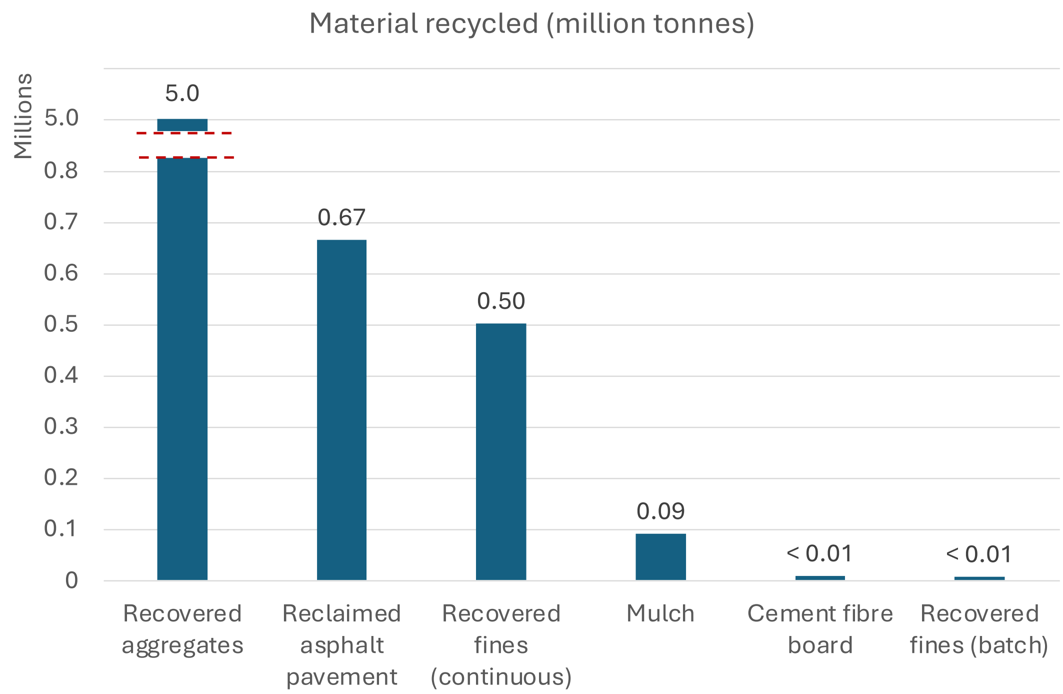

Figure 3: A 2019/20 snapshot of the amounts of materials recycled under NSW Environment Protection Authority resource recovery orders that could be derived from C&D waste.

1.2.3 Asbestos risk is not adequately captured by the concept of 'zero tolerance'

Within the *Protection of the Environment Operations Act 1997* (NSW) asbestos waste is defined as 'any waste that contains asbestos'. This has led to a strict interpretation in recent judicial decisions of zero tolerance of asbestos in waste[3], and does not allow for a risk-based approach accounting for volume, proportion and distribution of asbestos found or the medium in which it was detected. The belief that 'one fibre of asbestos can kill' has further supported the concept of 'zero tolerance'. Professor Tim Driscoll, Professor of Epidemiology and Occupational Medicine at the School of Public Health, University of Sydney illustrates this well in his publication *The Use of Asbestos-Contaminated Soil on Barangaroo*. An extract from the review is provided below (Driscoll, 2013).

[3] *Environment Protection Authority v Grafil Pty Ltd; Environment Protection Authority v Mackenzie* [2019] NSWCCA 174 at [325]-[329]; see also *Pullen v Smedley* [2017] NSWSC 1721, *Environment Protection Authority v Foxman Environmental Development Services Pty Ltd* [2015] NSWLEC 105.

> 'The risk of developing an asbestos-related disorder increases with increasing total exposure to respirable asbestos, but low-level exposure can result in both mesothelioma and lung cancer. The commonly used concept that 'one fibre of asbestos can kill' serves to highlight the importance of minimizing exposure to asbestos. However, it is rarely a useful concept when considering approaches to manage risks related to asbestos (or other carcinogenic substances), especially when the vast majority of the Australian population and elsewhere will have a considerable number of fibres in their lungs. It is correct to say that the only way to eliminate the possibility of risk from a carcinogenic exposure is to eliminate the exposure entirely. However, in the case of asbestos, like many other carcinogens, this is often not feasible because it is widespread in the environment, fortunately usually at very low levels. Complete elimination of exposure may be extremely costly, or have significant adverse consequences in other areas. For most carcinogens, including asbestos, exposure at very low levels is likely to result in no discernible increase in the risk of developing any of the diseases of relevance to the exposure. Therefore, for any carcinogenic exposure, including asbestos, the community should (and does) implement exposure control strategies by balancing the health benefits gained from eliminating exposure, the feasibility and costs of such elimination, and the risk of ill health at various levels of exposure.'

One way to balance low-level exposure risk with the feasibility and cost of complete elimination is with threshold levels, in contrast to a 'zero tolerance' approach. The term 'threshold' has a different meaning in environmental, health, and analytical contexts. In an environmental context, a threshold generally represents a certain concentration or limit above which further action is taken to manage the risk of exposure. Examples include the Australian workplace exposure standard for asbestos of an eight-hour time-weighted average (TWA) of 0.1 fibres/mL (a maximum average airborne concentration of asbestos over an eight-hour working day, for a five-day working week) (Safe Work Australia, 2024), and the Health Screening Levels (HSLs) for asbestos-contaminated soils in the National Environment Protection Measures (NEPM) (NEPC, 2013). These thresholds, applied within environmental/occupational settings to minimise the health risks associated with asbestos exposure, reflect a more nuanced understanding of the exposure/risk relationships present in different contexts.

Extensive consultations and stakeholder engagement as part of this Review (including site visits) revealed that, despite best efforts by waste recyclers to reject waste that contains asbestos, there is still a risk of undetected asbestos contamination in accepted loads entering recycling facilities. While the existing zero tolerance approach purports to ensure the complete absence of asbestos, there is still the potential for asbestos to be present in any product intended for beneficial reuse.

1.2.4 Responsibility lies mainly with the recyclers

Through efforts to understand the technical procedures behind asbestos inspection and management processes in C&D recycling, it became apparent that recycling and waste management facilities rely heavily on visual inspection to identify asbestos in mixed waste materials of different sizes and shapes delivered to the facility. This places a heavy reliance on staff experience at a key point in the processing chain: on-site visual inspection of incoming loads. Site visits revealed that staff at various facilities estimated that 1-4 loads per recycler are rejected per day (out of 200-300 loads) at the visual inspection stage due to suspected asbestos, with limited data collection or tracking of the subsequent alternative destination of any load following rejection. The actual number of potential rejected loads is likely much higher, due to applying a 'zero tolerance' approach to a process with inherent human error. In other words, there is a very high likelihood of Type II (false negative) errors when screening incoming loads using this approach. In one submission it was noted that a facility rejected over 1300 loads in a nine-month period, with the drivers directed to leave the site and the information recorded in the facility's rejected loads register as per standard 1.4 (NSW EPA, 2019a). However, the company was only able to identify 8% of these 1300 loads subsequently being received at landfill, raising the question of what happened to the remaining 92%.

This further highlights an emerging issue: the requirement of ’zero tolerance’ for asbestos is predominantly enforced at facilities which accept and process C&D waste in NSW, with some enforcement where the waste is generated. This leads to the responsibility mainly resting on one segment of the value chain and often on a single employee (i.e. those reviewing the load on arrival). A further lack of clarity on the protocol for dealing with unexpected finds of asbestos has led to recyclers using various methods to keep asbestos out of the process, including emu picking. Recyclers shared their frustrations at bearing the risk of asbestos contamination in their products while having relatively little control over waste coming into the facilities. Overall, rather than applying a threshold to waste, recyclers emphasised the need for a pragmatic, workable solution to manage asbestos.

1.3 Review methodology

The methodology for this Review followed established OCSE principles and procedures for independent reviews to deliver formal advice on issues and challenges as requested by the Premier and Ministers. OCSE commenced the review by first establishing an Expert Panel. The Expert Panel was chosen for their specific skills identified in a skills matrix, including experience with asbestos, health, environmental risk assessment, land management, construction, waste, sampling and analysis, and circular economy principles. The role of the Expert Panel was to:

1. Attend and participate in Expert Panel meetings
2. Provide advice on issues, literature, data, technology, and expertise relevant to the Terms of Reference
3. Review, draft sections of, and provide input into the content of the draft and final reports
4. Answer questions that might arise through the course of the project.

In addition, OCSE commissioned three Expert Papers (one on national and international standards and guidelines, one on sampling and analysis of asbestos, and the other on emerging technologies for asbestos detection in waste), organised site visits, and developed the Discussion Paper aimed at seeking feedback, comments and information from stakeholders. These Expert Papers are provided as supporting documents to this report.

This Final Report continues on from the Discussion Paper released as part of the consultation and stakeholder engagement process during the review. It does not revisit the content of the Discussion Paper but draws on the responses to the Discussion Paper (as well as other information) to address the TOR for the Review.

1.3.1 Site visits

OCSE conducted 11 site visits in both metropolitan and regional NSW over the course of this Review, which included a mix of C&D recycling facilities, an asbestos analysis laboratory, organics recycling facilities, and local council depots (Appendix 2). Consultations were conducted as small group meetings and facility tours, often including a walk-through of the waste delivery, inspection, and disposal process. The aims of site visits were to understand:

- the technical procedures of asbestos inspection and management
- place-based management of asbestos in regions across NSW
- the breadth of asbestos contamination in both C&D and other streams.

1.3.2 Submissions

The Review sought submissions from stakeholders on any matter relating to the Review TOR through distribution of a Discussion Paper outlining the scope, background, and key questions to be addressed. A total of 30 submissions were received from individuals, consultancies, recyclers, peak bodies, organisations, and Government agencies. Of these, 13 respondents provided information to OCSE in confidence. The remaining 17 submissions are published on the OCSE website (Appendix 3). Many submissions were of high scientific or observational quality, providing valuable information and insight to inform the Review findings:

- Twenty of the 30 total submissions[4] (i.e. 67% of respondents) expressed support for a through-chain risk-based approach to managing asbestos to minimise asbestos contamination in recycled materials and the environment, reduce the pressure on downstream facilities and landfill capacity, and improve safety throughout the recycling supply chain.
- Most of the submissions supported the identification and segregation of asbestos-contaminated waste at the source as an effective tool and should be prioritised to prevent asbestos from entering the recycling stream. Submissions also indicated that C&D waste entering the recycling stream had a high potential to contain asbestos due to various issues related to poor source separation practices.
- Suggestions in support of through-chain risk-based approaches included controls at several critical points, such as at the demolition sites, residential and DIY renovations and recycling facilities, and making asbestos disposal affordable and convenient.
- However, there were some reservations over the effectiveness of a through-chain risk-based approach. These included the need for additional resources and practical challenges which require extensive coordination between various stakeholders and Government agencies to be addressed.

Other common themes identified in received submissions include:

- Visual detection of asbestos-containing materials (ACMs) remains the key method relied on during load inspections, materials processing and sampling and analysis of end product. Hence, clear guidance, training and competency need to be prioritised to ensure a robust identification, reduction or elimination system.
- Naturally occurring asbestos (NOA) or ACMs have the potential to be found in recycling streams other than C&D, which suggests that this is not a C&D-specific issue.

Submissions provided their insight and opinion on solutions, such as:

- The applicability of adopting the NEPM asbestos soil screening levels for recovered materials for beneficial reuse.
- The challenges of implementing in NSW the Western Australia's *Guideline: Managing asbestos at construction and demolition waste recycling facilities* (WA Waste Guideline)
- Tools and processes that are currently being used to manage asbestos in waste at the recycling facilities, including their limitations and challenges
- Potential new technologies to identify asbestos and future processes that could be applied to manage asbestos
- The importance of training and education as well as standards and guidelines for better asbestos management

Some submissions expressed concern over:

- Inconsistent definitions of asbestos waste and differences in regulatory requirements for asbestos management in Protection of the Environment Operations Act 1997 (POEO Act), Contaminated Land Management Act 1997 (CLM Act) and Work, Health & Safety (WHS) regulations
- Understanding the potential health risks from background exposure level of airborne asbestos
- Potential exposure pathways during identification, segregation, processing and use of end product
- The application and interpretation of current sampling and analysis methodologies
- Sources of asbestos other than C&D waste stream, including NOA, kerbside and organic waste

[4] Note that four submissions expressed some reservations on the approach due to concerns over the requirement of additional resources and extensive coordination between various stakeholders and Government agencies. Six submissions did not provide a specific response to a through chain risk-based approach.

1.4 Process for developing the final report

In the process of conducting this review, OCSE found that the combination of a ’zero tolerance’ approach to asbestos in waste with current sampling and analysis requirements is not achieving the desired outcome of eliminating asbestos in waste for beneficial reuse. Through consultations with stakeholders, the review heard a broad range of views and constructive suggestions for improvement. This is a complex problem to which there are no easy solutions, nor solutions that will work perfectly for everyone. This complexity is echoed in the findings that few, if any, Australian jurisdictions have found complete solutions.

The current sampling approach is clearly insufficient, resulting in Type II (false negative) errors and leading to the presence of asbestos in waste intended for beneficial reuse. A key weakness in the current approach is the reliance on human (i.e. visual) detection in the context of a zero-tolerance approach, focused largely on a single point in the supply chain. To address this, OCSE mapped out the supply chain from the creation of C&D waste through to a product sourced from recovered fines and materials for beneficial reuse. OCSE then considered the supply chain through the perspective of the Swiss Cheese Model (SCM). The SCM provides a systematic approach to identify risks within a complex system and implement controls to mitigate these risks (Shabani, Jerie, & Shabani, 2024). The model’s core concept recognises the importance of redundancy in critical systems. In brief, multiple layers of defence, represented as slices of cheese with holes (potential weaknesses or failed defences), reduce the likelihood of active failures and their consequences in a system (i.e. holes aligning for failure).

While the SCM is not the only conceptual lens through which to view risk (Larouzee & Le Coze, 2020), it does provide a useful tool to help consider the risks associated with asbestos and guide potential risk management. Applying this framework – relying on research, site visits, stakeholder submissions, and Expert Panel input to identify the main risks associated with recycling C&D waste for beneficial reuse – led the review to consider a through-chain risk-based approach.

A through-chain risk-based approach is a systematic risk management approach that focuses on identifying, assessing and managing risks at each stage of the value chain. An example of this approach is the application of Hazard Analysis and Critical Control Points (HAACP) in the food industry, where food safety is addressed through the control of biological, chemical and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the final product. A through-chain risk-based approach to manage asbestos in recycled materials encompassing the entire process – from where waste is generated at the source through to the end use of the product – is considered in the report. This approach focuses on elimination or reduction of asbestos as much as possible at every step in the value chain. Importantly, the approach also requires monitoring and verification procedures, record-keeping and documentation, as well as corrective actions to ensure appropriate steps are taken when a deviation occurs.

The findings and recommendations therefore reflect a position of addressing the problem through the lens of a through-chain risk-based approach. Emphasis on eliminating and reducing at all stages, including through source separation, will likely provide better outcomes for managing asbestos in recovered materials and fines. It is important to highlight that dilution[5] is never the intention of this approach and is not supported.

Chapter 2 starts with a discussion and findings on the use of thresholds in waste for beneficial reuse, followed by discussion on sampling and analysis in Chapter3. Chapter 4 develops the concept of a through-chain risk-based approach and examines how thresholds and appropriate sampling and analysis methods can support this approach. Chapter 6 examines how a through-chain risk-based approach might work across industry and government with a common goal to eliminate and/or reduce asbestos across the supply chain, while supporting reuse (i.e. circular economy) and minimising landfill.

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[5] Dilution is the act of mixing materials into an existing stockpile to generate a product that meets specified criteria (i.e. dilution reduces the asbestos concentration in whole stockpile).

While the Review focuses on C&D waste, the presence of asbestos in recycled materials other than C&D end products indicates that asbestos contamination is not a C&D-specific problem. The advice herein also includes any existing and/or potential uses of thresholds and associated sampling and analysis requirements for asbestos in soils and other products intended for beneficial reuse (i.e. the end products of waste recycling). Therefore, OCSE considered relevant information and research associated with other waste streams to better inform the management of asbestos in potential beneficial reuse of C&D waste, as well as information on the end uses of waste, soils and other products of waste recycling.

1.5 Asbestos definitions and categories

Asbestos can be defined and categorised in different ways based on the mineralogy, type and forms of the products containing asbestos (e.g. friable or non-friable), sizes (e.g. fibre bundles or discrete fibres) and degrees of friability. This results in various terminologies used for different contexts (e.g. NEPM/ WA Waste Guideline and WHS), with some overlapping definitions. This may cause confusion when discussing threshold levels for asbestos and whether a threshold refers to regulated commercial asbestos fibres, asbestiform fibres in general, asbestos-containing products and materials (e.g. asbestos cement sheet). For consistency and clarity, the following definitions of asbestos and forms of asbestos will be used throughout the Review (see Table 1 below).

Table 1: Definitions of asbestos and forms of asbestos used in this Review

Asbestos and forms of asbestos	Description	Source
Asbestos	The asbestiform varieties of mineral silicates belonging to the serpentine (chrysotile [white]) and amphibole groups of rock- forming minerals, including actinolite, amosite (brown asbestos), anthophyllite, crocidolite (blue asbestos), tremolite, or any mixture of these	WHS Regulation and WA DOH
Asbestos-containing material (ACM)	Any material or thing that, as part of its design contains asbestos	WHS Act
Asbestos equivalents	The sum of the concentration of chrysotile asbestos and 10 times the concentration of amphibole asbestos, for bound (non-friable) as well as for friable asbestos	Swartjes & Tromp (2008)
Asbestos fines	All asbestos or ACMs, including loose fibre bundles and fragments of non-friable material that are smaller than 7mm x 7mm mixed/found in soil or waste	WA DOH
Asbestos waste (in WHS context)	Asbestos or ACM removed and disposable items used during asbestos removal work including plastic sheeting and disposable tools*	WHS Regulation reg 5
Bonded ACM	Materials that contain asbestos in an inert bound matrix such as cement or resin. Related to bonded, non-friable material greater than 7 mm x 7 mm mixed/found in soil or waste	WA DOH
Fibrous asbestos	Asbestos products or materials that are friable (e.g. loose insulation) or have become severely degraded or damaged such that they are partly or completely friable	WA DOH

Asbestos and forms of asbestos	Description	Source
Friable asbestos	Material that contains asbestos and is in a powder form or that can be crumbled, pulverised or reduced to a powder by hand pressure when dry	WHS Regulation
Naturally occurring asbestos (NOA)	The natural geological occurrence of asbestos minerals found in association with geological deposits including rock, sediment or soil	WHS Regulation s 5
Non-friable asbestos	Material containing asbestos that is not friable asbestos, including material containing asbestos fibres reinforced with a bonding compound. Non-friable asbestos may become friable asbestos through deterioration (see the definition of friable asbestos)	WHS Regulation

*Note: The WHS law considers all disposable items used during asbestos removal work as asbestos waste. This means specific requirements apply to the asbestos or ACM removed, including all disposable items used.
Sources: Refer to WA Soil Guidelines (WA DOH, 2021); WHS Regulation – Work Health and Safety Regulation 2017 (NSW).

2. Thresholds in combination with other processes are applied in some jurisdictions

This chapter explores thresholds and their use when managing asbestos in recovered fines and materials for beneficial reuse, seeking to address TOR 1 and 2. It starts by exploring the concept of thresholds, and reviewing national and international approaches where they are used to manage asbestos in waste for reuse. While the main focus of these is on environmental management, the review also explores the use of thresholds to manage workplace exposure to respirable airborne asbestos fibres. The review considers other factors relevant for setting these thresholds, and reviews the available evidence for these factors and potential reuse scenarios – noting areas where evidence is lacking or absent.

Findings regarding thresholds are presented in full at the end of this chapter and a set of recommendations will be made in Chapter 5. In short, it was found that several Australian jurisdictions have concentration thresholds for asbestos in waste: 0.001% w/w in WA, and 0.01% w/w in Queensland. Similar thresholds are used in countries such as Germany, the Netherlands and Belgium. These thresholds are generally either based on the limit of detection for a specific method of analysis, or on the Dutch study by Swartjes and Tromp in 2008 which found that asbestos concentrations below 0.01% w/w in soil were unlikely to result in significant levels of respirable fibres (Swartjes & Tromp, 2008).

There is no direct evidence correlating asbestos concentration in waste to asbestos-related disease occurrence. Health-related evidence used to support thresholds is based on predicted disease risk from inhalation of asbestos fibres, combined with models and studies quantifying how many fibres are released from various concentrations of asbestos in soils and other media. The available evidence suggests that asbestos soil concentrations below 0.01% are unlikely to generate airborne fibres above 0.01 Fibres/mL (f/mL). Additional safety factors may need to be considered for thresholds in waste and recovered materials, in consideration of their different properties compared to soil.

2.1 Definitions of 'threshold' depend on context

In environmental management, a threshold level generally represents a defined concentration of a contaminant in a material (such as waste) that, when exceeded, triggers actions to manage that material and risk. Currently, asbestos management across various jurisdictions involves complex and inconsistent threshold definitions. Thresholds vary in how 'asbestos' is defined and categorised, based on its form (such as bonded or friable) and how any concentration is determined. Some thresholds are expressed as a 'presence/absence' binary (occasionally directly linked to a limit of reporting of the detection method), whereas others use specified concentration limits.

There are also different implications for actions triggered when a threshold is exceeded – some thresholds may categorise waste as 'hazardous' or 'asbestos waste', whereas others may explicitly consider materials below the level as 'safe', 'end of waste' or otherwise 'asbestos-free'. They could also be used as a screening level that prompts further action, investigation or risk assessment. This is important because the nuances of these definitions result in different safety implications, demanding varying levels of supporting evidence and requiring different risk management strategies in addition to the threshold levels themselves.

Accordingly, while this chapter will explore the use of thresholds for asbestos in waste generally, a specific focus is made on where thresholds have been used to define a 'safe' concentration limit for reuse, as well as the evidence that would support this.

2.2 National and international approaches

This section explores the use of asbestos thresholds within Australia and internationally, with a focus on thresholds in waste for reuse. The review found that there is inconsistency across Australia relating to when waste is considered 'asbestos waste' or to 'contain asbestos', and among different regulatory schemes for contaminated land management, waste and WHS. This results in considerable confusion and lack of clarity around handling requirements for materials and when they may be reused. For waste specifically, some states (such as WA and Qld) have imposed concentration thresholds ranging from 0.001% w/w to 0.01% w/w, which could be seen as a tolerable threshold level for asbestos in reused materials. Similarly, several international jurisdictions have also set threshold levels ranging from 0.001% w/w to 0.01% w/w, some of which are used to define the material as 'asbestos free'.

2.2.1 Literature Review - crcCARE Paper SD1

OCSE engaged crcCARE to undertake a literature review of national and international standards and guidelines, particularly where threshold levels in waste for recycling have been established (see *Literature Review – National and International Standards and Guidelines for Asbestos Threshold Levels in Waste, Supporting Document 1 (crcCARE paper SD1)*). crcCARE reviewed information from national and international environmental agencies. Countries included in the review were chosen where their historical use of asbestos is similar to Australia and included New Zealand, European and North American jurisdictions. crcCARE also undertook a literature search on asbestos thresholds in recycled waste material. The review included engaging with national and international jurisdictions and/or reviewing information published on agencies' website. Wherever possible, crcCARE sought to confirm information sourced although in some situation this wasn't possible.

The crcCARE paper SD1 found there were a number of approaches to managing asbestos in waste for beneficial reuse: nil tolerance; threshold based on the NEPM HSLs values; threshold based on the limit of detection for the method of analysis prescribed; and a threshold based on Swartjes & Tromp (2008). Below is a summary of environmental and WHS management of asbestos in selected Australian and international jurisdictions based on the crcCARE paper SD1 and further research undertaken by OCSE and the Expert Panel.

2.2.2 Australian approaches

There is little consistency within NSW or across Australia regarding definitions of asbestos waste in an environmental or waste management context. Unlike the harmonised WHS regime, which includes a consistent definition for asbestos waste in the context of asbestos removal work, different states have different requirements for what is considered asbestos waste, or another special category of waste such as hazardous or restricted waste. The category of waste dictates its subsequent fate (i.e. whether it can be reused) and any special handling, transport or disposal requirements. These different definitions and requirements may therefore result in considerable confusion about the permissible reuse of waste that may contain trace levels of asbestos.

WA and Queensland are the only two jurisdictions with an explicit numerical threshold for asbestos in waste. In both states, the threshold defines a level below which the waste is no longer regulated as waste that contains asbestos – i.e. not subject to any special (asbestos-related) requirements or restrictions. While this is not a threshold for *reuse* specifically, it could mean that the waste can then be reused per any specific requirements, policies or laws around waste reuse/end of waste.

In all other states and territories apart from NSW, the criteria for defining asbestos waste are less clear. Most jurisdictions simply list asbestos or materials that contain asbestos as a controlled waste (or equivalent). Accordingly, while materials such as asbestos fibres or ACM (e.g. a piece of asbestos cement fragment) are clearly considered controlled waste, there remains some ambiguity regarding what else would be included as asbestos when defining asbestos waste. For example, these states do not specify whether waste that contains a small amount of asbestos, such as a volume of soil (e.g. stockpile or load) with a small piece of ACM in it, categorises the entire volume of soil as asbestos waste. This leads to further confusion when assessing management of asbestos waste. There is also inconsistency amongst states regarding tracking and reporting of waste code N220 (waste asbestos) under the Controlled Waste NEPM.

Thresholds in New South Wales

In NSW, asbestos waste is currently defined in the *Protection of the Environment Operations Act 1997* (NSW) ('POEO Act') s 50 as 'any waste that contains asbestos'. This has been interpreted judicially to mean that *any* amount of asbestos in waste renders it asbestos waste, regardless of the absolute amount of asbestos or its relative proportion[6]. This means that functionally, NSW has a threshold level of zero – one fibre of asbestos in the waste, if detected, would classify the waste as 'special waste – asbestos waste' (with no waste volume limit to which this categorisation would apply) and thus attract the special requirements for asbestos waste contained in the POEO Act and *Protection of the Environment Operations (Waste) Regulation 2014* ("Waste Regulation").

The POEO Act contains a number of these special requirements and offences for asbestos waste. Asbestos waste that is disposed off-site from where it was generated must be disposed of at a place that can lawfully receive the waste and it is an offence to do otherwise (POEO Act s 144AAA). It is also an offence to 'cause or permit asbestos waste in any form to be re-used or recycled' (POEO Act s 144AAB). The latter offence was previously introduced in a 2008 amendment[7] to cl 42(5) of the (now repealed) *Protection of the Environment Operations (Waste) Regulation 2005* (NSW), meaning the general prohibition against all reuse has been in place since 2008.

Despite the above, it is currently possible to reuse materials with trace levels of asbestos in NSW, such as asbestos-contaminated soils, in limited circumstances where the materials do not fall within the statutory definition of 'asbestos waste' (including more broadly the associated definition of 'waste'), or where doing so would not attract the relevant asbestos-related offences. One example is when asbestos waste is disposed of on-site, which is not an offence under s 144AAA. This allows the remediation of significantly contaminated lands (arising from on-site contamination) under the CLM Act. The NSW Environment Protection Authority (EPA) also has discretion in the decision to prosecute any offences contained in the POEO Act and may pursue non-prosecution options where doing so is in the public interest (NSW EPA, 2022d).

An example of reuse is excavated asbestos-contaminated soil in the construction of the Barangaroo Headland Park (now called Barangaroo Reserve). The original Ecological Risk Assessment produced for Barangaroo allowed for materials containing up to 1% w/w asbestos excavated from the Barangaroo site to be reused at Headland Park, provided it was buried more than 0.5 metres under the surface (Driscoll, 2013). The asbestos contamination primarily consisted of historical building material such as non-friable (i.e. bonded) asbestos sheeting and builders' waste, which had been previously used to fill in the wharves.

Once excavation commenced, levels of asbestos contamination were found to be much higher than initially expected and the Resource Recovery Exemption for the material was revoked by the NSW EPA. An independent review was commissioned which ultimately recommended that it was acceptable to reuse and re-work remediated soil previously contaminated with asbestos, albeit at a much lower concentration than the initial 1% w/w limit. The review recommended that only material previously contaminated with less than 0.001% asbestos by weight (bonded ACM less than 0.006%, assuming 15% of the ACM by weight is asbestos) should be re-used, and not material previously contaminated with friable asbestos. The review noted that '0.001% for asbestos in soil should provide levels of risk of asbestos-related disease well below levels of risk generally considered 'acceptable' in an occupational or public setting,' but that the difficulty in accurately measuring fibrous asbestos meant it was better to dispose of soil that contained any fibrous asbestos and asbestos fines.

Thresholds in Western Australia

In *Guidelines for the Assessment, Remediation and Management of Asbestos Contaminated Sites* in Western Australia (WA Soil Guidelines) (2009), the WA Department of Health (WA DOH) derived a threshold for the asbestos level in soil based on a Dutch study by Swartjes and Tromp (2008) (see Section 2.2.3 for further information). WA DOH used the same screening level of 0.01% w/w for non-friable asbestos in soil but applied 0.001% (w/w) to both fibrous asbestos and asbestos fines in

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[6] *Environment Protection Authority v Grafil Pty Ltd; Environment Protection Authority v Mackenzie* [2019] NSWCCA 174 at [325]; see also *Pullen v Smedley* [2017] NSWSC 1721 and *Environment Protection Authority v Foxman Environmental Development Services Pty Ltd* [2015] NSWLEC 105.

[7] *Protection of the Environment Operations Amendment (Scheduled Activities and Waste) Regulation 2008* (NSW).

consideration of the dryness of WA soils and the fact that the current WHS exposure standards treat the different mineralogical forms of asbestos as equivalent. These Guidelines were updated in 2021.

The *Environmental (Controlled Waste) Regulations 2004* (WA) identify material that contains 0.001% (w/w) or more of asbestos fibres as controlled waste. In the regulations, material containing asbestos is defined as 'material –

(a) which contains 0.001% or more of asbestos fibres weight/weight; and
(b) in which fibrous material is able to be detected by stereoscopic light microscopy at a magnification of not less than 10 times and not greater than 40 times; and
(c) in which the fibrous material is able to be identified as asbestos by polarised light microscopy at a magnification of not greater than 400 times or by a method approved by the Chief Health Officer under the Health (Miscellaneous Provisions) Act 1911.'

The WA Waste Guideline specifies an asbestos threshold (in any form) in recycled C&D product of 0.001% (w/w). The total asbestos content is related to total asbestos concentration from ACM and FA in waste materials and laboratory investigation using asbestos identification analytical techniques. The guidance outlines a risk-based approach that includes inspections and procedures based on likelihood for material to contain asbestos, validation testing and interpretation of sample results using a line-of-evidence approach.

Thresholds in Queensland

In Queensland, waste containing asbestos is primarily regulated by the *Environmental Protection Regulation 2019* (Qld). Asbestos defaults to being a 'category 2 regulated waste' per Schedule 9 Part 1 of the regulation, however under the waste framework, waste that is sampled and tested by an 'appropriately qualified person', such as staff of a National Association of Testing Authorities (NATA)-accredited laboratory (Queensland Government, 2024b), becomes a 'tested waste' and can be transported, processed or disposed of as the category of waste it became through the testing process, per reg 42(4). Under Schedule 9 Part 3 Division 2, a tested waste can become a 'non-regulated' waste (i.e. ordinary waste), provided that test results show that 'asbestos more than 0.01% (w/w)' is 'not present'. Accordingly, waste that is tested and contains less than 0.01% w/w asbestos is a non-regulated waste and can be treated as such.

The 0.01% w/w threshold was included in the legislation through the *Environmental Protection (Regulated Waste) Amendment Regulation 2018* (Qld), following industry consultation which proposed the introduction of a risk-based classification criteria for asbestos based on the NEPM's HSL values (Queensland Government, 2018). Notably, the 0.01% w/w value is not based on the limit of detection for asbestos, in contrast to Per- and polyfluoroalkyl substances (PFAS) and other persistent organic pollutants (POPs) which both have a defined concentration threshold of 0 mg/kg or µg/L respectively, per Schedule 9 Part 3 Division 2. This threshold of zero for PFAS and POPs is explicitly defined to mean less than the level of reporting limit, provided that the testing uses a NATA-accredited test method for that parameter, and the test selected has a limit of reporting (LOR)[8] that is the best achievable for that parameter (Queensland Government, 2024b).

While this process changes the category of waste from regulated to non-regulated, it does not remove the waste from other waste management controls, and there is no direct link to Queensland's End of Waste (EOW) Framework under the *Waste Reduction and Recycling Act 2011* (Qld). The EOW framework allows waste which meet certain quality criteria for a specified use to become an 'EOW resource' and to be removed from waste management controls. However, no relevant EOW codes could be found for construction and demolition waste or other categories of waste that may potentially contain asbestos (Queensland Government, 2024a).

[8] See Table 6 in 3.1.2 for further explanation on LOR.

Thresholds in Victoria

In Victoria, waste containing asbestos is referred to as waste asbestos. The Vic EPA regulates the disposal of waste asbestos, whether of domestic or industrial origin, under the *Environment Protection Regulations 2021* (Vic). Waste asbestos is a ’reportable priority waste’ and must be disposed of at licensed landfills. At present, waste asbestos is formally categorised under the environment protection scheme as either ‘packaged waste asbestos’, or ’soil containing asbestos only’.

‘Packaged waste asbestos’ is defined in Schedule 6 as waste asbestos (other than soil containing asbestos) contained in a manner so as to eliminate the release of airborne asbestos fibres, whereas ’soil containing asbestos only’ is defined as industrial waste that is soil that (a) contains asbestos, and (b) does not contain any contamination concentration exceeding the upper limits for fill material contaminant concentrations specified in *Waste Disposal Categories – Characteristics and Thresholds* (EPA Victoria, 2021). Neither definition specifies any threshold level for asbestos.

Separately, the management and removal of asbestos in workplaces is regulated by the *Occupational Health and Safety Regulations 2017* (Vic) (OHS Regulations). Victoria is the only state that has not implemented the harmonised WHS regime, which is discussed in the next section. reg 206 of the Victorian OHS Regulations excludes C&D waste of which less than 0.001% is asbestos-containing material from OHS requirements. The sampling and analysis method to measure the amount of asbestos was published in *Victoria Government Gazette No. S 253* Dated 31 December 2003 (Victorian Government, 2003). The *Gazette* clarifies that ’0.001%’ refers to “the percentage of construction materials that is asbestos-containing material” (i.e. not asbestos equivalents) and is determined based on a gravimetric analysis by weighing visually identified ACM that is deemed to contain asbestos or identified as asbestos-containing by an approved analyst, i.e. from a NATA accredited laboratory. The method is also referred to in WorkSafe Victoria’s guidance on Recycling Construction and Demolition Material (WorkSafe Victoria, 2007).

The OHS reg 217(2) also exclude soil from which ACM has been removed, so far as is reasonably practicable, by the person supplying, storing, selling, using or re-using the soil. This is done by visual inspection only. There is currently no formal requirement to test soil for the presence of asbestos fibres once the visible asbestos has been removed, although stakeholders indicated that WorkSafe Victoria is presently reviewing this aspect.

There has been little case law interpreting how the requirements and thresholds in the OHS Regulations, including the 0.001% w/w threshold, interact with the separate environment protection regulatory scheme regulating waste. The exclusion of soil by reg 217 of the OHS Regulations is cited as the relevant definition for soil that does not contain asbestos in Vic EPA’s Waste Disposal Categories – Characteristics and Thresholds (EPA Victoria, 2021), which suggests that the OHS thresholds and requirements do apply directly to waste as well. Accordingly, once the visible ACM is removed from the soil, so far as is reasonably practicable, the soil under the waste framework is no longer classified as ’soil containing asbestos only’ (becoming, for example, “fill material”) and thus can be reused (EPA Victoria, 2021).

This interpretation was also supported in *Greater Geelong CC v C & D Recycling Pty Ltd (Red Dot)* [2018] VCAT 831, where over 350,000 m^3 of mixed C&D waste was stockpiled at a materials recycling facility, in contravention of several permit conditions. Some of the stockpiles contained asbestos, though the extent of asbestos was unclear. An Asbestos Investigation Report confirmed the presence of asbestos in two samples of fines stockpiled on the site, albeit ’below the relevant regulatory standards’ (citing the reg 206 exclusion of C&D waste with less than 0.001% ACM) (at [25]). The tribunal opted against cancelling the permit (which would cause the entire waste stockpile on the site to be disposed of at a landfill) as there was still an opportunity for some of the material to be recycled or for alternative reuse or treatment options to be fully explored. The tribunal then ordered a staged enforcement approach involving a sampling program to determine the content and characteristics of all the stockpiles. While this case is not authoritative on this point, it suggests that the 0.001% threshold included in the OHS Regulations is also viewed as the relevant threshold for what would be considered ’waste asbestos’ in Victoria. The site was later remediated by EPA Victoria at a cost of $71m and with only 10% of the waste recycled due to widespread contamination with small pieces of non-friable asbestos (Jaeger, Gordon, & Vedelago, 2022; EPA Victoria, 2022).

Work Health and Safety regulation of asbestos

Any potential use or reuse of materials potentially containing asbestos is subject to requirements contained in relevant WHS laws. All states apart from Victoria (see above) have implemented the harmonised WHS regime which defines and regulates 'asbestos waste' and 'asbestos containing material' in a WHS context. In NSW, this is contained in the *Work Health and Safety Act 2011* (NSW) (WHS Act) and accompanying *Work Health and Safety Regulation 2017* (NSW) (WHS Regulation)[9].

The WHS regime generally imposes a risk-based approach to the management of worker health and safety. A core aspect of the WHS regulation is the imposition of duties to ensure the health and safety of workers 'so far as is reasonably practicable'. Accordingly, this requires an assessment weighing up 'all relevant matters' such as the likelihood of hazard occurring, degree of harm, the availability and suitability of ways to eliminate the risk, and the cost associated with eliminating or minimising the risk. As part of this risk-based approach, the WHS regulation of asbestos includes specific requirements to eliminate (or where elimination is not possible, to minimise) the exposure of people working with asbestos, imposing airborne concentration thresholds as maximum statutory limits.

Chapter 3, Division 7 of the WHS Regulation concerns managing risks from airborne contaminants, including asbestos. This imposes a duty upon a 'person conducting a business or undertaking' (PCBU) to 'ensure that no person at the workplace is exposed to a substance or mixture in an airborne concentration that exceeds the exposure standard for the substance or mixture'. As defined in reg 5 of the WHS Regulation, the 'exposure standard' refers to the document *Workplace Exposure Standards for Airborne Contaminants* (Safe Work Australia, 2024)which sets the workplace exposure standard (WES) for asbestos in air as 0.1 fibres/mL (TWA)[10]. Australia is now transitioning to using workplace exposure limits (WEL), which will be implemented from 1 December 2026 to align with international practice and better reflect the requirements of the WHS laws (Safe Work Australia, 2024). The WEL for asbestos remains unchanged.

Safe Work Australia has released guidance on the interpretation of the workplace exposure standards, in which they clarify that this limit does not define a healthy or unhealthy working environment, nor an acceptable level of exposure to workers (Safe Work Australia, 2024). The limit only establishes a statutory maximum upper limit. All reasonably practicable steps must be taken to minimise the exposure level, and reg 50 of the WHS Regulation imposes a duty to monitor airborne contaminant levels where necessary to determine whether there is a risk to health. Air monitoring is conducted by taking air samples within the breathing zone of the worker. The total sample duration should aim to collect a sample that is representative of the period in question, usually an entire shift. If respiratory protective equipment (RPE) must be worn to minimise the risk of exposure, its effectiveness can be taken into account when assessing compliance, provided all other controls have been implemented and the RPE is worn correctly.

In addition to the general duties and those for airborne contaminants, the WHS Regulation Chapter 8 regulates work involving asbestos or ACM and contains many duties specific to asbestos. Reg 419 prohibits all 'work involving asbestos', which is broadly defined to include 'manufacturing, supplying, transporting, storing, removing, using, installing, handling, treating, disposing of or disturbing asbestos or ACM.' This prohibition is then subject to a wide range of exemptions, including work done in accordance with other requirements in Chapter 8 (including licensing), work where the regulator (SafeWork NSW) approves a method for managing risk, or for the transport and disposal of asbestos or asbestos waste in accordance with the POEO Act. Notably, the prohibition also exempts soil which does not contain any visible ACM or friable asbestos, or if friable asbestos is visible, does not contain more than 'trace levels' determined in accordance with AS 4964:2004 (see Section 3.1.2 for more details).

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[9] For simplicity all references throughout are to the NSW legislation, although the requirements in other states and territories are generally the same.

[10] "Fibres longer than 5 µm, width less than 3 µm and with an aspect ratio of not less than 3:1, as measured by the membrane filter method, at 400-650X magnification using phase contrast microscopy."

Chapter 8 then contains many duties related to work involving asbestos. Workers who are likely to be exposed to asbestos must be informed of the health risks and trained in the identification and safe handling of asbestos, and health monitoring must be provided prior to starting work with asbestos. Employers must first ensure the exposure to airborne asbestos is eliminated. If it cannot be eliminated, the exposure must be minimised as far as is reasonably practicable, and the exposure limit must not be exceeded. There is also a duty to ensure that all asbestos or ACM at the workplace is identified by a competent person. Analysis to confirm the presence or absence of asbestos fibres must be done by a laboratory accredited by NATA to the relevant test method, or a laboratory operated by the regulator.

The WHS Regulation establishes a licensing scheme regulating asbestos removal work. The removal of less than 10 m^2 of non-friable asbestos or ACM does not require a licence. The removal of greater than 10 m^2, or of friable asbestos, requires a licensed asbestos removal contractor (with either a Class A or Class B licence) (Table 2).

Table 2: Overview of WHS licensing requirements for asbestos-related work in NSW.

		Removal of less than 10 m^2 non-friable asbestos or ACM	Removal of greater than 10 m^2 non-friable asbestos or ACM	Removal of friable asbestos
Removal by workers	No licence required	✓		
	Class A Removalist	✓	✓	✓
	Class B Removalist	✓	✓	

Domestic removal work by DIY home renovators is not subject to many of the requirements in the WHS Act or Regulation, as homeowners doing work themselves are not considered workers or PCBUs. However, the removal of > 10 m^2 of non-friable asbestos, or any amount of friable asbestos, is 'prescribed asbestos removal work' under the *Environmental Planning and Assessment Regulation 2021* (NSW) reg 152. Any complying development certificate[11] for building or demolition work must be issued subject to the condition that this prescribed asbestos removal work is undertaken by a licensed removalist per the WHS requirements. It must also specify the landfill site which may lawfully receive asbestos to which the waste will be delivered.

Other states and territories, such as the ACT and Queensland have also extended the WHS licensing requirements to cover homeowners as well (ASEA, 2022). WA's *Health (Asbestos) Regulations 1992* have some prohibitions and require reasonable precautions, but do not yet require licensing for home owners and currently promote the use of licensed removalists. Asbestos removal work in recycling facilities is subject to the WHS licensing requirements, so greater clarification or guidance may be required to determine whether and how the 10 m^2 threshold is exceeded in process work.

Airborne asbestos fibre monitoring can be used during and after asbestos removals to assess the effectiveness of control measures. For friable removals, the air monitoring is a mandatory requirement and must be undertaken by a licensed asbestos assessor. This involves static measurement of airborne asbestos fibres in static, or fixed locations. If results are greater than 0.01 f/mL, various actions are required. It is noted that results of static sampling cannot be compared to the workplace exposure standard for asbestos. Where the level is elevated, corrective action needs to be taken. The removal work needs to be stopped immediately and SafeWork NSW must be notified if air monitoring results are greater than 0.02 f/mL.

[11] "Complying development" is defined in the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (NSW) and includes some major residential building works such as renovating an existing house.

Following licensed asbestos removal work a clearance inspection must be performed by a licensed asbestos assessor or competent person who issues a clearance certificate. Per reg 473–474, it is only necessary to do a visual inspection of the removal area and vicinity of the removal area during the clearance inspection. To issue a clearance certificate, the licensed asbestos assessor or competent person must ensure the removal area does not pose a risk to health and safety, and the area must be free from visible asbestos contamination. Airborne fibre monitoring is required during friable asbestos removal, and per reg 474 and 477(4) is mandated for friable asbestos removal when an enclosure is used (which should be on most occasions). If air monitoring is performed as part of the inspection, the airborne asbestos fibre level must be below 0.01 f/mL.

The WHS regime imposes handling requirements for ’asbestos waste’, which is defined in reg 5 of the WHS Regulation as ’asbestos or ACM removed and disposable items used during asbestos removal work including plastic sheeting and disposable tools’.

As was noted by stakeholders, there are some inconsistencies between the WHS regime outlined above, and the requirements for asbestos waste contained in the POEO Act and Waste Regulation in NSW. The presence of a clearance certificate does not guarantee that all asbestos, whether residual or not, has been removed from a site. Visual inspection assesses for visible remaining asbestos materials and residues from the asbestos removal works only. While it does provide assurance that the work area is safe to be reoccupied, there is potential for clearance certificates to be misinterpreted as meaning that materials are free from asbestos. This is potentially an issue due to the different definitions of asbestos waste between WHS legislation and the POEO Act.

National ‘ban’ on asbestos

From 31 Dec 2003, all uses of chrysotile (white) asbestos were prohibited by the *National Code of Practice for the Control of Workplace Hazardous Substances*, subject to limited exceptions. This was originally contained in the *Amendments to Schedule 2 of the National Model Regulations for the Control of Workplace Hazardous Substances (Prohibition of Asbestos) 2001* (NOHSC, 2001).

This was given effect in legislation in each state and territory. For example, the (now repealed) *Occupational Health and Safety Regulation 2001* (NSW) listed amosite, chrysotile and crocidolite as a ’prohibited carcinogenic substance’ in division 3 reg 158, and in reg 159 made it an offence to supply carcinogenic substances, including ’an item that contains any form of asbestos that is a prohibited carcinogenic substance’. Reg 164 also made it an offence to use these substances. Both offences had limited exemptions.

While the above regulations have since been repealed following the implementation of the harmonised WHS legislation, the latter still contains a general prohibition on ‘work involving asbestos’ (which includes use and supply). There are then exemptions to the general prohibition, including an ability for the regulator (SafeWork NSW) to approve a method for managing risk. This means that asbestos is not strictly ‘banned’ but instead, all work involving asbestos and ACM is heavily regulated. The NSW WHS Regulation already exempts soil if there is no visible asbestos, or if visible, contains less than ‘trace levels’ of asbestos from this general prohibition. Similar mechanisms could be used to exempt recovered materials or impose requirements and methods to manage the risk, should a threshold be implemented. Notwithstanding the above, the importation of asbestos into Australia is currently banned under the *Customs (Prohibited Imports) Regulations 2015* (Cth).

Asbestos in soil

As outlined in the discussion paper, the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPM) specifies a range of HSLs for the management of asbestos in soil. These HSLs are concentrations of asbestos above which further investigation and a risk-based assessment will be required. The HSLs for asbestos vary across different intended land uses and forms of asbestos (Table 3). The use of the screening levels is to assess the site contamination and to determine whether further actions are required (NEPM). Any signs of visible asbestos will trigger further investigation and evaluation. When the soil screening level for a particular land use is not exceeded, no contamination management actions are necessary besides ensuring the surface soil is free of visible asbestos.

Table 3: Asbestos in soil: Health Screening Level

Form	Health Screening Level (w/w)			
	Residential A	**Residential B**	**Recreational C**	**Commercial/Industrial D**
	Residential A with garden/accessible soil also includes children's day care centres, preschools and primary schools	Residential B with minimal opportunities for soil access includes dwelling with fully and permanently paved yard space such as high-rise building and apartments	Recreational C includes public open space such as parks, playgrounds, playing fields (e.g. ovals), secondary schools and unpaved footpaths	Commercial/industrial D includes premises such as shops, offices, factories and industrial sites
Bonded ACM	0.01%	0.04%	0.02%	0.05%
Fibrous Asbestos	0.001%			
Asbestos Fines	0.001%			
All forms of asbestos	No visible asbestos for surface soil (top 10 cm)			

The HSLs in the NEPM were adopted from the WA Soil Guidelines (discussed above in Section2.2.2). The asbestos concentrations refer to the amount of asbestos equivalent in a measured amount of soil. For bonded ACM, the NEPM recommends gravimetric determination employing an estimation of the percentage asbestos content in the ACM, which may be estimated from product manufacturing data or by bulk material laboratory analysis (e.g. 10–15% asbestos content by weight is attributed to asbestos cement fence or roofs).

While the NEPM specifies a HSL of 0.001% for both fibrous asbestos and asbestos fines (i.e. <7mm x 7mm non-bonded/friable ACM), this applies where the asbestos in fibrous asbestos or asbestos fines collected from a sample of the host material (e.g. soil or waste) can be gravimetrically estimated/quantified (i.e. from field-based sampling or in the sample preparation steps of AS 4964). The NEPM notes that:

> 'As yet there is no validated method, readily available in Australia, of reliably estimating the concentration of free asbestos fibres in soil. Soil contamination by free asbestos fibres should therefore be simply determined according to the presence or absence of fibres, in accordance with AS4964 –2004' …

Many stakeholders provided feedback on whether they supported the HSLs contained in the NEPM being used as a tolerable threshold level for asbestos in waste and recovered materials. Eight out of 22 submissions supported the HSLs being used for waste, five did not support, and the remainder either partially supported or did not answer the question.

Most submissions that supported the use of HSLs appeared to support the broader concept of evidence-based thresholds generally in the context of NSW's current zero tolerance approach to asbestos in waste, rather than specifically supporting the actual HSL values of 0.001–0.05% w/w. The zero-tolerance approach was seen as impractical, incompatible with analysis methods (AS 4964:2004), and not reflective of the actual risk. In contrast, the NEPM's HSLs were viewed as a practical, risk-based approach with a robust scientific basis (based on the Swartjes & Tromp study, discussed below in

Section2.3.1). Some thought it was desirable to have a consistent approach for materials with identical contact and use profiles, such as soils and some recovered materials.

In contrast, those that did not support or only partially supported the use of HSLs for waste and recovered materials generally highlighted their different characteristics as compared to soils, such as heterogeneity, typical concentrations of asbestos, distribution profiles, handling practices, moisture levels, and exposure pathways (both in-process and end-use). Many believed that these different characteristics resulted in different risk profiles, such that the specific HSLs contained in the NEPM may not be directly applicable to their use for waste.

2.2.3 International approaches

Many countries have implemented threshold concentration limits for materials with asbestos that classify the materials as hazardous (or equivalent). This section mainly focuses on international jurisdictions that have implemented a tolerable threshold specifically for asbestos in reused materials.

European Union (EU)

Annex III of the Waste Framework Directive 2008/98/EC classifies waste containing a mass content of greater than 0.1% of a class 1A/1B carcinogen as hazardous, which includes asbestos. This threshold aligns with broader EU regulations on chemical safety, particularly those concerning the classification, labelling, and packaging of substances (CLP Regulation EC No 1272/2008) which in turn implements the Globally Harmonised System of Classification and Labelling of Chemicals (GHS).

The 0.1% threshold for carcinogens was previously found in the EU's Dangerous Preparations Directive but appears to be a pragmatic value that is not grounded in any specific scientific justification based on health evidence (ECETOC, 1990).

In the EU, the REACH Regulation (European Commission (EC)) 1907/2006 also prohibits the importation, manufacture, sale and use of asbestos fibres and of articles and mixtures containing these fibres. REACH applies to recycled materials or articles prepared for reuse, however there is inconsistency across the EU regarding how 'asbestos-containing' is defined (and thus what can be placed on the market for reuse) (European Commission: Directorate-General for Environment, 2024).

While there are no EU-wide thresholds specifically for asbestos in recovered materials, several member states within the EU have implemented thresholds domestically, including the Netherlands, Germany and Belgium.

Netherlands

The Dutch policy on asbestos in waste is contained in the National Waste Management Plan 3 (*Landelijk afvalbeheerplan 3, LAP3*) (Rijkswaterstaat, n.d.b), which contains several Sector Plans for different types of waste. For asbestos, the LAP3 imposes different concentration limits for serpentine and amphibole asbestos. The concentration of serpentine asbestos, plus 10 times the concentration of amphibole asbestos, must be below the 'residual concentration standard' of less than 100 mg/kg of dry matter (i.e. 0.01% w/w for serpentine asbestos or 0.001% w/w for amphibole asbestos). Generally, materials with a concentration of asbestos below the residual concentration standard are not considered to contain asbestos and are permitted to be reused per the relevant Sector Plan for that type of material.

Mixed waste from construction with asbestos levels below the residual concentration standard may be permitted to be reused per Sector Plan 28 (*Sectorplan 28: Gemengd bouw- en sloopafval, met gemengd bouw- en sloopafval vergelijkbaar afval van bedrijven en particulier gemengd verbouwingsafval*).

Sector Plan 37 relates to asbestos and asbestos-containing materials (*Sectorplan 37: Asbest en asbesthoudend material*). Per Sector Plan 37, all asbestos and asbestos-containing materials (i.e. with a concentration above the residual concentration standard) other than soil are required to be disposed of in a suitable landfill, unless the asbestos fibres can be destroyed by thermal or chemical techniques, or fibres removed to below the residual concentration standard (at which point the material is no longer classified as 'asbestos-containing material').

The policy for asbestos-containing soil is contained in Sector Plan 39 (*Sectorplan 39: Grond*), which defines soil to contain asbestos either when the concentration is above the residual concentration standard of 100 mg/kg, or if asbestos-containing (waste) substances have been deliberately added to the soil. The amount of asbestos is determined in accordance with the 2005 Asbestos Products Regulation (Dutch Government, 2018), which for soils refers to the Dutch standard NEN 5707, ’Investigation and sampling of asbestos in soil and soil stockpiles’. If the asbestos fibres in the asbestos-containing soil are able to be destroyed or removed to below the residual concentration standard, the soil is permitted to be recycled, with the separated asbestos fraction processed per Sector Plan 37. If the soil cannot be cleaned to an appropriate level, then the soil must be disposed of in a suitable landfill.

The Dutch thresholds were established on the basis of experimental data measuring asbestos concentrations in air from worst-case simulation and field experiments of activities involving known amounts of asbestos in soils (such as using a wind blower with dry soil containing friable asbestos, driving on contaminated roads, and digging, dumping and sifting humid soil containing asbestos) (Swartjes & Tromp, 2008). Personal air sampling in breathing zone of the workers, as well as stationary air samples near the activities, were collected and analysed with scanning electron microscopy with energy dispersive X-ray analysis (SEM/EDX, see Section 3.3.3 for more details). Their results indicated that activities involving soil with friable asbestos concentrations below the intervention value of 100 mg/kg of soil (dry weight, equivalent to 0.01% w/w[12]) were unlikely to result in airborne fibre levels above the ’Negligible Risk’ level of 1000 fibre equivalents/m^3 (0.001 f/mL).

Germany

In Germany, the *Bund/Länder-Arbeitsgemeinschaft Abfall* (Federal/State Waste Working Group, LAGA) is a working body of the *Umweltministerkonferenz* (Conference of Environment Ministers), aiming to ensure German waste law is as uniform as possible. The LAGA has published the LAGA M 23 as an aid regulating the disposal of waste containing asbestos, including construction and demolition waste. Per the LAGA M 23, materials with less than 0.010% w/w asbestos are clearly defined as ’asbestos free’ and therefore can be reused as per normal asbestos-free materials. This cut-off criterion/assessment value of 0.010% is twice the value of the method-specific average detection limit of VDI 3876. Importantly, asbestos-free status cannot be obtained by calculation in situations where the separation of components or materials containing asbestos is not possible (such as spacers containing asbestos) – even if the calculated proportion of asbestos in relation to the total mass of the waste could be below 0.010%, the waste will still be classified as ’not asbestos free’.

The LAGA M 23 imposes additional controls beyond the assessment value. All building materials from structures built before 31 October 1993, with no proof of asbestos remediation, are initially considered to potentially contain asbestos. An asbestos audit is therefore required before demolition, renovation or maintenance work begins, according to VDI 6202 Bl 3. As far as technically possible, ACM must be separated before the start of work.

The LAGA M 23 also distinguishes materials with NOA and intentionally added asbestos. Materials containing NOA up to 0.1% w/w asbestos can be marketed and recycled. However, products to which asbestos has been added intentionally to achieve desired technical properties cannot be sold or recycled, even if the total asbestos content is below 0.1% w/w.

Belgium

Waste framework plans are developed at a regional level in Belgium. In the region of Flanders, the environmental legislation is laid down in the Materials Decree that forms the basis for sustainable material management and VLAREMA that contains detailed regulations on special waste, raw materials, collection, transport, the obligation to register and extended producer responsibility (EEA, 2022).

In VLAREMA article 2.3.2.1 subsection 2.3.2.2 specifies the criteria for raw materials intended for use as building materials, including for recycled aggregates. The maximum asbestos content in the material is 100 mg/kg dry matter (0.01%) (Flemish Government, n.d.). The asbestos fibre concentration is the sum

[12] 0.001% w/w for amphibole asbestos.

of concentration of fixed asbestos fibre and 10 times concentration of loose fibres for all asbestos types as measured by TEM) (NICOLE, 2021).

2.3 Evidence and other considerations in determining threshold levels

A number of factors should be considered in determining the implementation of any threshold for asbestos in recycled materials, ranging from health effects to analytical sensitivity and end use context. The evidence base (and related limitations and assumptions) enabling rational assessment of these considerations is discussed in this section. Figure 4 summarises the factors for consideration when potentially setting thresholds:

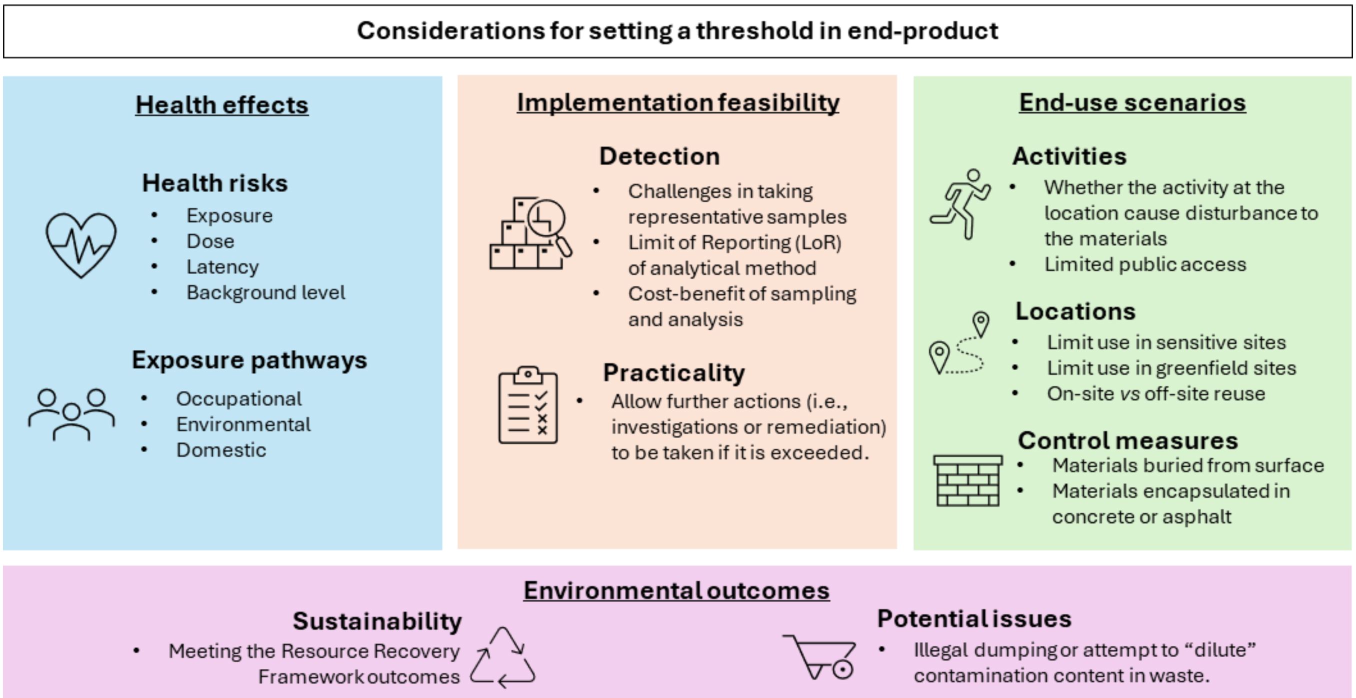

Figure 4: Factors for consideration in setting thresholds in end product

As potential effect on human health is the most important factor when considering the use of thresholds for asbestos in waste or in materials for beneficial reuse, this section will mostly focus on the health-related evidence for the likely effects of asbestos around typical concentration thresholds, and the effect of activities and end-use scenarios and controls. Implementation feasibility, including detection and practicality, will be further explored in later chapters.

2.3.1 Health-related evidence for effects of asbestos

Fundamentally, human health must be protected by avoiding exposure to asbestos fibres so far as is reasonably practicable. This assertion was strongly supported by stakeholders, who overwhelmingly indicated that the risk of exposure was the single biggest factor that should be considered when deriving any potential threshold level, followed by the ability to detect asbestos at suitable/appropriate concentrations.

The review did not find any scientific studies that have attempted to directly correlate the concentration of asbestos in waste or reused materials to asbestos-related disease levels. The use of epidemiological evidence to support thresholds in waste is therefore dependent on evidence in several other domains, along with an assumption that this evidence sufficiently reflects the characteristics of asbestos in waste to allow a tolerable assessment of the risk.

However, evidence in other domains is also limited. Respirable airborne asbestos fibres are present in the environment, and every person is exposed to some extent. The typical background exposure level of airborne asbestos is 0.0005 f/mL outdoor and 0.0002 f/mL indoor[13] (Safe Work Australia, 2020). This means that an average person may inhale up to 5,500 fibres per day or approximately 2 million fibres per year. The general population appears to tolerate this widespread background exposure to asbestos. The background rate of mesothelioma is very low, with approximately one case per million people per year (Hillerdal, 1999). Similarly, only 6.3% of voluntary participants in the Australian Institute of Health and Welfare's most recent voluntary asbestos exposure assessment were unable to identify an exposure above background levels, with 94% of those with mesothelioma assessed as having some possible or probable exposure to asbestos (AIHW, 2024).

Further, it is challenging to gather evidence directly correlating the concentration of airborne asbestos to asbestos-related diseases, as diseases have a very long latency period from first exposure. Direct evidence generally focuses on airborne asbestos concentrations at occupational levels, as occupational levels tend to dwarf non-occupational levels, making it difficult to isolate the effects of the latter. Emmett (2021) provides a succinct summary of the challenges involved in quantifying the risk of non-occupational exposure pathways (Emmett, 2021). Data on historic levels of exposure are generally sparse and the measurements made in the past suffer from serious historic methodologic limitations. Other factors include multiple potential exposure pathways, reliance on imperfect medical histories or questionnaires, and challenges with extrapolating results from one community to another. There are also challenging differences between communities due to differences in climate, rainfall, local habits and cultures – all which may affect the cumulative 'dose' received from non-occupational pathways. Therefore, the use of health-related evidence to support thresholds to date has generally focused on a predicted disease risk, rather than a direct link between asbestos concentration and asbestos-related disease, although there is an established and plausible biological mechanism linking the two (Institute of Medicine (US) Committee on Asbestos: Selected Health Effects, 2006).

A common pathway to assess this disease risk is to study the relationship between asbestos concentration in soils or other materials and the number of respirable fibres that are released, based on environmental measurements around simulated activities. Separately, other epidemiological studies attempt to correlate fibre exposure to the development of asbestos-related diseases. In this way, the release of respirable fibres is used as a relative measure of disease risk. However, there are several factors limiting the utility of this approach compared to studies directly correlating asbestos concentration in waste or recovered materials to disease risk. As discussed later in this section, differences between soil and waste (such as moisture content, typical heterogeneity and distribution profiles, and potential exposure pathways) mean that studies quantifying fibre release from soils may not be immediately applicable to waste and recovered materials. This is typically addressed using additional safety factors (such as WA's 10-fold lower threshold to account for drier conditions). However, more evidence on the inhalation exposure from asbestos in waste and recovered materials would better inform any potential threshold and avoid compounding uncertainties and limitations.

Despite these challenges, discussions of threshold levels in a health context need to consider what constitutes a tolerable amount of risk, including: the toxicity and relative potency of asbestos fibres, exposure/dose-response relationship, background exposure, mechanisms of carcinogenicity, exposure route (e.g. inhalation of fibres versus ingestion), long latency period, variability in fibre characteristics, and low concentration data scarcity. Exposure assessment should therefore also consider the exposure route of asbestos, i.e. inhalation, including how many fibres are released from asbestos in soil and waste, and any mitigating factors related to use. These data points should all be used together to determine what, if any, should be an acceptable concentration of asbestos in recovered materials.

Asbestos is likely a non-threshold carcinogen

Asbestos is classified by the International Agency for Research on Cancer (IARC) as a Group 1 carcinogen (IARC, 2012), meaning that there is sufficient evidence that it is carcinogenic to humans, with a relevant carcinogenic mechanism identified. However, as noted in the IARC Monographs, it is important to

[13] See also *Literature Review – Sampling and Analysis of Asbestos, Supporting Document 2,* Table 3.1

distinguish between a cancer hazard (which is an agent capable of causing cancer), and a cancer risk (which is an estimate of disease risk expected from exposure to a cancer hazard). IARC carcinogen classification groups refer to strength of evidence, not necessarily the relative risk of exposure.

The main exposure route of asbestos is through the inhalation of respirable fibres. As outlined in the Discussion Paper, the health effects of inhaled asbestos fibres are related to the intensity and duration of exposure. Some regulatory agencies have concluded that the current epidemiological data does not support the existence of a threshold (a level below which cancer will not occur) for asbestos-related diseases (ECHA RAC, 2021).

The development of asbestos-related disease has therefore been commonly described by a linear no-threshold dose-response model, which means there is no established safe level of exposure to asbestos. In this model, as cumulative asbestos exposure increases, so does the probability and frequency of occurrence of cancer. The exact shape of the dose-response curve depends on the measure of the dose and is subject to considerable debate. In the absence of reliable past exposure data and the long latency period of the development of asbestos-related diseases (Reid, et al., 2014), the linear model that has been used to extrapolate the effect at low doses is from observations of higher-dose effects. This model is likely to lead to an overestimate rather than underestimate of risks at very low doses (NIOSH-OSHA Asbestos Work Group, 1980).

Because there is no known safe level of exposure to asbestos, it is not possible to set an entirely health-based threshold concentration level for asbestos in recovered materials (i.e. a concentration that will not result in cancer). That is, even though very low exposure may carry some risk, quantifying this risk precisely is difficult. Instead, non-threshold environmental carcinogens are typically regulated by imposing an accepted concentration limit based on the total expected population-level excess lifetime cancer risk. The guideline values for the carcinogens from World Health Organization (WHO) are generally available for lifetime risks of 1 in 10 thousand, 1 in 100 thousand and 1 in 1 million from which national agencies can select a value to be used in their guidelines (WHO, 2000). This is to recognise that the acceptability of risk does not only depend on scientific data, but also social, economic and political factors (NEPM Vol 5 Schedule B4).

In Australia, the NEPM notes that a value of less than 1 in 1 million (1×10^{-6}) has commonly been adopted in guidance addressing population-wide exposures (NEPM Vol 5 Schedule B4), such as in drinking water guidelines. The NSW EPA considers an excess lifetime cancer risk below this value as acceptable, and a risk greater than 1 in 10 thousand (1×10^{-4}) as not acceptable (NSW EPA, 2022e). However, when using non-threshold toxicity reference values as dose-response criteria, the NEPM itself recommends an acceptable incremental lifetime risk value of 1 in 100 thousand (1×10^{-5}).

General population exposure to asbestos is therefore an important consideration in understanding what determines excess risk by minimising total exposure from all sources and maximising appropriate controlled disposal. When determining a tolerable threshold level for asbestos in waste, it is important to consider what airborne fibre concentration results in a tolerable excess lifetime cancer risk for various patterns of exposure, as well as how many respirable airborne fibres will be released from the waste and/or recovered materials.

The workplace exposure standard is an airborne fibre concentration of 0.1 f/mL

The Australian workplace exposure standard (WES) for asbestos is set by the *Workplace Exposure Standards for Airborne Contaminants* (Safe Work Australia, 2024) as 0.1 fibres/mL (TWA)[14].

The limit is adopted from the threshold limit value proposed by American Conference of Governmental Industrial Hygienists (ACGIH) (ACGIH, 2001). The ACGIH limit was first proposed in 1946 at 5 mppcf[15]

[14] "Fibres longer than 5 µm, width less than 3 µm and with an aspect ratio of not less than 3:1, as measured by the membrane filter method, at 400-650X magnification phase contrast illumination."

[15] Million particles per cubic foot.

(approximately 30-180 f/mL), but it has significantly decreased over time as more epidemiological data became available.

The same exposure limit of 100,000 f/m^3 (0.1 f/mL) is also recommended by the US National Institute for Occupational Safety and Health (NIOSH) (CDC, 2018). Their Recommended Exposure Limit (REL) was set at the limit of quantification for the phase contrast microscopy analytical method. Initially the averaging time for the REL was eight hours, but it was later changed to 100 minutes in accordance with NIOSH Analytical Method #7400 to 'identify and control sporadic exposures to asbestos and contribute to the overall reduction of exposure throughout the workshift' (NIOSH, 2002).

As discussed in Section 2.2.2, the WES should not be considered as representing an acceptable level of exposure, but rather is a statutory maximum upper limit (Safe Work Australia, 2024). Australia has not set ambient air quality guidelines for asbestos and the WES should not be considered as such.

A 2021 umbrella review of asbestos fibre burden and asbestos-related diseases indicated that there is little risk of lung cancer or mesothelioma at daily exposure levels below 0.1 f/mL (Rodilla, Cerrada, Pujadas, Delclos, & Benavides, 2022). One of the reviewed studies was the Hodgson and Darnton meta-analysis (Hodgson & Darnton, 2000), which sought to quantify the potency (risk per unit dose) of amosite, crocidolite and chrysotile, deriving cohort-level measures of excess cancer mortality against corresponding cohort average cumulative exposures (Darnton, 2024).

The original 2000 Hodgson and Darnton meta-analysis is cited in the WA Soil Guidelines, noting that cumulative exposure of 0.01 f/mL.year is estimated to increase risk for mesothelioma above 1 x 10^{-5} for crocidolite and amosite fibres while the risk is insignificant for chrysotile fibres. This is supported by a WHO health risk evaluation on asbestos (WHO, 2000). The risk estimates for lower concentrations found in the general environment are extrapolated from the available epidemiological data based on occupational exposure. It is concluded that the excess risk for lung cancer in a population with 30% smokers is in the order of 10^{-6} – 10^{-5} for a lifetime exposure of 0.0005 f/mL. This assumes a lifetime exposure of 70 years with the first 20 years without smoking not making a large contribution to lung cancer risk.

Additionally, the contribution of background level of asbestos fibres to mesothelioma has been shown to be very low compared to the disease incidence found in people known to have had some exposure (Otness, Pierina, 2021).

Asbestos in soil below 0.01% is unlikely to generate airborne fibres above 0.01 f/mL

As discussed above, Australia has not set ambient air quality guidelines for the public health management of asbestos. While the workplace exposure standard is 0.1 f/mL, it is not suggested that this should be considered to be a generally acceptable airborne concentration. As there is no known safe level of asbestos exposure, the airborne fibre concentration should be minimised as much as possible. However, as this section will discuss, the evidence suggests that concentrations of 0.001% – 0.01% w/w are not likely to result in levels of airborne fibres that would present a significantly increased risk.

There have been several studies and data published on the emission of asbestos fibres from soil to air. Addison et al from the Institute of Occupational Medicine (IOM) demonstrated that with an asbestos fibre concentration of 0.001% in dry soil (w/w homogeneous sample), the fibre concentration in air is unlikely to exceed the workplace exposure standard of 0.1 f/mL even if respirable dust up to 5 mg/m^3 is generated (Addison, Davies, Roberson, & Willey, 1988). The study also showed that clay and silt soils would reduce the fibre releasability by a factor of 10 compared to dry soil.

Imray and Neville (1993) suggested a level of <0.001 f/mL in air and <0.001 % in soil to classify a site as uncontaminated or unrestricted and suitable for all land uses based on the IOM study (Imray & Neville, 1993). However, readily available analytical techniques to quantify low levels of asbestos have not been identified.

Swartjes and Tromp (2008) published the approach for the assessment of human health risks of soil contamination in the Netherlands. The report was based on both data from the literature and data collected from measurement of asbestos concentrations in air based on simulation and field experiments. The Dutch Ministry of Housing, Spatial Planning and the Environment established human health criteria for airborne asbestos fibres based on lifetime risk of 1 in 10 thousand (Slooff & Blokzijl, 1989). The criteria were set as yearly average values with the Negligible Risk Level of 1,000 fibre equivalents/m^3 air and the Maximum Permissible Risk level of 100,000 fibre equivalents/m^3 air. Based on these criteria, an intervention value of 0.01% w/w (asbestos equivalents) for both friable and non-friable asbestos in soil was established. This concentration is expected to keep outdoor airborne fibre levels below 0.001 f/mL and probably around 0.0001 f/mL. This study forms the basis of the WA Department of Health Guidelines approach, as well as the NEPM (discussed below).

There have been multiple other studies in which simulated activities are performed with known concentrations of asbestos to attempt to quantify how many fibres are released. Some of these studies are discussed in Table 4. All studies showed that airborne fibres released from degraded bonded ACM are below the LOR (< 0.01 f/mL) of the membrane filter method (MFM) [NOHSC: 3003 (2005)] during simulated activities and when undisturbed (NOHSC, 2005). Even when low level of friable asbestos was detected in the soil samples, the airborne asbestos fibres concentration was still below <0.01 f/mL. The study on simulated agricultural tillage in field with extensive NOA showed elevated airborne fibre release of up to 0.04 f/mL. The field was in close proximity to an asbestos mine. However, the concentration of asbestos in the soil was not provided.

Table 4: Studies quantifying airborne asbestos fibre release from a range of undisturbed conditions or simulated activities

Study	Type of asbestos	Type of media (soil, waste, etc)	Simulated activities	Airborne fibres released (f/mL)
(Otness, Pierina, 2021)	Degraded asbestos cement (AC) products from a 1953 home with AC roof and cladding, surrounded by AC fencing and garden shed with exposed roof and wall sheeting	Surface soils containing 0.001-0.01% w/w asbestos	Indoor air sample monitoring of undisturbed sample	Not detected
	Textured ceiling with chrysotile asbestos	Building material, asbestos containing debris visible on ground.	Vacuuming the area	Below 0.01 f/mL (LOR) MFM Below 0.002 f/mL (LOR) – modified method
	Broken asbestos cement, loose fibres and fibre bundles	Contaminated playing field with historical unauthorised waste fill dumping between 1968-1974 Detected asbestos fines as loose fibres and fibre bundles in soil at 0.003% w/w	Running on track, kicking up dirt and playing cricket during worst-case conditions (dry, hot summer conditions)	Below 0.01 f/mL (LOR) MFM Below 0.002 f/mL LOR - modified method
	AC fencing	Soil Asbestos fines in soil 0.003% (w/w) No trace asbestos detected in soil samples per AS 4964	Fire damage	Below 0.01 f/mL (LOR) MFM for personal and static monitoring
(Spurny, 1989)	Corroded and weathered AC products	Soil	Outdoor air monitoring of undisturbed sample	0.0002-0.0012 f/mL
(Driece, 2010)	Friable and non-friable asbestos in waste used for public and private use to harden dirt tracks, yards and driveways during 1935-1974	Soil	Outdoor air monitoring of undisturbed sample	Background asbestos level: 0.000068 f/mL At 5m distance to a road with surface contamination of friable asbestos: 0.001674 f/mL At 100m distance, asbestos level is not statistically different from background level
(Turci, et al., 2016)	NOA (mainly chrysotile)	Soil	Tilling with a small tractor	Average of 0.016-0.026 f/mL, with a peak of 0.04 f/mL for personal monitoring Negligible release (0-0.002 f/mL) for static monitoring

Environmental exposure pathways and mesothelioma risk studies were carried out for 70 communities receiving asbestos-contaminated vermiculate material originating from Libby, Montana USA **(Noonan,**

2017). These communities extensively used mined vermiculate that was naturally contaminated with amphibole asbestos in locations such as in school running track, baseball field and residential gardens for soil amendment. Elevated standardised mortality ratios[16] were identified in seven of the sites **(Horton, Bove, & Kapil, 2008)**. Another study reported 11 mesothelioma cases among non-occupationally exposed residents, and only two of them had a history of para-occupational exposure. The data showed that elevated mesothelioma cases can be attributed to airborne asbestos exposure released from local asbestos-related industries, and potentially through contact with asbestos-containing commercial products. However, exposure classification is often problematic when detecting robust associations with mesothelioma, which is a rare outcome outside the occupational setting. Thus, the association between neighbourhood exposures from the use of asbestos-contaminated waste products and risk of mesothelioma remains unclear.

Data relating asbestos concentration in waste or recovered materials with airborne fibre concentration is limited

Established asbestos thresholds in recovered materials are typically derived from the asbestos screening level in soil, assuming the characteristics of waste are broadly similar to those of soil. For example, the intervention value of 0.01% w/w asbestos equivalents for managing asbestos in contaminated soil in the Netherlands is also applied to the residual concentration for recycling of soil material, dredging and demolition waste (granules) based on the Dutch interim policy on asbestos in soils, sediments, dredge materials and demolition waste (granules) (Swartjes & Tromp, 2008).

WA applies a conservative asbestos threshold of 0.001% asbestos (w/w) in recycled C&D waste (WA Waste Guideline) considering the location where the materials will be reused is not constrained (WA Department of Water and Environment Regulation (WA DWER) submission). This value is also adopted from the asbestos screening level in soil. More details on the sample analysis based on WA Waste Guideline is available in Section 3.2.2. Because the sample analysis result is only an estimate, the result is used to provide an indication of effectiveness of the risk-based approach and controls in place.

Waste and recovered materials are different to contaminated soil for onsite use as they may be subjected to processing (e.g. screening, crushing) which can disturb the materials and is assumed to potentially generate airborne fibres. Compared to contaminated soils, there may be less control over the management of the end use of the recovered materials as they are typically used in different sites. In addition, there are limited data on the relationship between asbestos concentration in recovered materials and airborne fibre release. Hence, while deriving an asbestos threshold in waste based on similar studies for soils may be a reasonable approach, any threshold may need to incorporate an additional safety factor until a more comprehensive evidence base is established.

Recovered materials potentially containing trace levels of asbestos have been used in applications such as road base and infill

In the Netherlands, recycled aggregates have been used in road construction as road base, which forms the basis for top layers such as asphalt or concrete (FIR, 2024). Since 2015 the Dutch national legislation has established the end-of-waste criteria for recycled aggregates (Dutch Government, n.d.). The waste materials accepted to be processed into recycled aggregates must not contain asbestos and the final product must meet the Asbestos Products Decree (Dutch Government, 2024), which allows trace amount of asbestos less than 100 mg/kg (0.01% w/w) asbestos equivalents. There are also requirements for material inspection, sampling and analysis as well as record keeping and documentation.

Because the supply of recycled aggregates has exceeded demand for road base construction in the Netherlands since 2010, the materials have found other uses, mostly by mixing them with a binder such as asphalt or cement. Recycled aggregates have been reported to be used as top layer for minor road and temporary work roads as well.

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[16] A standardised mortality ratio is the ratio of the sum of the observed deaths in the 'exposed population' (analysis area) relative to the sum of the expected numbers in the "exposed population". The 'exposed population' analysed for the study was 3,967,340.

2.4 An end-product specification threshold could be considered as part of an overarching risk-based approach

As will be discussed in Chapter 3, measuring the concentration of asbestos in waste is often difficult because of the heterogeneous nature of the waste, making it difficult to obtain representative samples. The gravimetric calculation of total asbestos concentration in waste sample is only an estimate because of assumptions made on asbestos concentration in pieces of bonded ACMs. In addition, the main analysis method used to detect the presence of asbestos fibres is AS 4964:2004[17] (Method for the qualitative identification of asbestos in bulk samples uses polarised light microscopy (PLM) technique) which relies on human detection of fibres. As its title suggests, it is a qualitative method and cannot be used to quantify asbestos in the sample below the limit of detection (LOD) of 0.01%.

In addition to the heterogeneity of waste input streams, the cost and labour intensity of asbestos analysis may also prohibit asbestos quantification early in the recycling process. Some submissions from relevant industrial bodies estimated that implementing the requirements in the WA Waste Guideline would result in approximately 50,000-60,000 additional samples per year for the analysis of recovered fines and aggregates, as well as an additional cost of $4.6 million to the industry. While the majority of submissions supported the implementation of a risk-based approach in NSW similar to the WA Waste Guideline, many noted that some specific elements of the WA approach may not be as applicable to NSW due to some key differences between the two states, including:

- the volume of the recovered materials[18]
- the cost of land
- the economics and practicality of conducting sampling and testing.

2.4.1 A weight-of-evidence approach can be used to assess risk and guide management

Quantifying the concentration of asbestos is one way to assess the health risk of materials. As discussed above (Section 2.3.1), there is evidence suggesting that asbestos concentrations of 0.001% – 0.01% w/w in end products are unlikely to result in airborne fibre concentrations that would present a significant health risk, especially for materials containing bonded ACM. Depending on the representativeness and extent of samples analysed, recovered materials found to contain a concentration of asbestos below these levels could be considered safe to reuse, regardless of end use.

However, there are other approaches that would also allow a comprehensive risk assessment and management of the safety of recovered materials. It should be noted that, while respirable asbestos fibres are invisible to the naked eye, their source is typically visually detectable. An understanding of the source of the waste, as well as visual inspection throughout the process, can allow a risk-based judgement of the character of the waste to assess whether the waste is likely to contain an asbestos fibre concentration above a certain level. This judgement can be combined with targeted sampling and analysis of the end product to provide an understanding of the risk, using any experimentally determined concentration as a tool to guide a more comprehensive risk assessment where required and taking into consideration all streams of evidence for the material. The results of any in-process airborne fibre monitoring are another control that would potentially allow a thorough risk assessment of any end products, as if fibres are not elevated during recycling and resource recovery operations, they are unlikely to be elevated during end use. However, airborne monitoring is unlikely to be informative in this context due to occlusion of the sample filters with non-fibrous dust particulates.

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[17] Now superseded by AS 5370:2024 – Sampling and qualitative identification of asbestos in bulk materials. AS 5370 also has a LOR of 0.01%.

[18] In 2020-21 the amount of recycled C&D waste in NSW was 7.5 million tonnes, three times the amount of recycled C&D waste in WA (2.5 million tonnes). https://www.dcceew.gov.au/environment/protection/waste/how-we-manage-waste/data-hub/data-insights/national-data-viewer

2.4.2 Thresholds can be combined with other in-process and end-use controls

While the WA Waste Guideline imposes a maximum total asbestos content in recycled materials, it is not the only control used to minimise the risk. The Guideline also covers procedures associated with the pre-acceptance, receipt and processing of C&D waste at recycling facilities. The WA facilities must not intentionally accept ACMs, but the Guideline recognises that inadvertent inclusion of asbestos in waste streams is possible. To mitigate this risk, the facilities are required to comply with the Guideline to detect, manage, and safety dispose of ACMs that may be encountered. One requirement is to perform a risk assessment of the material during the acceptance procedures based on the source of the load, the content/waste types within the load and the type of the load[19]. High-risk materials are subject to a more thorough inspection before being cleared for further processing.

In addition to in-process methods, controls over end-use can also be used as another tool to manage the risk of recovered materials. In WA, the legislation does not constrain the location or type of the reuse of crushed C&D product once it has left the gate of licensed premises, and hence a conservative threshold criterion is applied for that reason. In NSW, stakeholders reported that the current end use of recycled C&D waste is generally limited both on-site and off-site, with most being buried or encapsulated (in concrete or asphalt) to minimise access and disturbance. Eventually this material may be processed for reuse or disposed of. The controls and regulations in place need to consider this potential reuse of recycled material containing traces level of asbestos.

Many submissions viewed end use as a key factor that should be considered when deriving any threshold level for recovered materials. Stakeholders generally supported limiting the end use of recycled C&D waste, particularly at greenfield areas, sensitive sites, or locations where it is likely to be disturbed and become friable. Many suggested that reused materials should only be used where buried or capped, contained in encapsulated materials or binding matrices (such as concrete) or on sites with limited public access.

Further detail regarding additional controls that can adequately manage the risk of recovered materials will be discussed in Chapters 4 and5.

2.5 Findings

- Varying definitions for asbestos, asbestos material and asbestos waste in different legislation result in a level of confusion when managing asbestos.
- In respect to environmental management, only a few national and international jurisdictions have established asbestos thresholds (or limits) in waste for recycling. Thresholds have been used a part of a broader risk-based approach to managing asbestos in waste.
- The context of any threshold needs to be clearly understood. Where thresholds have been established by environmental agencies, they are based on the NEPM's HSL values, the limit of detection for a specified method of analysis or based on experimental estimates of potential respirable fibre count.
- Studies that correlate concentration of asbestos in waste to asbestos-related disease levels were not identified in any literature.
- Health-related evidence to support thresholds is generally based on predicted disease risk rather than a link between asbestos concentration and asbestos-related disease.
- Within Australia, thresholds (or limits) are utilised within WHS requirements, although these cannot be interpreted as an acceptable level of exposure, and more accurately reflect a maximum upper exposure limit.
- The workplace exposure standard for airborne fibre concentration is 0.1 f/mL over an eight-hour period, five-day week.

[19] See Table in Section 4.3.2.

- WHS limits are supported by other requirements to manage risk and minimise exposure, noting different requirements are set for DIY home renovators in NSW.
- In general risk is considered based on a correlation between asbestos concentration in material and concentration of respirable fibres measured in air (similar to Swartjes and Tromp (2008)).
- Experimental estimates of fibre release from soil found that “activities involving soil with friable asbestos concentrations of 100mg/kg of soil were unlikely to results in airborne fibre levels above ’Negligible Risk’ level of 1000 fibre equivalents/m3 (0.001 f/mL)”.
- Asbestos soil concentrations below 0.01% are unlikely to generate airborne fibres above 0.01 f/mL.
- Additional safety factors may need to be considered when establishing thresholds for waste and recovered materials.

3. Sampling and analysis in isolation are not sufficient to ensure absence of asbestos in recovered materials

This chapter seeks to address TOR 3 of the Review on the most appropriate sampling and analytical approaches for detecting asbestos in recovered materials. It first presents practical challenges in this area, clarifies misconceptions on the most common sampling and analysis methods for asbestos, and lays out factors to consider when designing sampling and analysis procedures.

The presented information is drawn from the Expert Paper (*Literature review – sampling and analysis of asbestos, Supporting Document 2 (EnRiskS, et al. SD2)*), OCSE research, feedback from the Expert Panel and submissions to the Discussion Paper. Much of the information available on sampling and analysis for asbestos is drawn from the context of soil testing, with less information available for the specific context of asbestos in waste. Therefore, the available information on sampling and analysis for soil has been used to guide discussion of sampling and analysis of recovered materials for beneficial reuse, from the generation of C&D waste through processing to end products.

The Review found that the heterogeneity of the matrix material (either soil or waste) and the non-uniform distribution of asbestos (i.e. formation of hotspots) makes representative sampling difficult. Current analysis methods are sufficient to detect and estimate asbestos content in recovered materials, although limitations and applications must be understood. As these methods rely heavily on visual identification of ACMS, appropriate training and internal/external quality assurance for personnel are critical.

The Review also found that a generic sampling and analysis plan for asbestos in recovered fines and materials is unlikely to provide a high level of confidence of detection. The WA Waste Guideline, however, provides a good resource for the sampling and analysis of waste for beneficial use as well as the recovered materials.

3.1 Limitations and challenges of sampling and analysis for asbestos

Limitations and challenges exist in measuring the concentration of asbestos in waste and recovered materials. These include: the difficulty in obtaining representative samples because of material heterogeneity and non-uniform distribution of asbestos (i.e. hotspots), difficulty around accurate quantification, operator training and competency, and limits of detection of the various analytical methods.

Methodologies designed to detect asbestos in soil may not translate to waste materials as differences in matrices have implications for sampling, analysis and the reliability of results. Below are the key considerations and limitations:

- Matrix differences – soil has higher relative uniformity and is a granular medium. Sampling methodologies for soil assume a consistent bulk matrix and density, allowing for randomised sampling strategies to be applied and concentration of total asbestos in soil to be estimated.
- Asbestos in soil is often dispersed heterogeneously (e.g. in fragments or fibres). However, soil's granular nature aids in defining methods like bulk sieving.
- Waste materials are far more heterogeneous, consisting of mix of solids of varying size, shape and density. The wide variability in physical and chemical characteristics of waste makes it difficult to develop a single generic methodology applicable across all waste types.
- Asbestos in soils is likely to be from the same source and subject to the same activities or environmental conditions, with some regularity of asbestos type and nature, and with areas of contamination able to be delineated.
- Asbestos in waste may be non-uniformly distributed throughout a load and include a greater variability of the type and nature of asbestos, especially where the load contains material from multiple sources.

3.1.1 Representative sampling of waste or products to enable a sufficient level of detection confidence

It is generally not feasible to analyse the entire volume or stockpile of waste or recovered materials (the population), so statistical methods are typically used to provide an estimation of the population as a whole, by analysing a defined number of representative samples (NSW EPA, 2022f). The number and type of samples is preferably determined based on the level of statistical confidence required to ensure that the samples are adequately representative of the population. This, in turn, is ultimately dependent on the context, sampling objectives and analytical sensitivity/limits (EnRiskS *et al*. paper SD2). For example, the NSW EPA waste classification guidelines contain concentration limits for a range of contaminants, and recommend that "the sample mean, the sample standard deviation and the 95% upper confidence limit (UCL) of the mean concentration is calculated for each contaminant to ensure that the 95% UCL for the mean concentration is less than or equal to the contaminant threshold (CT) limit value specified for that contaminant" (NSW EPA, 2014).

Relying on detailed statistical requirements and methods alone to determine sampling rates can impose a requirement for a significant number of samples. For example, the US EPA's Resource Conservation and Recovery Act (RCRA) guidance for the number of samples required is to use a simple random sampling range from 27 to >1,000 samples to provide 95% confidence of detecting a change in the characteristic of a material, depending on the size of change and power of the analysis[20] (EnRiskS *et al.* Paper SD2).

Further, mixed C&D waste and many processed recycled products have a heterogeneous nature, making it is difficult to obtain a representative sample. An overview of sampling guidelines for asbestos in soil, waste and end product in Australia, Germany and the Netherlands (Table 5) highlights the difficulty in achieving a representative sample due to a small proportion of volume sampled [0.003 – 0.300% volume/volume (v/v) of total stockpile]. Nonetheless, these sampling guidelines and results have been used in a weight of evidence approach to determine the degree of land contamination or to verify asbestos removal from the end product.

Table 5: Comparison of existing sampling guidelines at waste generation site and recycling facilities

	Waste generation site *(e.g. demolition sites, excavation sites, contaminated sites)*			**Processing site** *(e.g. recycling facilities)*		
Material composition	Heterogeneous soils and C&D waste for ACMs not separated and removed under an asbestos removal control plan			Introduction of product with random distribution of asbestos of variable nature and type End product with defined output grain size which is relatively more homogeneous than generated waste		
Sampling objectives	To assess stockpile or impacted soil layers to determine whether further actions are required			To prevent asbestos entering the recycling process To identify any asbestos inadvertently introduced into the process to allow separation and/or removal of asbestos from affected waste To verify asbestos absence from end product as a part of process quality assurance and quality control		
Material	C&D waste (e.g. mixed crushed building materials and soil)	Soil	Soil	Load delivery, including C&D waste and soil from multiple sites	End product (e.g. recycled drainage rocks, recycled road bases, grain size 0-27mm)	End product (e.g. recycled concretes, bricks, grain size 0-45 mm)

[20] Power analysis is a tool that combines statistical analysis, subject area knowledge and requirements to derive optimal number of samples, to give probability of detecting an effect.

	Waste generation site *(e.g. demolition sites, excavation sites, contaminated sites)*			Processing site *(e.g. recycling facilities)*		
Example of sampling guideline and jurisdictions	LAGA PN 98 (Germany)	Sampling design part 1 – application (NSW)	NEN 5707 (The Netherlands)	Guideline: Managing asbestos at construction and demolition waste recycling facilities (WA)		LAGA PN 98 (Germany)
Example sampling plan for a given stockpile	4 composite samples* of 4 litres each for 500 m^3 stockpiles	Minimum of 40 samples for initial assessment of 1,000 m^3 stockpiles (1:25 m^3)	50 samples of 30 cm wide x 2 cm long x 1 m depth, per 1 hectare of soil investigation area	Risk classification matrix and detailed visual inspection procedure corresponding to risk classification Stockpile management procedures	40 samples of 10 L each†, per 4,000 tonnes stockpile OR 1 samples of 10 L each† per 70 m^3 materials on conveyor belt	4 composite samples of 10 L each, per 1000 m^3 divided into 6 sectors
Proportions of volume sampled	0.003 % v/v	0.040% v/v stockpile	0.300% v/v	N/A	0.0140% v/v for continuous sampling conveyor belt	0.004% v/v
Reference	(LAGA, 2001) (LAGA, 2022)	(NSW EPA, 2022f)	(NEN, 2017)	(WA DWER, 2021)		(LAGA, 2001) (LAGA, 2022)

*For heterogeneous C&D waste sampling in LAGA PN 98, samples are taken from fine fractions portions (grain size ≤ 20 mm) of the stockpile.
† See Section 3.2.1 for more information on the sampling procedures in the WA Waste Guideline.

In addition to overall source matrix heterogeneity, asbestos contamination in materials often displays non-uniform distribution (i.e. asbestos occurs in hotspots originating from a visible source contamination). This differs from many other environmental contaminants such as heavy metal ions which may be more evenly distributed and/or more easily quantified by standard techniques employing calibration curves with peaks which can unambiguously be attributed to the contaminant of concern (Rajoria, Vashishtha, & Sangal, 2023).

The non-uniform distribution or hotspot contamination of asbestos also results in variability of asbestos concentration in samples, making it difficult to characterise the whole stockpile. In one study, 30 samples of 10 L each, were taken from a spread of 22 m^3 crushed building materials and soil-like materials with grain size of up to 4 cm (Stelling & Sjerps, 2005). The samples were sieved and searched for ACMs using visual inspection and PLM using Dutch standard NEN 5897 – *Investigation and sampling of asbestos in waste materials and demolition waste*. The mean chrysotile content (mg/kg) shows a large coefficient of variation (214%) with six of the 30 total observations being outliers, and no distribution patterns observed (i.e. neither normal nor lognormal distributions).

When dealing with contaminants such as asbestos, simply omitting outlier results is not recommended as these are not necessarily due to analytical errors, but likely represent non-uniform distribution of contamination, or hotspots (Stelling & Sjerps, 2005). Even when testing for other contaminants, such as metal ions and polycyclic aromatic hydrocarbons, outlying observations frequently occur. Therefore, if sampling and analysis are to be used as a part of compliance requirements, it is important to consider and account for non-uniform and highly variable contaminant concentrations in waste (Stelling & Sjerps, 2005). Considering the study was done on crushed building materials and soil-like materials with grain sizes of 4 cm and smaller, similar conclusions could be applied to end products with varying heterogeneity in grain sizes (e.g. road base specifications of 19 cm and smaller).

3.1.2 Limitations, assumptions and misconceptions of analytical methods

Asbestos contamination in recovered materials commonly occurs via visible asbestos building product sources such as asbestos cement fragments, where the fragments may be in sound condition, and the fibres are held within the matrix. There are two types of analysis that can be conducted: quantitative analysis to determine asbestos or asbestos equivalent concentration in material and qualitative analysis to identify asbestos in the material. Selecting the appropriate analytical method for sample analysis requires an understanding of the purpose of analysis, the applicability and limitations of the method.

In NSW, asbestos sampling and analysis in soil is carried out according to NEPM guidance for the management of contaminated land to determine the degree of asbestos contamination in soil. NEPM analysis is based on a gravimetric method to estimate the asbestos concentration in soil. NEPM also refers to the use of laboratory analysis based on AS 4964[21], which is a qualitative method to confirm the presence of asbestos in bulk materials using PLM and dispersion staining techniques.

For soil contamination, the purpose of the sampling and analysis is to determine the need for further actions such as remediation, contaminated sites memorial/classification (i.e. to inform site owners and prospective buyers of the presence of contaminant as well as remediation requirements) and/or other contaminated soil management. For soil that is obviously contaminated, remediation can be done without quantifying the contamination. Generally, sampling is only used to address any uncertainty, such as:

- confirming vertical or lateral extent of contamination, where it is difficult to determine visually
- confirming asbestos presence above the screening levels when preliminary site investigation indicates that the contamination level is low and uncertain
- validation sampling where concentrations may be low and evidence to confirm residual levels are below site-specific remediation criteria is needed.

There is currently no prescribed sampling and analysis method for asbestos in the NSW Resource Recovery Framework, as this framework states that materials accepted for resource recovery must not contain asbestos. Some recycling facilities have mentioned the use of AS 4964 to test their products, and then compared the quantitative analysis result with NEPM screening levels.

NEPM gravimetric method for asbestos in soil versus AS 4964

Because the NEPM gravimetric and AS 4964 methods are the most used methods in Australia, it is worth clarifying the differences between the two methods and common assumptions and misconceptions, and considering the new AS 5370 where relevant.

The sampling, analysis and reporting requirements for each method are illustrated in Figure 5. NEPM gravimetric method relies on visual identification of ACM and fibrous asbestos > 7mm x 7mm in the field. The asbestos content in soil is determined using the following equation:

$$\%\text{w/w asbestos in soil } = \frac{\%\text{ asbestos content x weight of ACM (kg)}}{\text{soil volume (L) x soil density (kg/L)}}$$

In this approach, asbestos content of an asbestos cement fragment is often assumed to be 15% (based on the typical composition of asbestos cement sheets) and soil density (for sandy soils) is assumed to be 1.65 kg/L. However, other bonded ACM products such as asbestos vinyl floor tiles may contain up to 30% asbestos (Workplace Health and Safety Queensland, 2011). Therefore, description of the type of ACM via visual identification, and information used to estimate asbestos content and soil matrix density is critical to justify any assumptions made for the calculation.

When the presence of asbestos fines is significant, either from an fibrous asbestos source or where greater than 10% of bonded ACM has degraded to asbestos fines, NEPM requires samples to be submitted to a NATA-accredited laboratory which can use the AS 4964 method to identify asbestos as <7mm debris, and as asbestos fibres and fibre bundles. The total weight of asbestos found can be calculated using the same gravimetric method as used for field samples. That is:

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[21] Now superseded by AS 5370:2024 (Sampling and qualitative identification of asbestos in bulk materials. The new standard is an adoption of an international standard ISO 22262-1:2012 (Air quality - bulk materials - Part 1: Sampling and qualitative determination of asbestos in commercial bulk materials) with national modifications.

$$\%\text{w/w asbestos in soil} = \frac{\text{estimated total asbestos fibre weight}}{\text{dry weight of soil sample}}$$

Using the NEPM method, the concentration level will be significantly influenced by larger debris found within the sample, including asbestos bound in cement fragments <7mm. As such, results need to be interpreted accordingly, with respect to potential for fibre release.

On the other hand, AS 4964 is a qualitative analysis method to determine the presence of asbestos. The result of AS 4964 analysis is reported as 'asbestos detected', 'trace asbestos detected', or 'no asbestos detected'[22]. Stakeholders welcome the new AS 5370 for analysis of soils, dusts aggregates and minerals, along with more detailed guide in using electron microscopy techniques to complement PLM. However, it remains a qualitative method for the detection of asbestos.

[22] In AS 4964, when the samples examined in trace analysis contain less than 5 asbestos fibres per two microscope slides, the result is reported as no trace asbestos has been detected at the reporting limit of 0.1 g/kg (0.01% w/w). This can be interpreted as no detectable free asbestos fibres in the sample. For residual analysis in AS 5370, if the total weight of all fibres observed per slide is below the LOR of 0.01 % w/w, 'no asbestos detected' is reported.

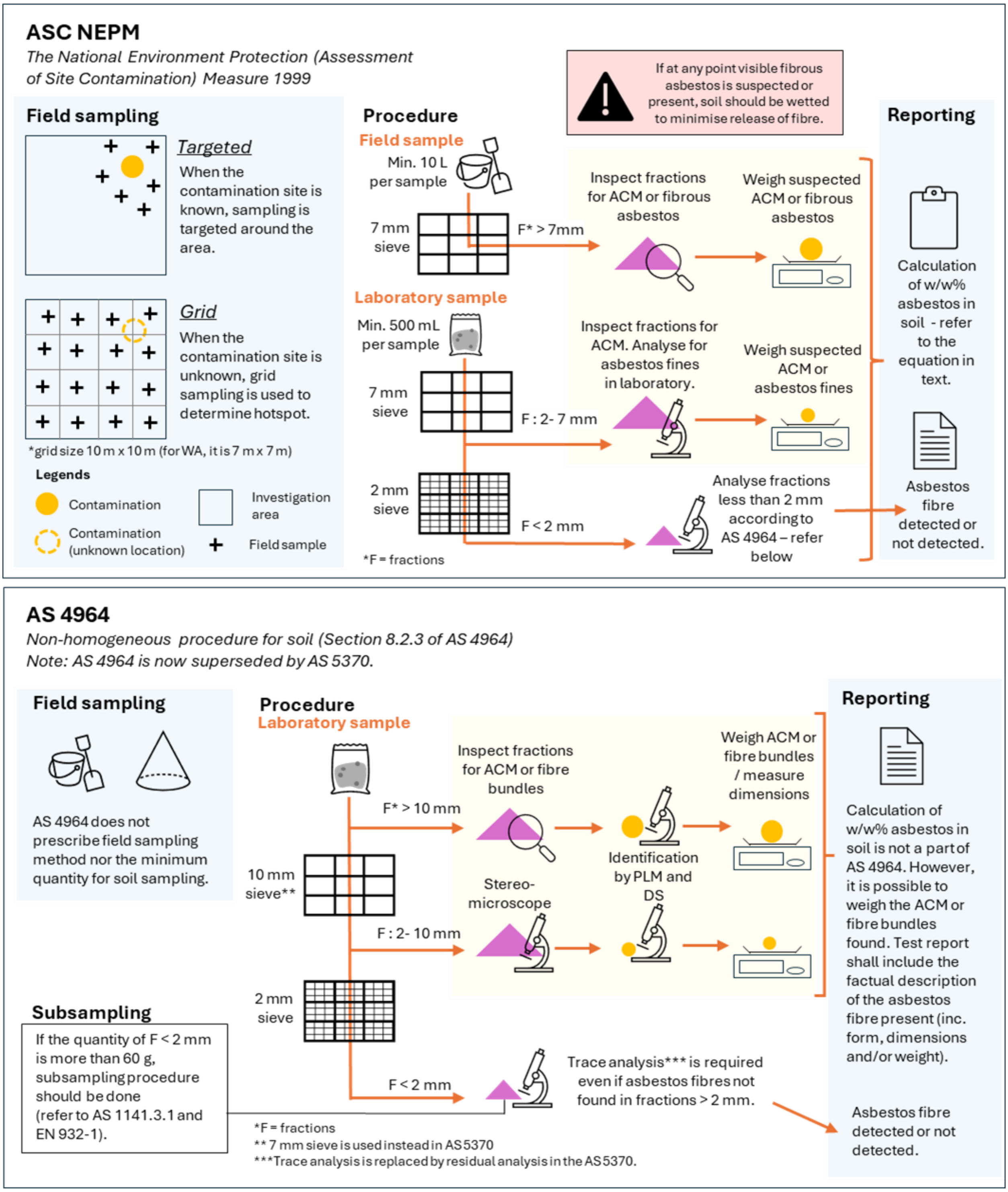

Figure 5: Sampling, analysis procedure and reporting in NEPM and AS 4964/AS 5370

The clarifications for the misconceptions present in the requirements, applications and result interpretations of NEPM and AS 4964/AS 5370 are listed in Table 6.

Table 6: Misconceptions and clarifications of the requirements, applications and result interpretations of NEPM and AS 4964/AS 5370.

Misconception	Clarification
AS 4964 method is less sensitive than NEPM gravimetric method because its limit of detection is 0.01% whereas NEPM result can be less than 0.01%.	The limit of reporting (LOR) is the lowest amount of fibre that can be reported in the laboratory report using a specific method. It usually depends on the LOD of the method, which refers to the minimum concentration at which the method can detect the analyte within the matrix, but not necessarily quantify it, with a certain degree of confidence. It is also defined as the lowest concentration distinguishable from background noise with some reliability. The detection limit of trace analysis method in AS 4964 is 0.01% to 0.1%, and for residual analysis in AS 5370 is 0.01%. The detection limit can be lowered if extreme attention is given to a small part of the sample. However, the uncertainty of measurement will increase because it is only applied to a small sub-sample which may not be representative of the entire sample. The detection limit of AS 4964 should not be compared with the asbestos-screening levels specified in NEPM because the screening levels require the use of a gravimetric method that compares the weight of the total quantity of asbestos and ACMs present in a soil sample to the total weight of (dry) soil in the sample. For the estimate of concentration to be meaningful, care should be taken in ensuring the sample collected is representative of the contaminated soil layer due to the heterogeneity of the matrix.
'No asbestos detected' is interpreted as asbestos is absent from the sample	It is important to note that when a laboratory reports 'no asbestos detected', it does not necessarily mean 'asbestos is absent'. It is more accurate to interpret that the asbestos content in the sample is below the LOR or LOD of the analytical method used (in the case of AS 4964/AS 5370, below 0.01% w/w). In other words, asbestos content below these limits cannot be reliably reported by the laboratories.
AS 4964 reports asbestos concentration in material	During the sample preparation step, it is possible to obtain % w/w based on the weight of ACM fragments and fibre bundles which do not pass through the 2 mm sieve. The information may assist with the assessment of soil concentrations relative to the appropriate screening levels as set out in NEPM. However, reporting this result is not part of AS 4964/AS 5370 methods.
It is not possible to use the threshold of 0.001% w/w as adopted in WA Waste Guideline which is below the LOR of AS 4964/AS 5370 (0.01% w/w)	The threshold of 0.001 % w/w adopted WA Waste Guideline is an estimate of total content of asbestos fibre 'in any form' (i.e. fibrous asbestos, asbestos fines or bonded ACM). WA Waste Guideline uses NEPM method which is the combination of gravimetric method and microscopic fibre analysis (in AS 4964/AS 5370). Using gravimetric method, it is possible to weigh ACM fragment in a stockpile and estimate its asbestos content. For example, 7 g of ACM (with estimated 15 % w/w asbestos content) in 100 kg of soil represents 0.00105 % w/w of asbestos in the sample. This would have asbestos content below 0.01 % w/w but exceeds the 0.001% w/w threshold. AS 4964 trace analysis with detection limit or LOR of 0.01% w/w represents a limit where asbestos fibres, fibre bundles or free asbestos fibres can reliably be reported by the laboratories. When using trace analysis, a result of 'trace asbestos detected' would mean exceedance of the 0.001% w/w threshold. Section 3.2.3 further explains how reporting from both methods could be used to inform decision making.
Result from AS 4964 analysis is less representative as it requires a smaller quantity of sample compared to NEPM	AS 4964 does not provide guidance for sampling. It only mentions that the sample taken should be representative of the larger bulk material as far as is practicable. The standard acknowledges taking representative sampling of soil and ores is difficult to achieve because of the complexity and size of deposits. The minimum quantity of sample for each analysis is:

Misconception	Clarification
	• For AS 4964 - for building materials, 5-100 g and for floor tiles, 100 cm^2. Subsampling using a validated procedure is recommended for soil and ore samples greater than 30-60 g. • For AS 5370 – for building materials, 5-100 g and for vinyl materials, 50 cm^2. Subsampling using a validated procedure is recommended for soil, dusts, aggregates and minerals fraction of less than 2 mm, if the samples are greater than 60g. To estimate asbestos concentration in soil, NEPM prescribes collection of a minimum of 10 L sample for bonded ACM sampling for field quantification of >7mm asbestos, and a wetted 500 mL sample for < 7mm asbestos in surface soils or deeper soil layers. Samples can be collected using test pits, trenches and core from bore holes for asbestos fines sampling in locations and soil layers as indicated by site history or investigations. Sampling and investigation of soils are provided in Schedule B2 of the NEPM. NEPM also notes that 'jurisdictions may have specific requirements where materials are to be recycled, recovered and reused for beneficial purposes'.

3.1.3 Operator training, competency and accreditation

Stakeholders are in apparent consensus that the accuracy and reliability of sampling and analysis depends on the training and competency of the personnel involved, whether they are a field sampler or laboratory analyst. Lack of guidance for sampling procedures at recycling facilities also contributes to the low level of confidence in sampling and subsequent analytical results.

The training and experience levels of analysts significantly influence their ability to differentiate asbestos fibres from other fibres which may be present in samples, ensuring the accuracy and reliability of microscopic laboratory analyses. Nonetheless in Australia, there is no official asbestos analysis training course for analysts. Instead, the laboratories are accredited against ISO 17025[23] and their in-house method, which are based on validated methods (e.g. AS 4964) by NATA. For context, there are over 40 NATA-accredited laboratories in NSW for various in-house asbestos fibre analyses including airborne asbestos fibres, and asbestos in bulk materials and non-homogeneous materials (soils, dust and ores).

There are also differences between laboratory test reports delivered under various accreditations of distinct in-house methods (EnRiskS *et al.* paper SD2), and some laboratories do not provide sufficient detail as required under AS 4964. For example, the test report for non-homogeneous samples in AS 4964 should include factual description of identified asbestos (e.g. form, dimensions and/or weight), but some laboratories only provide a weight of the sub-sample and an indication of the presence of asbestos, without providing descriptive information of asbestos observed.

Other laboratories provided additional information that is not covered by AS 4964, such as reporting % weight of asbestos in weight of soil, or introduce an incorrect assumption when performing the calculation (e.g. 100% asbestos content was assumed for cement sheet instead of 15% asbestos content).

Variability in reporting and asbestos detection are also observed across different international laboratories:

- Detection rates of asbestos in soil between five laboratories in the UK can vary from 1.4-20%. These may be attributed to datasets not distinguishing sample origins, such as large datasets coming from one or a small number of sites versus small datasets from a larger number of sites,

[23] Note that *ISO 17025 Annex Asbestos sampling and testing document* provides guidance and information for reporting of results including, but not limited to, soil and dust samples.

or samples from greenfield site versus brownfield site. The differences in the laboratory methods used to detect asbestos in the samples may also have a significant impact on the reported detection rate (SoBRA, 2020).

- A further review of Asbestos in Soils Scheme (AISS), a proficiency testing program, across 62 laboratories (mainly in UK and Europe) showed a high percentage of incorrect qualitative results (9% of labs), incorrect identification of asbestos type (9%) and unsatisfactory quantitative results (13%), with an average variation of 12%, indicating overestimation of the concentration compared to the actual sample. Considering the scheme was applied to manufactured samples, a higher error on real-life field samples might be possible (SoBRA, 2021).

3.2 Sampling and analysis for asbestos in WA Waste Guideline

The WA Waste Guideline provides clear guidance on the product specification of recycled C&D waste and the sampling and testing requirements of these materials. It is based on methodology developed for the WA Soil Guidelines, which has been adopted by the NEPM. In WA Waste Guideline, the total asbestos concentration in the forms of ACM, fibrous asbestos and asbestos fines in the recycled products must not exceed 0.001 % w/w asbestos.

3.2.1 Sampling procedures

Sampling under the WA Waste Guideline involves visual inspection for ACM and fibrous asbestos in the delivered and end products by trained operators following prescribed sampling procedures from conveyors or stockpiles. Suspect asbestos material or areas must be targeted for sampling. The inspection and sampling procedures for recycled drainage rock, recycled sand and recycled road base are given in Table 7.

Table 7: Inspection and sampling procedures for asbestos in recycled C&D waste (WA DWER, 2021)

Sampling location	Recycled drainage rock 20-27 mm	Recycled sand, screened to <10 mm	Recycled road base <19 mm
Stockpile	Systematic grid visual inspection only to identify any suspect asbestos material	Visual inspection and sampling to identify any suspect asbestos material Minimum sampling rate: 40 locations per 4,000 tonnes or 14 samples per 1,000 m^3	Systematic grid visual inspection and sampling to identify any suspect asbestos material Minimum sampling rate: 40 locations per 4,000 tonnes or 14 samples per 1,000 m^3
Conveyor	Visual inspection only to identify any suspect asbestos material	Visual inspection and sampling to identify any suspect asbestos material Minimum sampling rate: one sample per 70 m^3 of product	Visual inspection and sampling to identify any suspect asbestos material Minimum sampling rate: one sample per 70 m^3 of product

Each sample collected must be at least 10 L and sieved using a 7 mm sieve in the field. The >7 mm fraction is examined for any suspect asbestos material and if present, be retained for analysis and to calculate the level of asbestos contamination. The <7 mm fraction needs to be at least 500 mL, wetted and submitted for laboratory analysis according to AS 4964.

WA Waste Guideline applies a risk-based approach by allowing a sampling reduction rate when consistent product quality is demonstrated for a continuous six-month period, which is confirmed through an inspection or audit. The product sampling rate can be reduced to 1 sample per 600 m^3 or 5 locations per 4,000 tonnes of product. Other criteria considered for sampling reduction are available in the WA Waste Guideline section 4.3.6.

3.2.2 Analysis method

WA Waste Guideline uses a combination of gravimetric determination of total asbestos and laboratory analysis according to AS 4964 to calculate the total weight of asbestos in a known weight of recycled material. The ACM and fibrous asbestos concentrations from >7 mm sample fractions are determined using the gravimetric method in Section 3.1.2. The <7mm fractions are analysed in the laboratory for fibrous asbestos and asbestos fines according to AS 4964 or equivalent standards.

An exceedance of asbestos concentration in the product occurs when the total asbestos fibre content is greater than 0.001%. For example, if an asbestos cement fragment of approximately 7g (assuming 15% asbestos content) is found in 100 kg of sample, this is already an exceedance as the asbestos content in the sample is 0.00105%. If no visible asbestos is found during inspection, but trace analysis according to AS 4964 results in a detection, this is also considered an exceedance although the method cannot be used to quantify asbestos in the sample below the LOD of 0.01%. This is because any detected free fibre could originate from other source (e.g. bonded ACM fragments from the pile) and thus any detection will lead to an exceedance of the product specification.

3.2.3 Reporting

Figure 6 shows an example analysis summary report of asbestos in residential soil. The reporting starts with detailed description of the separated, suspect material observed and identified by PLM and the total dry weight of the sample. The trace analysis result as per AS 4964 can be provided to report any detection of free asbestos fibres which may be distributed throughout the sample. For each material found in the sample, the dimensions and the measured or estimated weight are described. The estimated asbestos content in the sample can be expressed as a percentage of the total dry weight of the sample separately based on the categories below:

- > 7 x 7 mm bonded ACM
- > 7 mm fibrous asbestos
- < 7 mm asbestos fines

In this example, the brown coarse grain soil contains two types of identified asbestos fragments: grey fibre cement fragments (> 7 x 7 mm, assuming asbestos fibre content of 15%) and weathered grey fibre cement fragments (> 2mm and < 2mm, assuming asbestos fibre content of 20%). There are also synthetic mineral fibres and organic fibres detected in the sample. Trace analysis for the debris < 2mm as per AS 4964 indicates there is no 'respirable' asbestos fibres[24].

Using the gravimetric method to calculate asbestos content in fragments found in the field as well as asbestos fines analysis in the laboratory, the total asbestos concentration is 0.029% w/w, which is an exceedance of ACM and asbestos fines screening criteria in residential soil. A similar result in waste would be interpreted as an exceedance of the product specification.

This example also demonstrates that visual sampling for asbestos is key to determining the nature and type of asbestos contamination. The identified ACM fragments have exceeded the 0.001% w/w limit

[24] Note that the PLM magnification used during trace analysis is insufficient to detect respirable fibres (i.e. asbestos fibres less than 3 µm width and greater than 5 µm length, with a length-to-width ratio greater than 3:1). Asbestos fibres detected during trace analysis are free fibres which have been released from ACM. Detection of these free fibres indicates a higher risk profile when handling the material.

although the microscopic trace analysis indicates no free asbestos fibres were detected above 'trace levels'.

Test/Reference	LOR	Unit	
Asbestos in Soils (AS:4964-2004)			
Sample Description	-	Comment	Brown coarse grain soil
Total Dry Mass	0.1	g	1404
Total Analytical Fraction	0.1	g	1404
Asbestos Detected	-	Yes/No	Yes
Materials Identified	-	Comment	1. Grey fibre cement fragments with green paint layer (3x fragments > 7x7mm) 2. Weathered grey fibre cement fragments (9x fragments >2mm, 3x fragments < 2x2mm)
Fibres Identified and approximate Asbestos Content	-	Comment	1. Chrysotile and amosite asbestos detected; 15% 2. Chrysotile and amosite asbestos detected; 20% Synthetic mineral fibre detected Organic fibre detected
Asbestos Content (as asbestos)	0.01	% w/w	0.029
Trace Analysis	0.1	g/kg	No respirable fibres
Asbestos in Soils (ASC NEPM 2013) - non-NATA			
Asbestos Containing Materials (ACM) >7mm			
Total ACM (>7mm)	0.1	g	2.38
ACM % asbestos (weighted average)	-	%	15
ACM in Soil (as asbestos)	0.01	% w/w	0.025
Fibrous Asbestos (FA) >7mm			
Total FA	0.0005	g	< 0.0005
FA % asbestos (weighted average)	-	%	N/A
FA Asbestos in Soil	0.001	% w/w	< 0.001
Asbestos Fines (AF) <7mm			
Total AF	0.0005	g	0.232
AF % asbestos (weighted average)	-	%	20
AF Asbestos in Soil	0.001	% w/w	0.0033

Figure 6: An example of asbestos analysis reporting based on the WA Waste Guideline. Note that the sample was taken from residential soil, but the reporting elements are also applicable to waste. (Source: WA DOH)

3.2.4 Result interpretation

The WA Waste Guideline applies a multiple-lines-of-evidence approach in interpreting inspection and sampling results, from acceptance of waste materials to end product specification. Any indication of asbestos in visual inspections or analytical results exceeding the product specification leads to classifying the stockpile or process batch as asbestos waste for disposal, subjecting it to further remediation or demonstrating its acceptability by additional assessment. Detection of a single fragment of bonded ACM or fibrous asbestos (e.g. 1 cm^3 fragment in 10 L sample) can be considered an isolated case if no other contamination is present, and the stockpile is allowed for beneficial reuse. If there are multiple contaminations in a localised area, that section can be excavated to remove any visible asbestos, making the rest of the stockpile suitable for reuse.

Laboratory analysis results should not be averaged across samples. For a single exceedance at a level less than 0.01% w/w, the stockpile may not be classified as contaminated, provided that additional samples of adjacent areas do not show exceedances.

Results from different assessment methods for the same type of stockpile should not be considered in isolation. In the case of exceedances, an investigation into the likely cause for the presence of asbestos in the end product should be carried out and controls implemented to prevent future reoccurrence. A record of the investigation, findings and preventative measures, as well as any action taken on the stockpile that do not meet the specification should be made.

3.3 Principles of sampling and analysis design

In seeking to address TOR 3 of the Review (below), it is clear that framing an appropriate sampling and analysis approach for asbestos in recovered materials is a complex task.

What is the most appropriate sampling and analytical approach for asbestos in recovered materials? In answering this question, consideration should be given to:

a. How many samples to collect and test for a given volume to be fair, cost-effective and representative
b. What test methods would represent best practice, for example, AS4964-2004, NEPM gravimetric and asbestos fines/fibrous asbestos sampling, or other test methods?
c. The technology available in the context of the recommended acceptable thresholds and its accessibility

As apparent from the challenges in conducting sampling and analysis for asbestos presented above (Section3.1), there is no single sampling procedure and/or analytical method that would apply to all types of recovered C&D waste which would provide an appropriate level of confidence for compliance purposes.

Under the current zero tolerance approach in NSW, the available sampling and analysis methods for determining asbestos content cannot provide a guarantee that the sample is asbestos-free because the absence of evidence is not the same as the evidence of absence. In addition, a sampling objective to demonstrate absence of contaminant in recovered materials is impossible due to the limit of detection of the analytical method. Even with a threshold introduced, the challenges in sampling and analysis for asbestos in Section 3.1 demonstrate that it is difficult to obtain reliable results to verify adherence to the threshold.

Hence, the limitations of sampling and analysis methods should be considered in determining and applying any potential threshold level of contaminant in recovered materials, and mitigated by applying other measures to minimise asbestos contamination in the end product. This approach will be discussed in Chapter4.

This section presents the principles of sampling design for asbestos which can be considered for developing a sampling plan. The key principles to be considered include the following (discussed in detail below):

- Defining sampling objectives
- Choosing a sampling strategy appropriate for the characteristics of the material and the type of data required
- Understanding limitations and assumptions of the measurement/analysis technique
- Better defining confidence by analysing data for reliability and validity once collected.

3.3.1 Sampling objectives

Sampling objectives need first to be determined to develop an appropriate sampling design. The sampling objective for contaminants in recovered materials is usually to (DTSC, 2024):

a. confirm the detection or non-detection of contaminant in the material, and/or
b. meet relevant product specifications (e.g. contaminants below a certain threshold level).

In meeting the product specifications, the following specific objectives can be considered:

- Ensuring worker and public health protection (i.e. may indicate the need for air sampling to assess exposure risk).
- Complying with WHS and environmental legislation applicable to asbestos (i.e. may indicate identification analysis that contains asbestos with respect to regulatory control measures related to asbestos waste and asbestos-related work).
- Aligning with public expectations and maintaining a social licence to operate by demonstrating proactive and transparent environmental management of contaminants in recycling processes (i.e. may indicate need for visual inspection/field sampling).

3.3.2 Sampling strategies

When formulating a sampling strategy, it is important to consider the factors that will impact data collection and quality, such as location and accessibility (e.g. truck loads, stockpiles or conveyor belts), processing workflows, characteristics of the material (e.g. heterogeneity, load/stockpile size) and potential non-uniform distribution of asbestos in the material (i.e. presence of hotspots).

For asbestos sampling, there are two applicable sampling strategies which are (1) judgemental sampling/targeted sampling and (2) probability sampling. The descriptions, advantages, disadvantages and examples on where to use such sampling strategies are summarised in Table 8.

Table 8: Summary of sampling strategies to detect asbestos.

Sampling strategy	Description	Advantages	Disadvantages	Example of applications
Judgmental sampling/ targeted sampling	Sampler decides where and/or when to collect the samples Based on existing knowledge of the waste characteristics and contamination	Efficient method to determine the worst-case impacts	Introduce potential bias Heavy reliance on the experience and expertise of the sampler Difficult to infer meaning to general population as it is non-probability based	Apply risk-based approach to determine the number of samples and frequency of sampling If there is a higher risk of asbestos contamination in the materials, collect higher number of samples If suspected ACM fragment is spotted, collect samples for visual analysis Use data collected from judgmental sampling to inform future sampling strategies. Perform systematic analysis of risk, based on aggregated data
Probability sampling	Sampler uses random sampling approach to ensure that all parts of the material have a statistically equal chance of being selected and hence capture a representative subset of the entire stockpile or 'population' Statistical software is often used	Useful when little information about the waste is available Can provide unbiased result	Requires a large number of samples and significant cost, if being used as a compliance tool	Conduct a pilot study to obtain statistical estimates of mean, standard deviation or variance of the samples If available, use existing data from a study of similar waste stream to obtain the estimations Use the estimates to determine the number of samples required based on desired precision and confidence level* Consider practicality including time and cost of sampling to determine final number of samples

* Refer to the sample size equations (equation 8) in Section 5.4.1 of US EPA's RCRA Waste Sampling Draft Technical Guidance (US EPA, 2002). This can often be solved using a statistical software.

As discussed above, guides on sampling of soil for contaminated land assessment are more widely understood and available compared to waste/end-product sampling for asbestos. The list below shows notable sampling guidance that can be considered when determining a sampling plan:

- NSW EPA (2022) Sampling design guidelines for contaminated land
- NEPC (2013) National Environment Protection (Assessment of Site Contamination) Measure 1999 Schedules B1 and B2
- EPA Victoria (2004) Soil sampling for waste soils
- US EPA (2002) RCRA Waste Sampling Draft Technical Guidance
- WA DWER (2021) Guideline: Managing Asbestos Waste in Recycling Facilities
- WA DOH (2021) Guidelines for the assessment, remediation and management of asbestos contaminated sites
- Swartjes & Tromp (2008) A Tiered Approach for the Assessment of the Human Health Risks of Asbestos in Soils
- Wroble et al (2017) Comparison of soil sampling and analytical methods for asbestos at the Sumas Mountain Asbestos Site - Working towards a toolbox for better assessment[25]

3.3.3 Measurement and analysis techniques

Sampling for asbestos analysis can be carried out at numerous points throughout the processing chain: when the C&D waste arrives at the facility, during processing and before the end product leaves the facility. Different techniques and technologies can be employed at different sampling points, ranging from manual visual inspection and portable asbestos analyser[26] to formal laboratory analysis. A review of emerging technologies for asbestos detection in waste that have the potential to improve data quality and reduce costs is available in Section 5.4.3 and the Expert Paper *Asbestos Sensing Review: Emerging technology for asbestos in waste, Supporting Document 3 (NSSN Paper SD3)*.

Laboratory analysis is most often employed to confirm the detection/non-detection of asbestos in bulk material (e.g. part of a building product) or to detect low levels of asbestos contamination within media (e.g. soil or crushed recycled product) as the objective. When selecting an analytical method, it is important to consider the limit of reporting of the method and the type of reporting result (qualitative versus quantitative). Table 9 provides a list of Australian and international analytical methods for asbestos detection or measurement in soil or bulk building materials. The list is not exhaustive, but it shows that the most common technologies available are stereomicroscopy, PLM, scanning electron microscopy (SEM) and transmission electron microscopy (TEM). More details on the description of each analytical procedures using various modes of technology can be found in EnRiskS *et al.* paper SD2, *Section 8: Analysis*.

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[25] Wroble et al. (2017) in their paper describe incremental sampling methodology as an effective and systemic form of compositing.

[26] Portable asbestos analysers (i.e. near infrared spectrometers) use a broad-spectrum of near infrared light to analyse the target material and identify the material by comparing the results with a reference spectrum. It is best used for building products that may contain asbestos such as cement sheets or tiles.

Table 9: Australian and international analytical methods for asbestos detection or measurement.

Analysis method	Application	Limit of reporting (LOR)	Reporting	Technology
AS 4964	Bulk and non-homogeneous (soil and ores)	0.01% w/w (trace analysis)	Qualitative - No asbestos detected/ trace asbestos detected/asbestos detected	Stereomicroscopy and PLM
AS 5370 (based on ISO 22262-1)	Bulk and non-homogeneous (soil, aggregate and mineral ores)	0.01% w/w (residual analysis)	Qualitative - No asbestos detected/ asbestos detected	Stereomicroscopy and PLM, SEM or TEM
ISO 22262-1	Bulk	0.01% w/w	Qualitative - No asbestos detected/ asbestos detected	Stereomicroscopy and PLM, SEM or TEM
ISO 22262-2	Bulk	0.1% w/w	Quantitative	SEM, TEM
ISO 22262-3	Bulk	0.01% w/w	Quantitative	XRD
HSG 248 – Appendix 2	Bulk	0.0001% w/w (in theory) >0.0001% w/w (in practice) *	Qualitative - No asbestos detected/ trace asbestos detected/asbestos detected	Stereomicroscopy and PLM, optional SEM or TEM
VDI 3866 Sheet 5	Bulk	1% w/w	Qualitative	SEM
VDI 3876	Non-homogeneous (soil, C&D waste)	0.005% w/w	Qualitative and quantitative (% w/w)	PLM
NEN 5896	Bulk	0.1% w/w	Qualitative	Stereomicroscopy and PLM, SEM
NEN 5898	Non-homogeneous (soil, sediment, C&D waste)	0.0002% w/w (2 mg asbestos/ kg of dry soil)	Quantitative (% w/w)	PLM, SEM, XRD
USEPA – EPA600/R3/116	Bulk	0.1% w/w	Qualitative and semi-quantitative (estimation of asbestos % w/w)	Stereomicroscopy and PLM, XRD, SEM, TEM
NIOSH 9002(refers to EPA600/R3/116)	Bulk	<1% w/w (estimated LOD)	Qualitative and quantitative (% w/w)	Stereomicroscopy and PLM
ASTM D7521-22 (refers to EPA600/R3/116)**	Soil	0.25% w/w (analytical sensitivity) 0.1% w/w (optional procedure)	Quantitative (% w/w)	Stereomicroscopy and PLM, TEM
M435* (CARB 435)**	Soil, Serpentine aggregate	0.25% w/w (lowest detection limit)	Quantitative (% w/w)	PLM

PLM – polarised light microscopy; SEM – scanning electron microscopy; TEM – transmission electron microscopy; XRD – X-ray diffraction

*In practice, the detection limit will be higher (i.e. less sensitive) as there are a number of matrix-dependent factors that may make it more difficult to detect and identify the asbestos fibres.

** Sample preparation includes drying and sieving.

*** Sample preparation includes milling.

As presented in Table 9, optical microscopy techniques are widely used in most analytical methods, including AS 4964 (superseded by AS 5370). Low magnification (10x to 40x objective) stereomicroscopy is used to first examine the sample for presence of any suspect ACM or fibre bundles (whether asbestos or other). PLM is then used to observe the morphology and optical properties of the fibres, including colour and pleochroism, birefringence, extinction characteristics, sign of elongations and refractive indices. These observations facilitate the identification of asbestos fibres (i.e. chrysotile, amosite or crocidolite asbestos) from other interfering fibres (e.g. polyethylene fibres, natural organic fibres, man-made vitreous fibres (formerly known as synthetic mineral fibres), talc fibres etc.) (Standards Australia, 2024).

Electron microscopy techniques, such as SEM/TEM offer much higher magnification than PLM, allowing detailed imaging and quantitative analysis of asbestos through fibre counting. Although the new AS 5370 provides detailed guidance on using SEM/TEM for asbestos analysis, it remains a qualitative method. SEM/TEM technology can be used to perform energy dispersive X-ray analysis (EDXA) and selected area electron diffraction (SAED, only applicable to TEM) to validate PLM analysis results or to address challenges in asbestos fibre identification, particularly when dealing with tremolite, actinolite or anthophyllite asbestos. The acquisition of EDXA spectra allows determination of the elemental composition of the fibre. For example, chrysotile fibre can be identified by comparing the characteristic magnesium/silicon peaks ratio to the reference spectra, provided that any iron, manganese and aluminium peaks are small. The SAED function in TEM can provide data on the crystalline structure of the fibre which is useful to further differentiate fibres that have similar EDXA spectra, such as fibrous talc versus anthophyllite asbestos (Standards Australia, 2024).

Similarly, X-ray diffraction (XRD) technique can also be used to resolve identification problems (qualitative) while providing an additional ability to quantify asbestos. This is outlined in methods such as ISO 22262-3, NEN 5898 and USEPA – EPA600/R3/116. Qualitative identification of asbestos is based on the diffraction pattern produced by the unique crystalline structure of asbestos, which can be compared to standard reference patterns. For quantitative analysis of asbestos, the mass content in bulk samples can be determined from the integrated area of the selected diffraction peaks (US EPA, 1993). XRD, however, cannot determine that a mineral meets the morphological criteria of asbestos.

Beside any method's detection limit and capability to meet the sampling objectives, selecting the appropriate analytical method also needs to consider practical aspects such as cost of analysis, accessibility of the technology and level of training required for analysts when selecting the analytical method. A summary of asbestos detection/measurement techniques by considering these factors is shown in Table 10. In Australia, PLM is currently the most used and accessible technology for asbestos identification with NATA accreditation because of the widespread use of AS 4964. The technology itself costs less and requires less training than the use of electron microscopy and XRD. However, if there are new standard requirements for more accurate detection or quantitative measurement, laboratory capabilities to provide SEM/TEM analysis can be increased and the costs can be lowered to meet the industry demands.

Table 10: Summary of current asbestos detection technology based on its function, level of training, cost and accessibility

Technology		Function	Level of training*	Cost*	Accessibility*
Optical microscopy**	**Stereo-microscopy**	Detection of fibres within a sample, tentative identification of fibres for formal identification via PLM	Low	Low	High
	PLM	Asbestos fibre identification by observing optical properties of individual fibres using criteria such as fibre morphology and refractive index	Low	Low	High
Electron microscopy	**SEM**	Asbestiform morphology identification Elemental composition the fibre when coupled with EDXA Quantification of asbestos - fibre counting	High	High	Low
	TEM	Asbestiform morphology identification Elemental composition of the fibre when coupled with EDXA. Crystalline structure of the fibre when coupled with SAED Quantification of asbestos - fibre counting	High	High	Low
Diffraction	**XRD**	Crystallinity and quantification of asbestos in residue	Medium	Medium	Medium

EDXA – energy dispersive X-ray analysis; PLM – polarised light microscopy; SAED – selected area electro diffraction; SEM – scanning electron microscopy; TEM – transmission electron microscopy; XRD – X-ray diffraction

* Relative comparison

** Note that the stereomicroscopy and PLM are used together as a package for asbestos identification.

3.3.4 Data reliability and validity

The collected data is assessed through data quality assessment, which is the scientific and statistical evaluation of data to determine if the data is of the right type, quality and quantity to support their intended purpose (US EPA, 2024). The assessment process can be used to evaluate sample analysis results from the pilot study conducted to provide estimates.

The assessment process includes five steps:

1. reviewing the sampling objectives and sampling design to ensure they are still applicable
2. preparing the data for statistical analysis
3. conducting a preliminary review of the data and checking statistical assumptions
4. selecting and performing statistical test, and
5. drawing conclusions from the data.

The result of the data quality assessment process is to determine if further sampling is required and to report the result from the selected sampling design. If other decision-making criteria are applied, such as a weight-of-evidence approach, then the result of that decision-making process should be reported.

The report from data quality assessment can be used for the auditing process as other supporting evidence in ensuring that the end product meets the material specifications (see Section 5.4.2).

3.4 Findings

- There are a limited number of guides for sampling and analysis of asbestos in waste (i.e. recycled end product). Soil sampling guides are widely understood and available for asbestos sampling and analysis.
- Obtaining a representative sample for analysis with high confidence can be challenging due to heterogeneity of materials and non-uniform distribution of asbestos (i.e. hotspots).

- Visual identification of ACMs remains the first key step in detecting asbestos, whether at the demolition site, the receiving/tipping point at recycling facilities or during analysis procedures in the field or laboratory.
- Current methods using NEPM gravimetric and AS 4964 (now superseded by AS 5370) laboratory analysis are sufficient to detect and estimate asbestos content in recovered materials, however their limitations and applications to end product must be understood.
- Appropriate training and internal/external quality assurance through accreditation of those undertaking asbestos sampling and analysis are critical to ensure the competency of the analysts and minimise variability in reporting results.
- Sampling in the WA Waste Guideline focuses on assessment of the end product by targeting areas with visible suspect asbestos materials. The samples are analysed using gravimetric method and AS 4964 to estimate the total asbestos content.
- Interpretation of sampling and analysis results in the WA Waste Guideline applies a multiple-lines-of- evidence approach to deciding whether the stockpile meets the product specification of 0.001% w/w asbestos.
- In the case of exceedances in a stockpile, investigation of the cause must be carried out and preventative measures must be taken to prevent a future occurrence. Any actions taken on the stockpile must be recorded.
- A generic sampling and analysis plan for asbestos in recovered fines and materials is unlikely to provide a high level of detection confidence. The sampling and analysis of end products should consider the sampling objectives, sampling strategies in the field, the limitations and applicability of selected analysis method and data quality assessment.

4. A through-chain risk-based approach to asbestos management

Chapter 1 demonstrated that the existing zero tolerance approach has not always been effective in minimising risks related to asbestos in recycled waste. Recyclers carry a disproportionate share of responsibility in ensuring the risks are controlled although they rely heavily on visual detection to identify asbestos in incoming loads.

This chapter aims to address TOR 5 by exploring a different approach to managing asbestos in recovered materials. It starts by introducing the concept and principles of a through-chain risk-based approach, followed by mapping asbestos management in the recycled waste value chain and then demonstrating how this approach might be applied to asbestos management in C&D waste in NSW to reduce potential risks.

A through-chain risk-based approach focuses on identifying, assessing and managing risks at each stage of the value chain. It is designed to ensure that potential risks are understood and mitigated at every step, from the beginning (such as raw material sourcing) to the end (such as waste disposal or recycling). The review found that there is general support for a through-chain risk-based approach to managing asbestos.

Early intervention through source separation would likely be effective in preventing most asbestos waste from entering the recycling stream and hence avoid contamination of end products. However, multiple barriers through the chain should be implemented to minimise the risk of asbestos contamination and exposure. Several case studies are presented to show how similar through-chain risk-based approaches have been applied by other states in Australia and internationally.

4.1 Overview of a through-chain risk-based approach to asbestos management

4.1.1 Risk-based approaches to managing/minimising contamination

A risk-based approach enables organisations to focus their resources to target process steps which pose the greatest risk to achieving their objectives (OECD, 2010). It involves a series of steps to determine the organisation's risk appetite, identify and assess risks, allocate resources and apply measures based on risk priorities, and monitor and review the plan.

Risk-based approaches to regulation have been used by all levels of government to ensure that regulatory approaches are efficient, effective, sustainable, proportionate and account for risk across policy objectives (OECD, 2010). NSW Government has a range of guidelines in place to assist departments and agencies in developing risk management policies and risk-based regulation. For example, *The Guidance for Regulators to Implement Outcome and Risk-based Regulation* provides a clear and practical framework (NSW Government, 2016).

An example of risk-based regulation is the risk-based licensing system implemented by the NSW EPA since 1 July 2015 (NSW EPA, 2024c). This system aims to ensure that all environment protection licensees are subject to an appropriate level of regulation based on the environmental risk of the activity. This allows the EPA to better target regulatory efforts towards high risk and poor performing licensees. Licensees with a higher risk level will receive an increased level of regulatory and compliance oversight, whereas licensees with a lower risk level will benefit from reduced red tape and reduced regulatory burden. In addition, licensees who perform well are rewarded with a reduction of their administrative fees, while poor performing licensees will pay licence fees that provide an incentive to improve their performance. NSW EPA publishes licences once the environmental risk levels are determined for each licence. This provides the community with more information about the environmental risks posed by licensed activities and the compliance performance of individual licensees. It also provides greater transparency and insight into the EPA's regulatory decision-making process (NSW EPA, 2024c). However, the current zero tolerance for asbestos in waste does not allow for a risk-based approach to asbestos management (See Section1.2.3).

Risk-based approaches have also been applied by industries and businesses to manage their resources more effectively, comply with regulatory requirements, enhance the organisational resilience and protect their reputation. An example of a common risk analysis and assessment method used in manufacturing industry is the Failure Mode and Effects Analysis (FMEA). This tool is used to discover potential failures modes and eliminate those failures during the product development process. Other well-known risk analysis and assessment methods in the manufacturing industry to ensure safety include Hazard and Operability Study (HAZOP), Quantitative Risk Assessment , risk matrix and bow tie analysis.

4.1.2 What is a through-chain risk-based approach?

A through-chain risk-based approach is a systematic method that focuses on identifying, assessing and managing risks at each stage of the value chain. This section contains a detailed description of the components of a through-chain risk-based approach.

A value chain typically covers all stages in a product's life cycle, from supply of raw materials to re-use, recycling and disposal after use. A value chain comprises all the activities that provide or receive value from designing, making, distributing, retailing and consuming a product or a service. The value chain normally comprises all the stakeholders and participants directly undertaking those activities and includes those who can influence those activities. The value chain thus incorporates not only the physical assets and processes, but also all the activities linked to value creation such as business models, investments and regulation (United Nations Environment Programme, 2021).

The concepts of value chain, supply chain and lifecycle are demonstrated in Figure 7. The concept of value chain should not be confused with supply chain, which deals with a more restricted notion of building the product and getting it to the consumer and is focused mostly on sourcing raw materials, and the process and logistics of product delivery. The value chain extends beyond merely selling of goods and products – it focuses on capturing value throughout the entire product lifecycle. In the context of asbestos, contaminated products have a negative value and require remediation, whereas decontamination would add value.

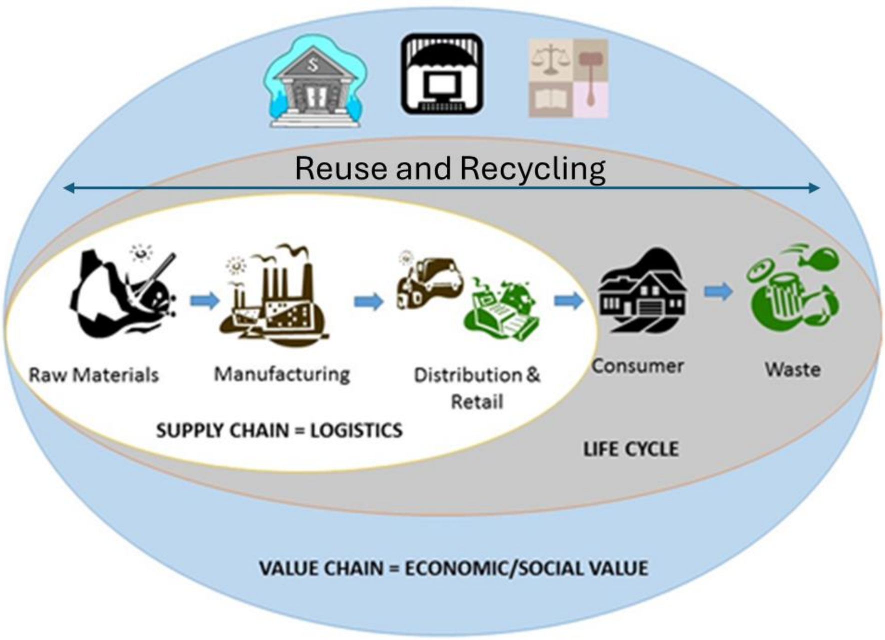

Figure 7: Value chain in relation to supply chains and lifecycle by UN environment programme adapted by OCSE (UN Environment Programme, 2024).

A value chain or through chain approach considers the entire ecosystem of the product value chain and all economic activities encompassed within. The approach needs to consider activities at different stages of the value chain, and how the value chain operates as part of a broader system. The value chain approach can identify key points for intervention at each stage of the product lifecycle that may enable actions built on existing knowledge and available data. The fundamental outcomes of the value chain approach are:

- identifying where the greatest opportunities for improvement occur
- defining actions required to take advantage of these opportunities by each stakeholder group
- identifying enabling conditions required, and who will take the lead responsibilities for actions to establish/maintain these conditions.

Key aspects of a through-chain risk-based approach are shown in Figure 8, with each step explained in detail as follows (OECD, 2010):

- **Value chain mapping**. This exercise maps all the stages, processes, actors and activities across the value chain of targeted industry and understands how each component interacts with the rest of chain under the whole system.
- **Risk identification**. At each stage of the value chain, potential risks are identified. These could be risks to human health and safety, product quality, adverse economic or environmental impact.
- **Risk assessment**. Once all potential risks are being identified, risks are evaluated based on their likelihood and potential impact. This assessment helps prioritise which risks need to be managed more aggressively. The assessment can be done objectively or subjectively. Quantitative measures are more common in the context of environmental and food-related risk assessment, whereas qualitative assessment is used for financial, management and government risks.
- **Risk control and mitigation**. Risk control and mitigation strategies are developed to mitigate or manage identified risks. This might involve changes to processes, additional safeguards or contingency planning. The effectiveness of the risk management strategies is continually monitored, and the process is reviewed regularly to identify any new risks or changes in existing risks.
- **Risk monitoring and review**. The effectiveness of the risk management strategies is continually monitored, and the process is reviewed regularly to identify any new risks or changes in existing risks.
- **Integration across the chain**. The approach is applied consistently across all stages of the chain, ensuring that risks are managed holistically rather than in isolation. This ensures that risks in one part of the chain do not negatively impact other parts for accumulated risks down through the chain.

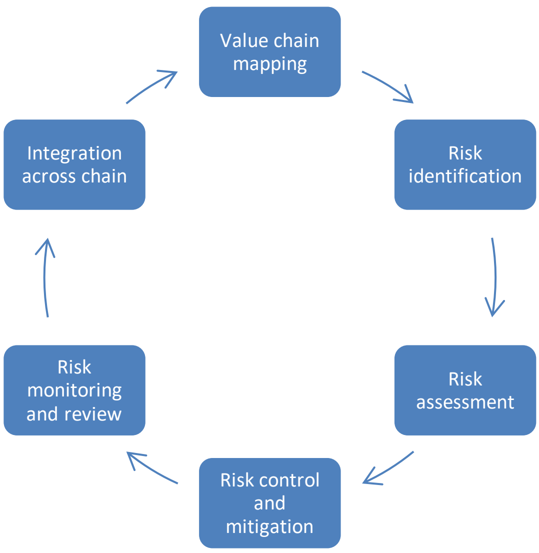

Figure 8: Through-chain risk-based approach

Through-chain risk-based approaches or similar systems for managing contamination risks are used by many industries. For example, the concept of Hazard Analysis and Critical Control Points (HACCP) is a well-known through-chain risk-based approach for the food industry (Australian Institute of Food Safety, n.d.). It is used to ensure food safety by identifying, assessing and controlling hazards throughout the food production process, from raw material production to distribution and consumption of the final product. Another example is water management where a risk-based approach is used to control contaminants from source to tap (NHMRC, NRMMC, 2011). Water utilities and regulators apply risk assessments at different stages – such as source water, treatment processes and distribution networks – to identify and control potential contamination points.

4.1.3 Risk Control Principles

In deciding control measures, organisations need to decide how much risk they are prepared to tolerate (OECD, 2010). Work, health and safety risks are usually managed to the level of 'as low as reasonably practicable' noting that that there is a residual level of risk to remain (Safe Work Australia, n.d.). Other policies related to food additives, veterinary drugs and cybersecurity may aim for 'notional zero-failure' although the impact of such policies is difficult to measure in absolute terms (OECD, 2010).

It is also important to recognise that every decision comes at a cost. The cost of selecting control measures can come from Type I or Type II errors. In asbestos management, an example of Type I error (accepting the hypothesis that the product or process is not safe when it is) is rejecting a large stockpile of C&D waste because it is deemed contaminated although the contamination is minor and localised. This results in the disposal of valuable resources to the landfill. Type II error happens when the recycled materials are mistakenly considered free from asbestos based on sampling and analysis result only. The decision on which control measures are to be implemented needs to be proportionate with the risk and the cost of tolerating the risk.

As pointed out in Section 2.3.1, the degree of risk tolerance is not only determined by scientific evidence, but also by financial, social and political context. Risk communication can play an important role in helping all stakeholders involved to understand the risks and decisions behind the selected control measures (enHealth, 2021).

Minimising risks

The core principles of risk control follow the hierarchy of control measures by prioritising risk elimination, followed by risk reduction through isolating the hazard and reducing exposure using engineering controls, administrative controls and personal protective equipment. Previous sections discussed that the current risk management approach in the asbestos chain focuses on a few key points, including sampling and analysis and the reliance on human inspection to detect asbestos contamination either of which is not fit for purpose to reduce overall risks. It is therefore important to consider the concept of redundancy as represented by the Swiss Cheese Model (SCM) below (Figure 9) when designing a system to minimise risks – having various approaches in place that will serve as multiple barriers. These can include:

a. designing and implementing process controls
b. conducting monitoring and audit
c. defining standards of performance and equipping workers
d. other levers such as data collection, incentive and coordination programs to inform and support the integration of other measures.

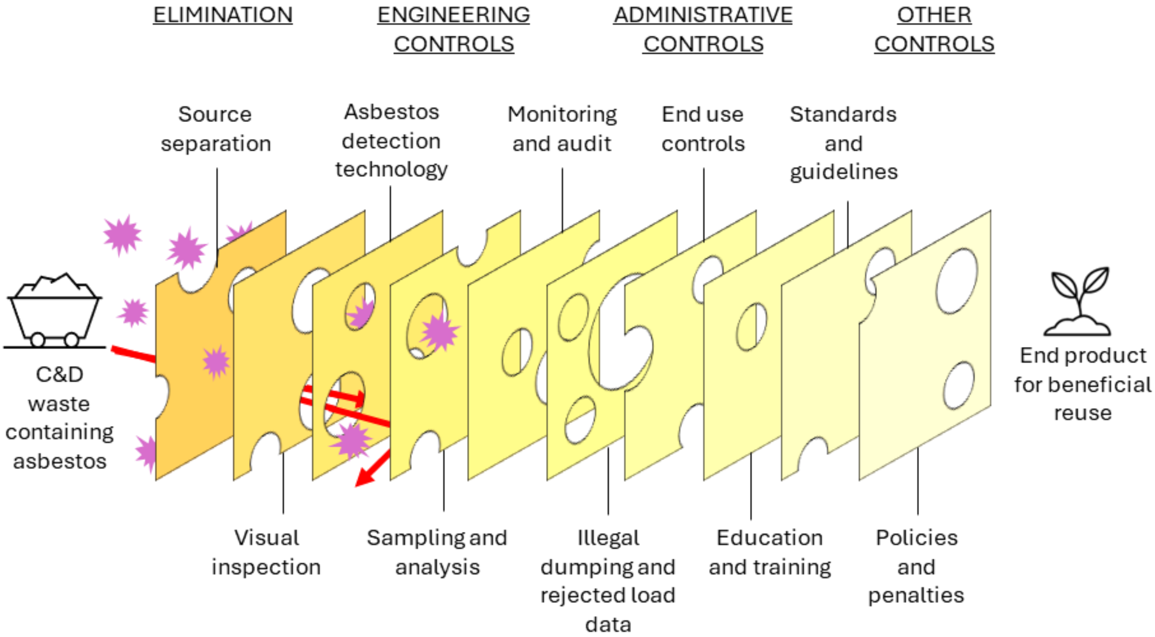

Figure 9: Swiss Cheese Model (SCM) diagram illustrating multiple control measures to minimise the risk of asbestos contamination in the end product.

4.1.4 Mapping asbestos management in the recycled waste value chain

The identified elements of the recycled waste life cycle relevant to asbestos can be divided into three main stages: starting from generation of asbestos waste at demolition/renovation site (*source*); waste transport and processing of recovered materials (*middle*); and end use of recovered materials (*end*). The through-chain elements relevant to these stages include participants, process, and program and policy. Examples of these elements are outlined in Figure 10.

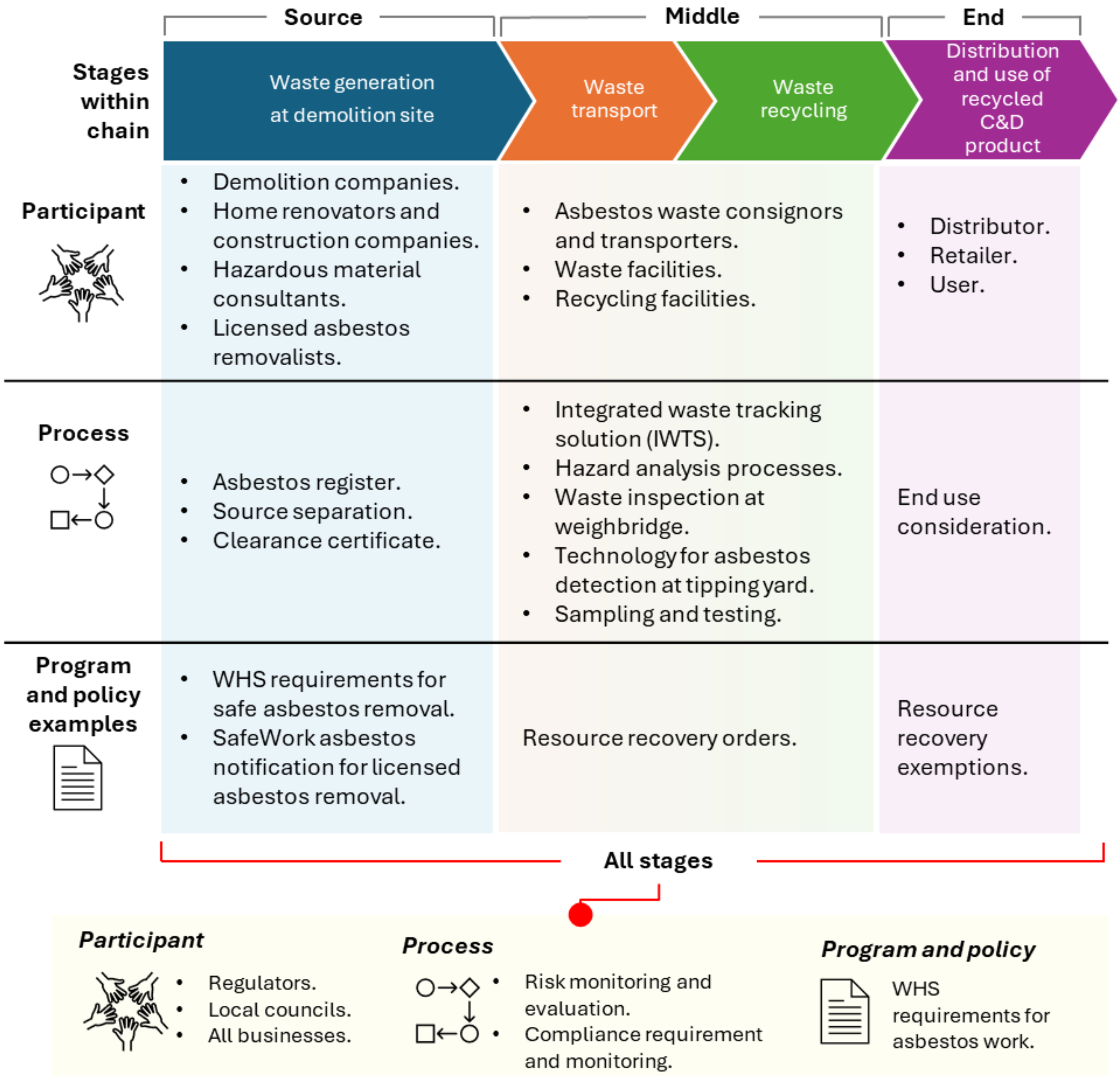

Figure 10: Elements and existing controls in asbestos management

It is important to note that although the Review was asked to provide advice on management of asbestos in recovered fines and materials for beneficial reuse that mainly originate from C&D waste, asbestos contamination has become an issue that affects sectors and participants beyond the C&D recycling industry. These include private and commercial demolition, non-C&D waste recycling, contaminated land management, transport, planning and development.

Planning requirements and removal during renovation or demolition

Any renovation or development works are governed by either the state planning laws or the local council regulations. Under the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (NSW) (Codes SEPP), some low environmental impact renovation and development works may be considered 'exempt development' and do not require any approval provided that they meet the relevant development standards as identified in the Codes SEPP. Complying development has more substantial impact than exempt development, but the approval process can be fast-tracked through a certifying authority, which is either the local council or a private certifier. Any other developments require a planning approval through a development application (DA), which must be approved by the local council.

As previously mentioned, any asbestos removal work must comply with the regulatory requirements set out in WHS Act and WHS Regulation. Contractors performing the work have the duty to identify asbestos and ensure licensed asbestos removal is carried out by a licensed asbestos removalist. A hazardous material consultant may be engaged to evaluate the occupational risks, project manage removal plan and provide a clearance certificate. The issuance of clearance certificates relies on visual inspection of an independent asbestos assessor to ensure any visible asbestos has been removed. The nature of the visual inspection is subjective, and it does not guarantee the remaining materials following asbestos removal work are free from asbestos.

For complying development or development requiring a DA, if it involves the removal of bonded ACM over 10 m^2 or any amount of friable asbestos, approvals must be issued subject to conditions ensuring safe asbestos removal and disposal (NSW Government, 2021). Namely, the asbestos removal work must be undertaken by a licensed removalist, and a copy of a signed contract with a licensed asbestos removalist must be provided which also specifies the landfill site that can lawfully accept the asbestos waste. This does not apply for the removal of less than 10 m^2 of bonded ACM. For exempt development, the Codes SEPP also requires that demolition work is performed in accordance with AS 2601-2001, which itself requires the removal of asbestos to be in accordance with the Model Code of Practice: How to safety remove asbestos (SafeWork NSW, 2022) containing similar licensing requirements. However, as exempt development does not require any development consent, the compliance with and efficacy of these safeguards is unclear.

Notably, while these requirements apply to developments involving asbestos removal, it is unclear whether there are any mandatory prior requirements to positively identify asbestos or hire a licensed asbestos assessor. Some councils may provide information to homeowners, renovators and developers on safely managing asbestos. This can be done through a pre-development application service offered by councils triggered by any asbestos-related issues raised by the proponents (Office of Local Government, 2015).

Disposal of removed asbestos

Transporters and waste facilities transporting and accepting disposal of asbestos waste over 100 kg or 10 m^2 within NSW must track and report to the NSW EPA through the Integrated Waste Tracking Solution (IWTS) (NSW EPA, 2024d). There are different requirements when householders plan to transport their domestic asbestos waste over 100 kg or 10 m^2 to a waste facility themselves (NSW EPA, 2024b). The purpose of asbestos waste tracking is to monitor the movement of asbestos waste to help to prevent harm to the environment and human health. Importantly, C&D waste loads later found to contain asbestos (e.g. during inspection and subsequent rejection at recycling facilities) are not tracked.

There are also financial considerations and incentives relevant to asbestos handling and disposal which influence behaviour of participants within the C&D waste recovery industry. At present, asbestos disposal is subject to a waste levy paid to the EPA by landfill operators. Some stakeholders raised concerns that the levy may create perverse incentives for illegal dumping to avoid this levy. These concerns previously led to the Review of NSW waste levy[27]. Other factors that may contribute to illegal dumping of asbestos, particularly for householders who must transport the waste themselves, include lack of knowledge about asbestos and its risks, lack of practical skills to identify and handle ACMs, and availability and proximity of licensed landfills (ASEA, 2023b).

C&D waste free from asbestos contamination

After the separation and disposal of asbestos waste, the remaining C&D waste is assumed to be clear of asbestos and transported to recycling facilities, which accept and process it according to the corresponding resource recovery order (RRO) requirements. Processes employed to attempt to confirm that the materials are free from asbestos contamination include visual inspections of incoming loads at weighbridges and tipping yards, and sampling and analysis of the end products. During consultations, some recyclers stated that they do not supply recycled materials to projects in sensitive areas, such as hospitals and schools, even though testing indicates no detectable asbestos in their products. This reflects a lack of confidence in current inspection and testing procedures and indicates avoidance of any

[27] The review of the NSW waste levy is ongoing during the preparation of this report in October – November 2024. The issues paper can be found at https://yoursay.epa.nsw.gov.au/nsw-waste-levy-review.

potential risk through fear of inadvertent asbestos contamination, despite recyclers' best effort to avoid or eliminate it.

Risk control

Permission to use recycled C&D waste is obtained through meeting the resource recovery exemption (RRE) requirements, which may include reporting and record keeping. At present, the risk of asbestos contamination and exposure from end products is largely managed by restricting the end use of the materials. For example, recycled aggregates, concrete, asphalt and soil are only used in areas with limited access, encapsulated or buried. However, concerns persist about risk of contamination when the materials are sourced from multiple processors/suppliers for large projects, or when blended by third party distributors before supplying them to consumers.

The identified risks at each stage of asbestos management are shown in Figure 11. Down the chain, the risk becomes more difficult to control as asbestos becomes dispersed, making it harder to detect and remove. Therefore, the first critical point to control the risk of asbestos contamination is where the waste is first generated.

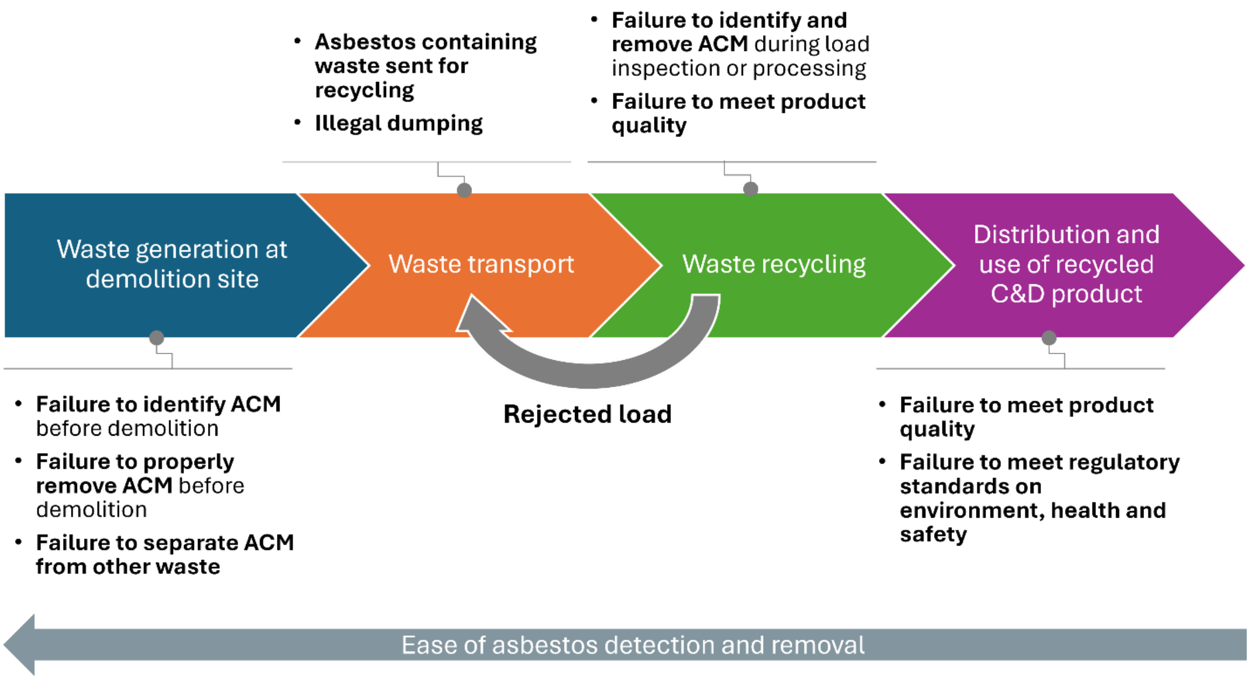

Figure 11: Identified risks in asbestos management

4.2 Effective risk control and mitigation starts at the source

Effective risk control and mitigation would be best achieved by implementing various controls that act as multiple barriers focused on preventing, eliminating and reducing the risk of asbestos contamination at every stage. The current approach, relying on human visual inspection of incoming waste and the sampling and analysis of a final product, has limited redundancy. This makes the current risk control and mitigation process prone to Type II (false negative) errors and provides a false sense of security. Multiple layers of defence, analogous to the SCM, will implement controls to better mitigate risks of error (Shabani, Jerie, & Shabani, 2024). Submissions to the Review suggested potential process controls, programs and policies to support asbestos management throughout the chain. Those examples are summarised in Figure 12. The decision to implement each control needs to be weighed against the risks, practicality, cost and the effectiveness of the measure. For instance, when asbestos fragments are found during waste transport, processing, distribution and use of recycled product, they should only be safely removed when the contamination is minor and localised.

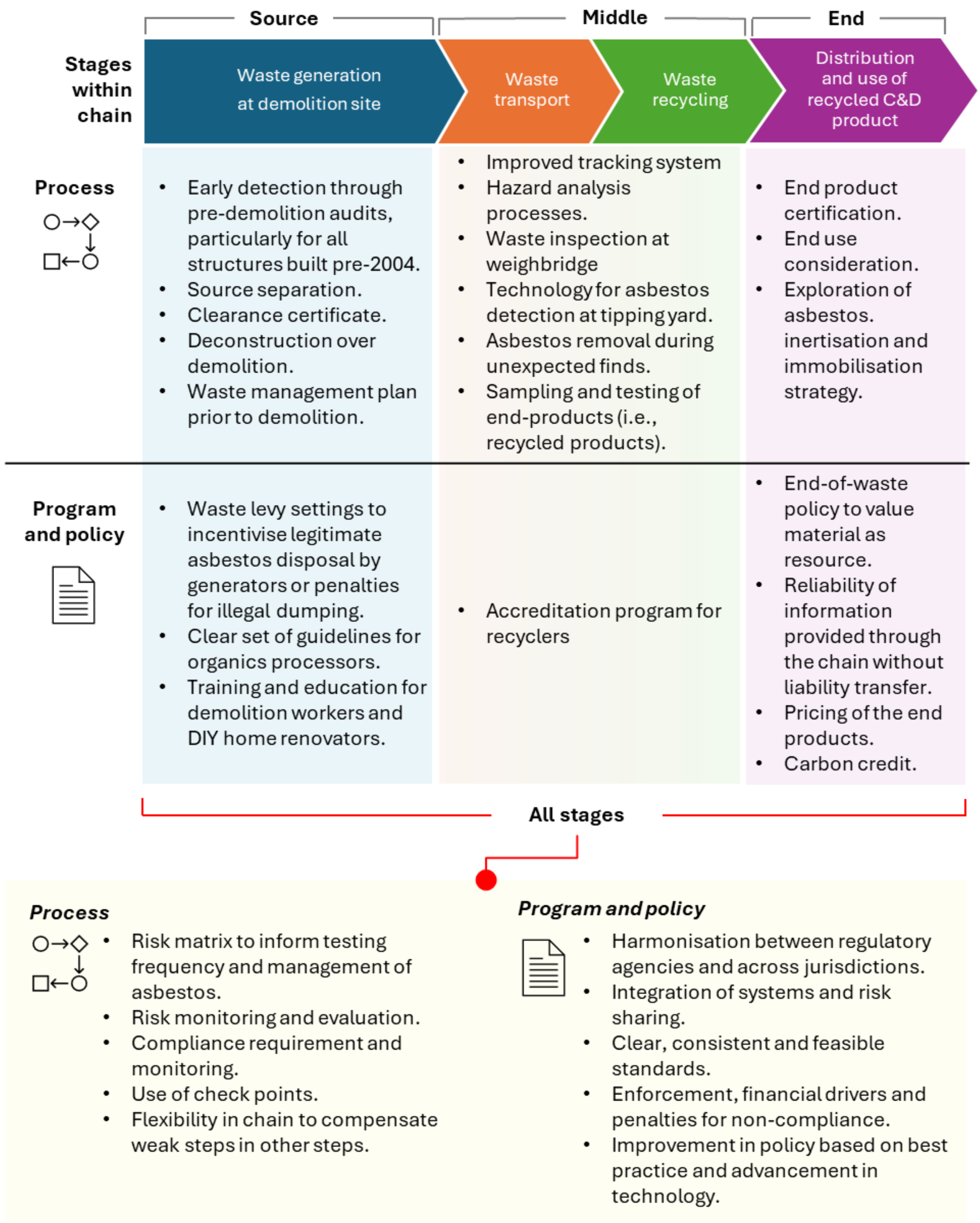

Figure 12: Through-chain risk-based approach for asbestos management

Overall, stakeholders are supportive of upstream control (43% of submissions) through source identification and separation, while acknowledging the need for other controls in mid-stream (23%), downstream (18%) and at all stages through monitoring and auditing (16%). Upstream control largely focuses on preventing asbestos from entering the recycling stream through early asbestos identification, removal and source separation.

Figure 13 demonstrates that early intervention prior to demolition can more effectively prevent asbestos contamination downstream compared to actions being taken at later stages. Proactive action such as removing asbestos from existing buildings in high-risk areas can prevent asbestos from contaminating the environment due to unpredicted disasters (e.g. fire, bushfire, cyclones and flood). However, it is important to recognise that asbestos management cannot rely solely on upstream management as the only control because asbestos may not be readily identifiable when broken, damaged, and blended or embedded in other materials. Further, human error can contribute to asbestos contamination at later stages, and the reuse of recycled C&D waste may introduce trace asbestos contamination to new construction projects. Continuous risk management must take these factors into account when determining the fate of the material.

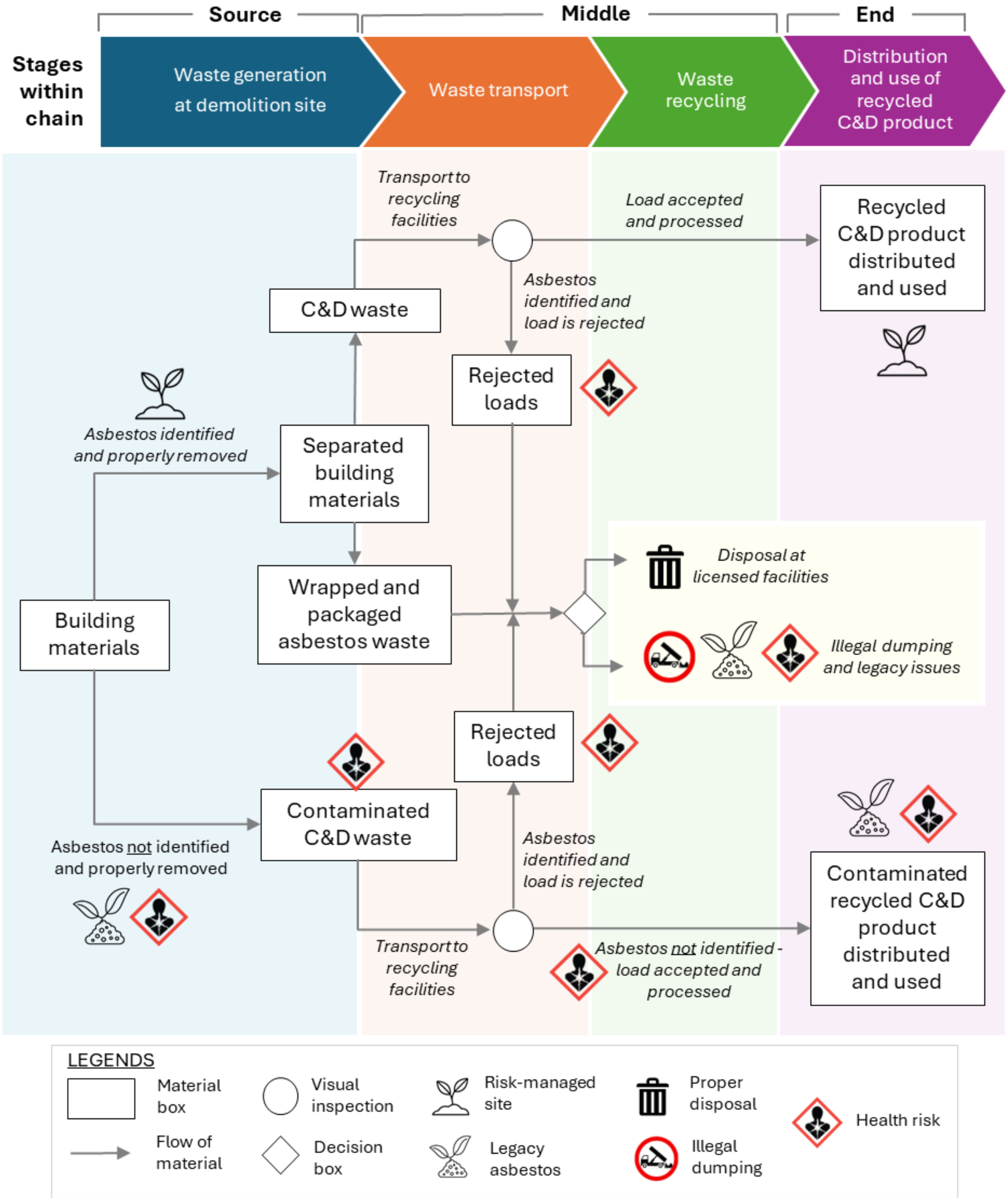

Figure 13: Risk control strategy at the source

Barriers

A number of barriers to proper identification and disposal of asbestos were identified by stakeholders. These include:

- a lack of awareness and competency of workers and renovators
- cost of disposal
- location of the licensed landfills able to receive waste.

Any of these may lead to illegal dumping of asbestos waste or disposal in kerbside bins (red, yellow and green bins). Running education and training programs to raise awareness and programs to incentivise asbestos disposal can be costly, but they can improve safety and encourage proper disposal. Lessons learnt through residential asbestos removal programs are discussed in Section 5.6.

Transport

Effective asbestos management during waste transport and recycling can benefit from the use of technology to either track asbestos waste or detect asbestos in waste and end products. Tracking asbestos waste can provide surveillance information to increase education and compliance (see section 5.8), whereas the use of technology has the potential to reduce error in asbestos detection associated with visual inspection. Emerging technologies for asbestos detection will be explored further in Section 5.7.

End use control

End use control, which limits where recycled material will be used, can reduce the exposure risk. Fourteen out of 16 submissions agreed that recycled C&D waste that may contain trace levels of asbestos should only be reused in areas with limited access to the public, or being encapsulated, capped or buried (e.g. road base and fill materials). To prevent contamination legacy issue, the material should not be in used in greenfield sites.

Continuous improvement of a through-chain risk-based approach

Finally, each process control should be evaluated to support continuous improvement. Auditing and monitoring the various points of intervention or control can provide information and data to further improve the control measures in an adaptive way. This approach should be supported by clear guidelines and standards for each stage, harmonisation on regulatory frameworks across agencies and jurisdictions, and improvement in policy based on best practice and advancement in technology.

There are concerns about the effective implementation of a through-chain risk-based approach for asbestos management because it requires active involvement of participants throughout the chain to work together, which may lead to a lack of clarity around the responsibility of each participant within the system. Nonetheless, industry stakeholders expressed support for the through-chain risk-based approach and willingness to work with government agencies to co-design the approach. A coordinated and cooperative approach that sees government and industry participants actively working together reassures the public that all aspects of asbestos management are being carefully considered in the design and implementation of the through chain model. A transparent, co-designed approach builds public trust and shows commitment to accountability, which will be critical for the success of the proposed new approach. Details on requirements for better asbestos management will be discussed in the next chapter.

4.3 Case studies on through-chain risk-based asbestos management approaches

This section highlights risk-based approaches for asbestos management adopted by Australian and international jurisdictions. It is not meant to be an exhaustive summary of all measures by each government and should be read in conjunction with crcCARE Paper SD1. Not all case studies are examples of risk-based approach that apply to the whole value chain, but some elements can be considered for the proposed through-chain risk-based approach for asbestos management in NSW.

4.3.1 Victoria

The Victorian Government has adopted a risk-based approach to managing asbestos in government-owned buildings, focusing on the systematic identification, assessment, and removal of ACM. The approach includes the development of three key tools (Victorian Government, 2003):

Asbestos Identification and Rating System (AIRSystem)

AIRSystem is a consolidated database that contains details of buildings owned by the Victorian Government and identified ACMs within those buildings. AIRSystem allows the state agencies to manage asbestos and plan for a risk-based approach to prioritise the removal of ACMs. Risk ratings are applied to the identified ACMS using the risk assessment model (discussed below) to inform asbestos removal recommendations.

AIRSystem has some key features that allow easy access and use of information stored:

- Each building containing ACM has a unique number and QR code, allowing the user to scan the QR code and access AIRSystem. Such feature allows site workers to have access to the details of ACM prior to commencing work.
- Data can be visualised in different ways to help users and duty holders understand the asbestos legacy within the built environment, including understanding which ACMs are most prevalent, the condition of the ACMs and where there is a potential for high disturbance potential within specific locations.
- Other digital assets such as floor plans and 3D rendering can be integrated into AIRSystem. A 3D rendering enables the user to move virtually through the building, see the location and details of an ACM and access the full details within AIRSystem.

Risk Assessment Model

The Victorian Asbestos Eradication Agency (VAEA) developed an asbestos risk assessment model to allow an objective approach to ACM removal based on risk. The model assigns a percentage weighting for each risk factor to generate an aggregated risk score. The VAEA assessment model with risk factors and levels is demonstrated in Figure 14. ACM friability and ACM condition are determined based on information from the survey assessment of each ACM. VAEA has made the risk assessment model available for public use to assist management of existing workplace asbestos registers through the ACM risk calculator[28].

The VAEA assessment model incorporates the following risk factors:

- ACM friability - refers to how easily an ACM can be crumbled, pulverised or reduced to a power by hand pressure when dry
- ACM condition - refers to the state of an ACM with regard to its appearance, quality or surface treatment (sealing or encapsulation)
- ACM disturbance potential - refers to the ease with which building occupants and maintenance personnel can access and disturb an ACM based on expected activities.
- Building rating - refers to public access, frequency of use and duration, level of activity and presence of mobile plant.

[28] https://vaea.my.site.com/ram/s/

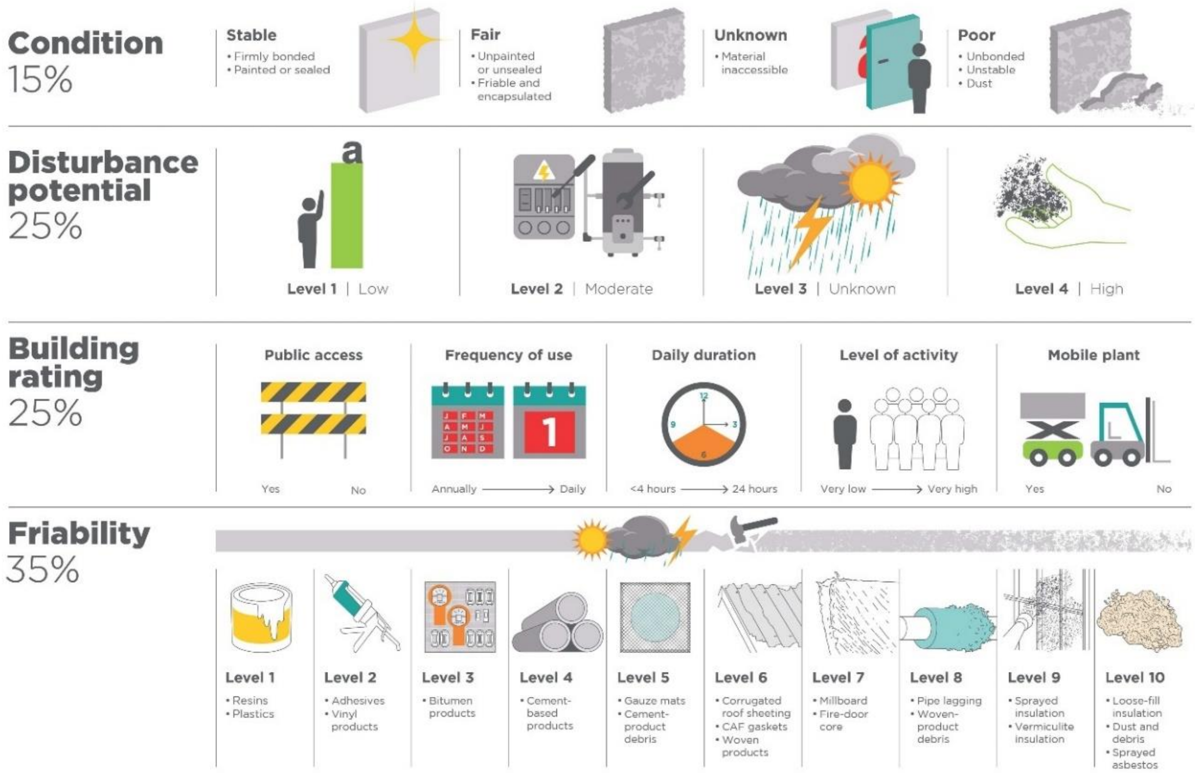

Figure 14. VAEA risk factors overview (VAEA, 2024)

Schedule for Prioritised Asbestos Removal

Victoria is the only jurisdiction that has a state-wide schedule for prioritised asbestos removal from government-owned buildings. The schedule is informed by the data collected through the AIRSystem and the risk assessment model, focusing on high-risk sites to enhance public safety. During 2021-22 the VAEA completed the ACM removal from State Library Vitoria, many regional TAFEs and state-owned community buildings (ASEA, 2023c). The VAEA's prioritised asbestos removal schedule is aligned with the *Asbestos National Strategic Plan: Phase Three 2024-2030* on delivering safe prioritised removal (ASSEA, 2024b). In addition, Victorian Government has an interactive tool[29] that guides the process of finding and identifying asbestos in home or workplace (Victorian Government, 2023). The tool gives step-by-step instruction guiding users through locations where asbestos could be found, and practical guidance on how to manage or remove it. Factsheets to help homeowners, tenants, employers and employees understand the risks of asbestos are translated into other languages.

4.3.2 Western Australia

Not only does WA have a threshold for asbestos in recycled material but has also adopted risk-based approaches. The WA Waste Guidelines covers procedures associated with the pre-acceptance, receipt, processing and management of C&D waste at recycling facilities. A risk-based approach is adopted for the acceptance procedure under the WA Waste Guideline. A risk classification matrix is used to assess the risk of C&D waste based on the material type and source, as shown in Table 11 (WA DWER, 2021).

[29] Visual reference for products with ACM is also available on ASSEA's Asbestos Product Guide. https://www.products.asbestossafety.gov.au/buildings/

Table 11: WA risk classification matrix

	Type of load		
Material type	**Commercial**	**Public, utes, cars and trailers***	**Skip bins**
Clean concrete (without formwork)	Low	High	High
Clean brick	Low	High	High
Clean bitumen/asphalt	Low	High	High
Mixed construction waste	High	High	High
Mixed demolition waste	High	High	High

*If it is possible to view the entire load of incoming C&D waste (e.g. a small trailer with a shallow load) then consideration may be given to classifying these loads as low risk.

The WA Waste Guideline notes that general buildings and structures constructed after 1990 are unlikely to have ACM within them, whereas buildings and structures constructed before this date may have been built using ACM. The WA Waste Guideline gives justification on how risk levels are assigned on load material types and sources in the matrix. For example, large buildings and structures undergo regulated asbestos removal programs and inspections before they are demolished are considered low risk as the probability of asbestos being present in the demolition debris should be low. On the other hand, mixed waste from unknown sources is considered high risk because such waste commonly contains an amount of asbestos, particularly in skip bins or from small-scale demolition or refurbishment activities (WA DWER, 2021). There are other factors to be considered in determining the risk level based on material type. For example, the WA Waste Guideline explicitly states that clean materials without formwork are classified as low risk. However, these materials are classified as high risk where contamination can remain in asbestos formwork embedded or attached to concrete columns and in asbestos piping from reclaimed road.

It is important to note that WA DOH is moving away from focusing on threshold levels and emphasising the use of risk assessment methods under a more robust framework that is under development. Under this framework, threshold levels are not the only determining factor, but it is used as an indicator of the effectiveness of the quality assurance and quality control processes (crcCARE Paper SD1).

4.3.3 European Union

The through-chain risk-based approach for asbestos management has been applied in some EU jurisdictions. Some EU Member States made pre-demolition audit mandatory particularly for public buildings to identify potential hazardous substances including asbestos prior to demolition, deconstruction or renovation (European Commission: Directorate-General for Environment, 2024).

France requires all properties with a building permit granted before 1 July 1997 to be screened for asbestos whenever the buildings are rented, sold or demolished (ICLG, 2024). If the last asbestos report is dated before 2013, a new one must be carried out in accordance with the new regulations in place. If asbestos is detected, removal work may be required depending on the condition of the ACM. There are plans to remove household asbestos by introducing a subsidy scheme on building and construction materials and products (European Commission: Directorate-General for Environment, 2024).

The main disposal option for asbestos waste in EU is landfilling. In some countries the waste levy for asbestos waste is very low or exempted because there is no alternative disposal option to landfill, and it can discourage illegal dumping. In the Netherlands, asbestos or asbestos-containing products from roofing are exempt from the waste levy to accelerate asbestos roof remediation[30]. The urgency to remove asbestos roofs is supported by research that shows weathered asbestos roofs are prone to release asbestos fibres that will end up in the soil through rainwater (Tromp, Spaan, & ten Brug, 2022).

There is a landfill ban proposed for ACM in the Netherlands Waste Management Plan to promote the development of asbestos waste recycling and treatment technologies (Rijkswaterstaat, n.d.a). The ban has not yet come into force but it becomes effective when the ACM recycling plant is capable of treating 75% of the total amount of ACM waste produced in the Netherlands per year. Additionally, it must be demonstrated that treated or recycled material is safe for health and the environment, there is market for the product, and the treatment process must cost no more than 150% of the equivalent landfilling tariff (European Commission: Directorate-General for Environment, 2024)

Some EU Member States such as Germany and the Netherlands have a prohibition on recycling and reuse of asbestos waste in their national legislation and have a threshold level associated with the definition of asbestos waste. The Netherlands Asbestos Product decree prohibits the manufacture, import, possession, provision to others, use or processing of asbestos or asbestos-containing materials (Dutch Government, 2024). The prohibition does not apply to treated asbestos-contaminated waste[31] which after the treatment contains less than or equal to 0.01% w/w asbestos equivalents[32].

Within the EU, the CINDERELA project has developed a proposed harmonised EoW criteria protocol for waste used as aggregates (The CINDERELA Project, 2021). The proposal includes a maximum asbestos content in the material of 0.01% w/w and would allow certification of the recycled material to be declared non-waste and asbestos-free. The European Commission has not yet implemented any end-of-waste criteria for such waste under the Waste Framework Directive (European Commission, n.d.). However, some member countries such as Ireland have implemented their own end-of-waste criteria for recycled aggregates – Ireland's specifies a physical contaminant limit for asbestos of 'No Asbestos Detected' following a visual inspection per HSG 248, and also mandates pre-demolition asbestos surveys to ensure no asbestos is present in the waste inputs (EPA Ireland, 2023).

The EU also has a waste classification system (European List of Wastes) which classifies eight types of asbestos waste as hazardous (European Commission, 2000). The Member States that use this classification can build centralised datasets on asbestos inventory to track their progress and asbestos waste movement including import and export.

4.4 Findings

- The current approach to managing asbestos in C&D waste in NSW does reflect a partial risk-based approach applied at specific stages but does not follow through the value chain to the end use of recycled materials.
- The Current controls in asbestos management in NSW include a requirement for safe handling and disposal of asbestos, tracking of asbestos waste, visual inspection of incoming waste and end-use control of recycled products.
- Lack of knowledge/and awareness of asbestos presence, lack of practical skills to identify and handle ACMs, avoidance of disposal costs, and inadequate surveillance activities contribute to risks in asbestos management in NSW.

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[30] The waste levy exemption requirements include engaging a certified asbestos removal company, reporting the remediation project in the national asbestos monitoring system, completing the roof remediation by 2024 at the latest, and disposing the removed asbestos no later than 31 March 2025.
https://business.gov.nl/regulation/landfill-tax/

[31] Asbestos-contaminated waste is waste to which no asbestos has been intentionally added.

[32] Concentration of asbestos is the sum of the concentration of serpentine asbestos and 10 times the concentration of amphibole asbestos.

- There is general support for a through-chain risk-based approach focusing on source separation for effective asbestos management in NSW, although reservations on the approach's implementation and practicality remain.
- Early intervention through asbestos identification and removal at the source can more effectively prevent asbestos contamination downstream, where it becomes dispersed and harder to detect and remove.
- The mapping of asbestos management in the recycled waste value chain suggests that having multiple barriers through the chain can minimise the risk of asbestos contamination and exposure; this can be achieved by implementing a combination of process controls and supporting programs and policies at multiple stages.
- Conceptual design and elements of the through-chain risk-based approach for asbestos management in C&D waste in NSW can be informed by case studies from other states in Australia and overseas.
- The WA Waste Guideline has a comprehensive, risk-based approach to managing asbestos in waste for re-use that incorporates pre-acceptance procedures, material risk classification matrix during acceptance procedures, waste processing controls, and sampling and analysis of the end products to validate the effectiveness of quality assurance and quality control processes.

Considering these findings, a set of recommendations will be made in Chapter 5.

5. What's needed for better asbestos management?

Chapters 2 through to 4 provide evidence, evaluation and findings relating to thresholds, sampling and analysis, and a through-chain risk-based approach to managing asbestos in recovered fines and materials. When these findings are considered in the context of the TOR, it becomes clear that individual recommendations following from each specific section are interdependent and should be implemented as a coordinated whole.

Chapter 2 highlights that where thresholds are established, additional measures must also be implemented to manage risk and minimise exposure. This is also the case where thresholds have been applied to waste for beneficial reuse. Therefore, thresholds should support a risk-based approach but are not sufficient in isolation and must be complemented by comprehensive systems and processes throughout the chain to help eliminate and/or reduce asbestos.

Chapter 3 concludes that sampling and analysis in isolation are not sufficient to ensure the absence of asbestos in recycled materials. A generic sampling and analysis plan for asbestos in recovered fines and materials is therefore unlikely to provide a high level of confidence. Limitations of sampling and analysis methods and specific application context should be considered when determining and applying any potential threshold level of contaminant in recovered materials. These limitations can be mitigated by the concurrent application of other through-chain measures to minimise asbestos contamination in end products.

Chapter 4 considers various aspects of a through-chain risk-based approach to asbestos management. Early intervention through asbestos investigation and removal at the source can more effectively prevent asbestos contamination downstream, and complement thresholds and sampling and analysis processes. Mapping of the management of the asbestos value chain suggests that having multiple barriers throughout the chain, using a combination of process controls, supporting programs and policies at each stage, will minimise the risk of asbestos contamination and exposure.

This chapter brings together earlier sections and proposes a holistic approach to managing asbestos in recovered fines and materials. This chapter also details factors to consider when designing and implementing a through-chain approach, addressing asbestos management at the source, at waste transport and recycling facility stages, and at end use. This is followed by suggestions for other supporting elements of a through-chain risk-based approach that can be applied at any stage through whole-of-sector coordination. These recommendations are context dependent, and it is difficult, and not supported, to consider any of these recommendations in isolation.

5.1 Asbestos management at the source

As discussed in Section4.2, effective risk control and mitigation measures begin at the waste generation site. Management of asbestos at commercial and residential C&D sites involving contractors must comply with the WHS Act and WHS Regulation[33], with the underlying principle of eliminating or minimising risks 'so far as is reasonably practicable'. These requirements only apply to approved asbestos-related work, which includes identification of asbestos, implementation of an asbestos register and management plan, notification to the regulator, worker training, removal of asbestos before future building work, asbestos waste disposal, and clearance inspection.

Effective asbestos management at source requires coordination and collaboration with Government agencies and key members of demolition industry sectors, supported by improved competence-based training and education for people receiving, inspecting and/or handling asbestos at all stages throughout the chain, including (but not limited to) recyclers, demolition workers, and sampling and analysis laboratory technicians. Additional training would support source separation at larger demolition sites as well, allowing for more recovered asbestos waste to be encapsulated on site or for improved waste

[33] Refer to Work Health and Safety Regulation of asbestos in Section2.2.2.

inspection prior to a load leaving the demolition site. Education and training are further discussed in Section5.4.1.

In supporting effective source separation at residential sites, coordination will be required between local councils, waste recovery facilities, landfill operators and the community to provide safe and convenient solutions to dispose of packaged ACMs. Highlights on programs run by local government areas (LGAs) and key lessons learnt can be found below.

5.1.1 Residential removal programs to support source separation

Local councils in NSW are responsible for managing asbestos in their LGAs, however there are significant barriers to proper asbestos disposal in residential areas. These include cost, volumes of asbestos and the difficulty of transporting waste. Limited information and challenging access to disposal facilities present further barriers. For example, 13% of the NSW population lives more than 120 minutes from a facility that accepts asbestos (Ascend Waste and Environment, 2021). Some of these facilities no longer accept asbestos waste in person but have not updated this information online. In areas where asbestos in houses and C&D waste is a significant concern, these barriers can lead to widespread illegal dumping and mismanagement of asbestos waste.

Approaches taken by LGAs, supported through grant programs or local council funding, can include safety initiatives and asbestos management policies designed to remove the structural barriers to safely handling and disposing of asbestos. These approaches, as part of a through-chain approach, can assist with responsible removal and isolation of asbestos through source separation at residential households.

Pilot and grant-funded programs

Programs often start as pilot initiatives funded by state or federal grants, allowing councils to tailor offerings to local needs and assess their effectiveness before expanding. One example is the Householders' Asbestos Disposal Scheme (HADS), delivered by NSW EPA as a pilot program supporting LGAs to develop and implement activities encouraging safe, affordable and lawful disposal of asbestos by home renovators. NSW EPA, under HADS, awarded $781,000 of funding and the waiving of the waste levy to 23 councils (Sydney metropolitan, regional areas and councils outside the levy paying area) and two private landfills over ~12 months from 2014 to 2015 (NSW EPA, 2019b; NSW EPA, 2017). The scheme was delivered flexibly, and individual councils could tailor their offering, in consultation with NSW EPA, to deliver the most effective program for their area.

The scheme mainly targeted illegal dumping. However, most councils do not have a robust system for recording illegal dumping incidents, and it is not mandatory for NSW councils and other public land managers to use NSW EPA's 'Report Illegal Dumping Online' (RIDOnline) portal. This results in an incomplete picture of how HADS directly affected illegal dumping and highlights the inherent difficulty in establishing a baseline to which asbestos disposal can be quantitatively compared when implementing trial through chain measures.

There were several enduring benefits to the scheme. Grantees felt like HADS raised awareness of asbestos and asbestos disposal amongst council staff, as well as amongst householders. This shows how pilot programs can set the stage for local councils to refine and continue existing programs or start their own asbestos management programs.

Source separation and responsible disposal

Programs can focus on separating and isolating asbestos from other waste streams at the source (e.g. during demolition), helping to prevent downstream contamination. For example, in Victoria, the Asbestos Disposal Points (ADP) Grants program aims to increase accessibility for safe disposal of bonded ACM (non-friable) in small quantities (less than 10 m^2) for a fee early in the chain (Sustainability Victoria, 2024). This grant program is not only targeted towards local councils but also welcomes the participation of existing waste facilities such as transfer stations, resource recovery centres or landfills in areas that have no present asbestos disposal route. The funding can be used for capital purchases and preparation of the on-site ADP including consultancy costs and contract work. The establishment of the

ADP will be according to the *Guide to Developing and Managing Asbestos Disposal Points for the Temporary Storage of Non-Friable Asbestos Waste* (Sustainability Victoria, 2023).

Affordable disposal access

Programs can aim to reduce costs, both perceived and actual, associated with legal asbestos disposal. For example, the Western Sydney Regional Organisation of Councils (WSROC) introduced the Western Sydney Regional Asbestos Disposal Scheme (WSRADS) to reduce the illegal and unsafe disposal of asbestos in Western Sydney. This scheme was initially run from August 2014 to August 2015 as part of the HADS pilot. The program offered a council-issued rebate for residents correctly disposing of asbestos to landfill. At the completion of the event, 506 households had participated in the WSRADS program, 65 tonnes of asbestos waste were disposed of lawfully, and over $12,000 in asbestos disposal rebates were issued to residents (WSROC, 2015). The ease of council-organised collection and disposal aided residents in removing legacy asbestos, or small volumes of asbestos inherited when purchasing or moving into a property.

Another way to approach affordable disposal access is through low-cost asbestos disposal fees at local facilities. For example, asbestos waste generated within the Shellharbour and Kiama Local Government Areas is accepted for disposal at Dunmore Recycling & Waste Disposal Depot (DRWDD). Asbestos disposal fees are $655/tonne, with a minimum charge of $320. An application must be lodged and approved at least five working days prior to transporting waste to DRWDD, and before starting any renovations or repairs. Once an application is received, a Council Supervisor organises an inspection of the asbestos. The asbestos is then packaged appropriately for transport and disposal, i.e. double-wrapped in polyethene with joints fully taped and clearly labelled 'ASBESTOS'. The DRWDD facilities address the cost and inconvenience of correct asbestos disposal that is a barrier to many residents by offering affordable local disposal facilities that allow residents to safely transport small amounts of asbestos waste themselves.

Convenient collection services

Councils can organise free or subsidised collection services where licensed contractors collect asbestos from residents' homes. This is particularly useful for managing legacy asbestos, where small amounts of asbestos are left from previous property owners. For example, several collection services were offered in Cumberland Council (formerly Holroyd) through collection trials. These included:

- 2013: a free two-day asbestos collection trial for pieces of asbestos less than 10 m^2, resulting in the collection of 1.2 tonnes of asbestos containing materials from 25 households. An additional seven collection days were added, resulting in the collection of a further 8.92 tonnes of asbestos (Holroyd City Council, 2014a).
- 2013: an expansion of the collection trial, resulting in the removal of 11.42 tonnes of asbestos waste from 180 properties in the council area, accompanied by three asbestos information nights giving residents practical advice in relation to asbestos identification, removal and disposal. Illegal dumping of asbestos in the community dropped from 8.9 tonnes (1 July 2013 – 31 Dec 2013) to 5.14 tonnes (1 January 2014 – 30 June 2014) (Holroyd City Council, 2014b).

Cumberland Council currently offers free collection of less than 10 m^2 of non-friable household asbestos. A property is surveyed, and a licensed contractor ensures the material is removed safely. This initiative mainly targets legacy asbestos and is not currently designed to encourage renovation. Prior to this initiative, the nearest waste facility accepting ACM was located approximately 45 minutes away with a minimum charge of $188.50 for disposal, making legal disposal inaccessible for many of the LGA's residents. One of Cumberland Council's aims is to make legal asbestos disposal as easy and accessible for residents as possible through convenient collection services.

Liverpool Council also offers an asbestos management program through their general council fund by providing free asbestos removal on set dates (e.g. 20-24 May 2024). Residents first register their interest with an Asbestos Management Officer. The asbestos must be loose (already removed) and packaged. A licensed asbestos contractor then collects and disposes of up to 10 m^2 of bonded ACM. This program is only available for eligible Liverpool City Council residents and the number of households is strictly limited.

Ongoing challenges and need for coordination

Councils struggle with high operating costs of programs and limited funding. There is a cost barrier to a through-chain risk-based approach when implementation is optional at a local scale, and it can be difficult for programs to become permanent. Programs are expensive to run (high administration costs) and often rely on grant funding or local government funds. There is a demand for these programs from both councils and residents, but funding certainty needs to be secured.

Additionally, there is a need for more coordination with government bodies. For instance, in the case of HADS, tracking illegal dumping incidents and subsequently using data to improve programs is a challenge due to incomplete data collection practices. While these programs are in high demand, it is not possible to ascertain the direct effect that they have had on illegal dumping, and available data suggests that illegal dumping from residential waste is not large-scale. Further research needs to be conducted into the prevention of asbestos dumping by commercial operators to understand if future programs would be better targeted at commercial asbestos disposal. Council use of RIDOnline to collect and manage asbestos dumping data to inform future asbestos dumping prevention strategies has been suggested and would require support from the NSW EPA.

Finally, increasing program accessibility and encouraging community engagement (e.g. through feedback channels) can help councils better understand and address residents' needs. For example, in the case of WSRADS, an unexpected outcome of the program was that it encouraged residents to call council waste staff and discuss their concerns regarding asbestos. This allowed councils to better understand the barriers to proper asbestos disposal that residents face. Several local councils subsequently chose to continue their version of the program due to positive feedback and high demand.

5.2 Asbestos waste transport and management at recycling facilities

5.2.1 Asbestos waste tracking

Sharing knowledge and information on the movement of asbestos can help identify areas that require improvement and focused attention, with the aim of improving practices to eliminate and/or reduce asbestos throughout the value chain.

Asbestos waste transport within NSW is tracked through the online system, IWTS. Under clauses 76 and 79 of the Waste Regulation, waste operators, transporters, and waste and recycling facilities must provide information to the NSW EPA when consigning, transporting or accepting more than 100 kilograms of asbestos waste, or more than 10 m^2 of waste asbestos sheeting, in any single load (NSW EPA, n.d.).

Despite the availability of data collected on asbestos waste, this data is not currently being used effectively for asbestos risk management. There are loopholes in the value chain and in the type of data being collected. Examples of useful data being collected in a haphazard manner and that could be improved on include:

- Illegal dumping data: RIDonline allows members of the public to report illegal dumping online. However, use of RIDonline by NSW councils and other public land managers is not mandatory, leading to approximately one-third of NSW councils using RIDonline to record all illegal dumping incidents and a further third of NSW councils using RIDonline to some extent as of 2018 (NSW EPA, 2018). While the number of public users registered with RIDonline increased from 977 (reported in 2018) to ~1500 in 2022, it is unclear what the number of users is relative to and therefore how widely the RIDonline platform is utilised (NSW EPA, 2018; NSW EPA, 2022a). Data entries are also often incomplete. Additionally, NSW councils also report the total number of illegal dumping incidents annually through the Waste and Resource Recovery Survey, running the risk of duplicate customer reports of incidents. Some survey responses completely omit illegal dumping annual totals and other public land managers do not participate in the Waste and Resource Recovery Survey.

- Licensed asbestos removal notification: SafeWork NSW requires licensed asbestos removalists to lodge electronic notifications five days prior the removal work (SafeWork NSW, n.d.). The type of information collected includes the location of asbestos and the amount of friable and non-friable asbestos, the date of removal work as well as the waste disposal site information. The NSW Asbestos Waste strategy 2019-21 (NSW Government, 2019) proposed integrating this notification system with EPA's asbestos waste system to prevent illegal dumping. However, the outcome of the action has not been reported.
- Rejected load data: A C&D waste facility must keep and maintain a rejected loads register per *Standards for managing construction waste in NSW*, which must be made available for inspection to an authorised officer of the EPA if requested (NSW EPA, 2019a). However, this data is not annually reported, and there is no standardised portal for data to be uploaded into. This leads to high variability in reporting format among sites. Additionally, the eventual destination of loads following rejection is not clear or recorded. Often loads are turned away from one facility with no follow-up about whether the load went next to an appropriate facility for disposal. This also places financial and other burdens on transporters, leading to unintended and harmful consequences, including illegal dumping.

Illegal dumping and rejected loads are symptoms of poor disposal or source separation practices. These data can be used as an indicator of how effective the management upstream is in keeping asbestos out of the recycling stream in the area. Standardised collection, analysis and use of this data by the EPA would allow for a detailed risk assessment process, identifying high-risk areas and activities where asbestos exposure may occur as well as better visibility of the sources of asbestos in waste.

It is noted that national waste reporting under asbestos NEPM code N220 can vary by state and territory. Some report only the quantities of plastic-wrapped ACMs, but others include waste (soil or rubble) contaminated with friable asbestos or bonded ACM. A harmonised national asbestos waste recording could support the understanding of the rate of legacy ACMs being removed from built environment (ASSEA, 2024c).

5.2.2 Asbestos management at recycling facilities

The current classification of asbestos waste based on presence or absence of asbestos during waste acceptance procedures at recycling facilities has led to the following outcomes:

- rejection and disposal of large amounts of resources even when the asbestos contamination is minor and localised, or
- assumption that the accepted material is safe for beneficial reuse without any validation steps.

Applying risk-based approach to asbestos management at recycling facilities can prevent the above-mentioned unwanted outcome by prioritising elimination and/or reduction of asbestos during waste acceptance procedures and processing. This would result in changes in rejected load criteria and rate where recyclers could choose to accept contaminated load under a certain threshold and remediate it by removing the fragments. Other safeguards including pre-acceptance requirement, continuous monitoring, sampling and analysis of end products, and auditing, should be implemented as part of managing the asbestos through-chain.

Setting a threshold for asbestos in the end product can be used as a verification tool to ensure that the implemented process controls are fit for purpose. Developing sampling and analysis procedures as well as procedures for reporting and safe removal of asbestos where asbestos is found during processing and in the end products, will provide clear guidance for recycling facilities in managing asbestos. Changes in the number of rejected loads recorded due to new unexpected finds protocols could change the rate of load rejection, further highlighting the need for greater and more standardised intelligence around rejected load data. All of these, including a consistent approach to the definition of asbestos waste and harmonisation between applicable legislations, require coordination and co-design between state and national agencies and industry stakeholders. The development of sampling and analysis procedures and asbestos management plan can be co-designed through a staged pilot program trialled at selected facilities. Because asbestos contamination has a different risk profile in various materials, tailoring the process for specific industry or material should be considered.

Asbestos thresholds in recovered materials

Research on asbestos thresholds was considered in Chapter 0. While the use of thresholds for asbestos in waste intended for beneficial reuse is not common, thresholds (or limits) have been used within WHS requirements. The workplace exposure standard (or limit) for airborne fibre concentration is 0.1 f/mL over an eight-hour period. These limits are supported by other requirements to manage risk and minimise exposure. The limits are not an intended as an acceptable level of exposure but are more reflective of a maximum upper level. This means that, in practice, efforts should always be made to ensure exposure at a level as low as possible.

The review could not identify any studies that correlate concentration of asbestos in waste to asbestos-related disease levels. Where thresholds for asbestos in waste for beneficial reuse have been established, they are based on a study undertaken by Swartjes and Tromp (2008). In this study, experiments with known amounts of asbestos in soil were undertaken to measure the potential of fibres to become airborne and available for inhalation. These experiments indicated that:

> 'activities involving soil with friable asbestos concentrations of 100mg/kg of soil were unlikely to results in airborne fibre levels above Negligible Risk level of 1000 fibre equivalents/m^3 (0.001 f/mL)'.

This research also concluded that a screening level of 100 mg/kg of soil (0.01% w/w asbestos equivalents[34]) for both friable and non-friable asbestos in soil is appropriate for the Dutch local context.

WA DOH used the same screening level of 0.01% w/w for non-friable asbestos in soil but applied 0.001% (w/w) to both friable asbestos and asbestos fines in consideration of the dryness of WA soils and the fact that other Australian standards treat all mineralogical forms of asbestos as equivalent.

The research undertaken by Swartjes and Tromp (2008) indicated that an asbestos soil concentration of 0.01% w/w is unlikely to generate airborne fibre levels above 0.001 f/mL, and with the dryness factor applied by WA DOH, exposure levels are unlikely to be above the workplace exposure standard of 0.1 f/mL over an eight-hour working day, five-day working week. WA adopted the asbestos screening levels in soil and applied a conservative asbestos threshold in any form of 0.001% w/w in the recycled C&D product considering no constraint on the location where the product is reused.

While the evidence presented above provides some assurances relating to workplace exposure, the end use of waste processed for beneficial reuse has the potential for more long-term exposure depending on use. As such, until further evidence is available, recovered materials and fines for beneficial reuse should only be used in non-contact situations.

As noted in Chapter2, where thresholds have been applied, other requirements are implemented to manage risk and minimise exposure. This is also the case where thresholds have been applied for waste for beneficial reuse. As such, the threshold should support a risk-based approach, in combination with other through-chain systems and processes to assist with eliminating and reducing asbestos. Any threshold should therefore ultimately apply to the recovered materials or fines for beneficial reuse (i.e. end product). Elsewhere through the processing chain, a threshold can assist with determining whether the systems and processes are achieving the desired end-product outcome.

Inspection, sampling and analytical approach for asbestos in recovered materials

Any set threshold needs to be accompanied by sampling and analysis procedures. As noted in Chapter 3, sampling and analysis for asbestos in waste and recovered materials are particularly challenging because most of the available guidelines are for asbestos in soil, which may not translate to waste materials. In addition, obtaining representative samples is difficult due to the material's size, heterogeneity and the non-uniform distribution of asbestos. Accurate quantification is difficult to achieve, and analytical

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[34] For definition, see Table 1.

methods have limits of detection. Ultimately, the accuracy and reliability of the results also depend on the training and competency of the personnel performing the sampling and analysis.

Considering the heterogeneity of the material, it is preferable to perform sampling and analysis of the end product. The associated sampling and analysis plan must be first developed by considering:

- the sampling objectives
- field sampling/inspection methods and sampling methods for laboratory analysis
- the limitations and the applicability of the selected sampling and analysis method
- the data quality obtained
- interpretation of results.

It is important to note that any developed sampling and analysis plans cannot provide full assurance that the product meets the threshold requirement. Both threshold and any associated sampling and analysis plans are only verification tools to check the efficacy of the process steps and to allow corrective actions to be taken as continuous improvement of the process.

There is no one-size-fits-all sampling rate and size that can be applied for asbestos detection in any material. As recovered fines are akin to soil, sampling procedures for asbestos in soil can be referred to for guidance. Examples of soil sampling plans are as follows:

- NSW EPA (2022) Sampling design guidelines for contaminated land
- NEPC (2013) National Environment Protection (Assessment of Site Contamination) Measure 1999 Schedules B1 and B2
- EPA Victoria (2004) Soil sampling for waste soils
- ITRC (2020) Incremental Sampling Methodology (ISM) Update ISM-2.
- HDOH (2017) Guidance for Soil Stockpile Characterization and Evaluation of Imported and Exported Fill Material
- SoBRA (2015) Soil Sampling Protocol for Asbestos in Soil
- Lamé et al (2005) Validated sampling strategy for assessing contaminants in soil stockpiles

For recycled aggregates, the sampling plan in WA Waste Guideline can be referred to. The full description of the sampling plans for recycled drainage rock, recycled road base and recycled sand can be found in Section3.2.

Current analytical methods using NEPM gravimetric and AS 4964 (now superseded by AS 5370) laboratory analysis are sufficient to detect and estimate asbestos content in recovered materials, however their limitations and applications to end product must be understood (see Section3.1.2).

The WA Waste Guideline also provides a good example of risk-based approaches applied at the recycling facility. The guideline allows reduction of sampling frequency of end-product if certain criteria are met. The criteria include an audit of the activities at the premises to validate that effective measures are taken to prevent asbestos contamination in end product. Adoption of WA Waste Guideline in NSW should consider the higher volume of recovered materials processed and the cost of land in NSW, as well as the economics, practicality and capacity of the industry and laboratories to conduct sampling and analysis. Therefore, coordination between environmental regulators and industry stakeholders is important to co-design appropriate sampling plans, which can be validated through a staged pilot program by businesses undertaking the program (see section below).

As sampling and analysis of end product is only one line of evidence in assessing risk of asbestos contamination, other lines of evidence to inform risk assessment to support a through-chain risk-based approach can be gathered from:

- Visual inspection during material acceptance, processing and storage and handling of end product

- Data from rejected load registers and partnership programs between recyclers and waste generators to ensure the quality of accepted waste for recycling
- Audit of the waste processing procedures to verify the effectiveness of asbestos management measures and address source of contamination.

In addition, assessment of asbestos risk exposure can be gathered from static air-monitoring and job/activity-based personal monitoring during processing (e.g. screening and crushing) to determine the concentration of airborne asbestos generated. The data can be used as an indicator for airborne asbestos exposure during end use in which the level of material disturbance is generally less, and of shorter frequency and duration, than that during material processing.

Consistent definition of asbestos waste and harmonisation between applicable legislations

As discussed in Section2.2.2, there is inconsistency in what is considered as 'asbestos waste' in the environmental and waste management context across Australian jurisdictions. Different states have different definitions and requirements of asbestos waste which lead to a specific waste classification. This has created confusion around if or when waste containing trace levels of asbestos can be reused.

Stakeholders further expressed concern about differences in regulatory requirements for asbestos management in POEO Act, CLM and WHS regulations. This limits the implementation of a through-chain risk-based approach to manage asbestos in recovered materials. For example, in efforts to eliminate and/or reduce asbestos throughout the recycling process, facilities will be required to implement ongoing process controls, which may include hand-picking of suspected ACMs.

These activities would be considered as work involving asbestos or ACM and would require the development and approval of risk management measures from the WHS regulator (i.e. SafeWork NSW). However, the WHS laws generally focus on asbestos removal work specifically, and usually on individual removal projects. The WHS regulator may need to consider how the WHS laws might be applied to ongoing process-related activities at waste and recycling facilities, especially around clearance inspections and specific competency and licensing requirements. For example, the WHS laws impose licensing requirements for the removal of friable asbestos, or non-friable asbestos over 10 m^2[35]. These would encompass the removal of asbestos in recycling facilities, so greater clarification or guidance would likely be required as to when the 10 m^2 threshold is exceeded in process work.

The WHS laws also contain the process/requirements for asbestos clearance certification following asbestos removal work[36]. Clearance certification must include visual inspection and may include air fibre monitoring showing asbestos below 0.01 fibres/mL. Clearance certification is intended to provide assurance that the work area is safe to be reoccupied, not as a certification that remaining materials are free from asbestos, and there is potential for clearance certificates to be misinterpreted. This may be an issue due to different definitions of asbestos waste in the WHS legislation and POEO Act.

With the introduction of a threshold for end products as part of a proposed through-chain risk-based approach, amendment of either the POEO Act or Waste Regulation may be needed to specify whether waste meeting all the threshold requirements below can be reused:

- no visible ACM,
- below 10 mg/kg weight of total asbestos/weight of product (i.e. 0.001% w/w) and
- asbestos not detected using AS 5370.

However, this does not mean that the above thresholds are the only indicator of compliance. Regulators should consider other lines of evidence such as prior knowledge of contamination, risk assessment, audit requirements or conditions related to end use to be specified in the resource recovery orders/exemptions.

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[35] WHS Regulation regs 485–488.

[36] WHS Regulation regs 473-474.

Staged pilot program to co-design asbestos management guideline at recycling facilities

Multiple pilots of the program should be considered to enable a more nuanced understanding of how to design an effective sampling plan, establish specific points within the supply chain where thresholds should be applied and determine acceptability of proposed threshold levels. By running pilots across diverse settings, such as different geographic areas, types of buildings and waste categories, the NSW Government could gather a comprehensive dataset that will help the design of a fit-for-purpose program.

A rigorous cost-benefit analysis (CBA) of the staged pilot program is essential as a first step. Such an analysis would investigate the program's financial and social benefits, balancing health, environmental, and economic impacts with the costs involved. CBA offers the opportunity for early industry engagement and consultation to inform decisions on a staged pilot program design and implementation. CBA also serves as the tool for NSW Government to identify pilot program locations by working with industry, local councils and communities.

The WA Roads to Reuse (RtR) program is a good example of a staged pilot program for asbestos management with a through-chain risk-based approach. The RtR is an initiative from WA Government to encourage the use of recycled C&D products in civil applications, such as road construction (WA Waste Authority, 2024). The program started as a pilot project between WA Main Roads, the Waste Authority and DWER, with assistance from the Waste and Recycling Industry Association of WA. The pilot project was completed in 2020 and was found to deliver cost-effective products with good performance and environmental benefits (Waste Authority of Western Australia, 2020). RtR products include recycled road base (sealed with asphalt) and recycled drainage rock produced by accredited recyclers. To produce RtR products, C&D waste recyclers must meet several requirements for accreditation, including preparing a Materials Acceptance and Sampling Plan (MASP) approved by the WA Waste Authority and allowing an initial audit. The program provides a support scheme to help C&D waste recyclers cover the costs of preparing a MASP and undertaking intensive sampling and testing. To maintain accreditation, recyclers must submit periodic audits, produce material that meets the product specification and agree to independent audits.

5.3 Asbestos management at end use

Considering the limited data and evidence on long-term exposure to recycled materials containing trace levels of asbestos, a precautionary approach is recommended to use recovered fines and materials only in non-contact situations, such as being encapsulated, capped or buried. Further studies could be considered to confirm airborne asbestos exposure levels does not present an unacceptable risk, confirming the suitability of the established threshold value.

Further, development of clear guidance for unexpected finds in resource recovery materials used offsite should be considered. This will require coordination between the public works, health, safety and environmental regulators with the end users including consultants, developers, contractors and the public. A contaminated mulch management plan was developed by a technical working group consisting of NSW Public Works Advisory, EPA and SafeWork and NSW Health, and aligns with the NSW WHS Regulation (NSW EPA, 2024a). The plan contains proactive measures of assessment, categorisation and removal of contaminated mulch and provides clear communication to wider communities and stakeholders. Therefore, there is an opportunity to develop a risk-based management plan for other contaminated resource recovery materials.

5.4 Supporting elements of a through-chain risk-based approach

5.4.1 Education and training

The implementation of a through-chain risk-based approach to managing asbestos relies heavily on awareness of all participants of asbestos risks and competency at all levels, from demolition through to processing at recycling facilities to the reuse of recovered materials. The participants also require tools and knowledge to help them to identify and handle asbestos safely. Education and training serve as important tools for raising awareness about asbestos risks to ensure health and safety and to provide opportunities for participants to contribute to development of better controls. Competence-based training for workers involved through the chain optimises asbestos management procedures at all stages.

At renovation/demolition sites, DIY home renovators are at a higher risk of exposure to asbestos, partly due to their limited awareness of risk. Some councils have taken initiatives to educate their residents on identifying asbestos, understanding its risks and safely handling it for disposal. This includes public information campaigns, workshops and awareness resources designed to be accessible to multilingual communities. For example, Cumberland Council currently runs a campaign about asbestos safety in the community through free asbestos awareness workshops held for residents at least monthly. The workshops run for two hours and attendees receive a free asbestos removal kit, although there are challenges associated with the reach of the workshops in a multilingual community. The Council promoted asbestos awareness in 2014/15 through their 'Fight the Dust' campaign, which included posters displayed in prominent areas, coasters distributed to local pubs, promotion in local media and targeted mailouts. The Council has also developed an ongoing asbestos awareness website (www.asbestosanswers.com.au) that includes a fact sheet and a short video in five languages other than English: Arabic, Chinese, Farsi, Hindi and Tamil (Holroyd City Council, 2015). A multi-faceted asbestos management and disposal program can provide communities with both the information and the services to properly and safely dispose of asbestos.

Effective communication is also a key part of ensuring the uptake of asbestos management programs. In the case of Liverpool Council's free asbestos removal program there is very little information available about the program online. The success of the program could be improved by an accompanying campaign to raise awareness and enable better risk communication to residents.

Currently the detection of asbestos from demolition through to processing at recycling facilities and finished product reuse relies heavily on visual detection. Laboratory analysis for the detection of asbestos also relies heavy on visual detection, either with the naked eye or with the assistance of laboratory instruments. Additionally, competency in sampling techniques to obtain representative samples will affect the reliability of the analysis results. Thus, clear and consistent guidance, training and competency for the workers, field samplers and laboratory analysts need to be prioritised to ensure robust asbestos identification and handling at demolition sites and recycling facilities and to provide assurance in analysis results.

5.4.2 Data, verification tools and intelligence activities

Data, verification tools and intelligence activities are essential for supporting a through-chain risk-based approach to asbestos management, as they form the basis for informed decision-making, proactive risk mitigation and continuous learning to adapt processes to better achieve desired outcomes over time. A through-chain model ensures that asbestos risks are assessed, monitored and managed at every stage of the lifecycle, from identification and containment to removal, disposal and regulatory compliance. By leveraging comprehensive and accurate data from all parts of the value chain, organisations can better understand the distribution and potential impact of asbestos and its associated risks, validate process controls and monitor compliance.

One submission suggested promoting the development of a data collection framework that could be used in both metropolitan and regional councils, requiring regulatory agencies to liaise with the C&D industry more broadly to make final asbestos and C&D waste generation volume data from every build worksite mandatory as part of the building inspection process. Evidently, there is an opportunity to build a systematic record of data to inform future management of asbestos contamination in incoming waste to the recycling facilities. Data collected from rejected loads could also be used to minimise unlawful activities and to enforce compliance.

Data obtained from sampling and analysis for asbestos in recovered materials can be used to verify the efficacy of the process controls and to confirm adherence to the product specification for beneficial reuse. When the data consistently demonstrates results below the established threshold through an audit process, it can also support the use of performance-based measurement, provided that other process controls remain in place.

Through data gathered from historical records (pre-2004), building surveys (government, commercial and residential) and monitoring systems, risk profiles can be created to inform targeted intervention strategies and mitigation actions. The intelligence and data enable the prioritisation of resources and actions where they are most needed, ensuring that mitigation efforts are both efficient and effective.

Examples of data available in the form of risk profiles mapping are listed below:

- The mapping of high, medium, low and very low probability of areas of NOA in NSW (NSW Government, n.d.)
- The National Residential Asbestos Heatmap by Asbestos and Silica Safety and Eradication Agency (ASSEA) shows predictions for the likelihood of asbestos presence by geographic area. The first version was developed as a part of the National Strategic Plan for Asbestos Awareness and Management 2019-2023.

Note that the maps above show potential presence and/or predictions that should be used with discretion and followed up by investigation to better inform the risk assessment and control in the affected area.

5.4.3 Technology

Current asbestos detection relies heavily on visual inspection and manual processes. There is a need for more accurate and effective asbestos detection technology for the implementation of a through-chain risk-based approach. Through research, consultation, submissions and site visits, OCSE were made aware of commercially available and emerging technologies for asbestos detection. To provide an updated perspective on these technologies, the Review commissioned the NSW Smart Sensing Network (NSSN) to produce an expert paper on the current and emerging technologies that are relevant to real-time asbestos sensing*, Asbestos Sensing Review: Emerging technologies for asbestos in waste, Supporting Document 3 (NSSN Paper SD3*). NSSN Paper SD3 considered both commercially available products and those under development as reported in the global academic literature.

The NSSN Paper SD3 reports that technologies for real-time asbestos detection remains a vibrant field of research even though the use of ACMs in Australia was gradually phased out in the 1980s. Recent work is fuelled by advances in automation and the miniaturisation of sensor technologies.

The NSSN Paper SD3 finds that the generally accepted approach involves sampling materials and analysis in laboratory settings. Optical and electron microscopy methods are often used, with spectroscopic measurements also assisting (see Table 1 in NSSN Paper SD3). Commercial handheld spectroscopic devices are available, but there are challenges associated with using these in real-world environments. The scientific basis of the spectroscopic devices is sound. However, when the environment consists of a wide variety of ACMs and non-asbestos materials, the performance of these devices may not be optimal. Some of the parameters that should be carefully considered when utilising these techniques are reported in the NSSN Paper SD3.

Overall, the NSSN Paper SD3 finds that:

- Real-time asbestos detection and quantification from a single system remains a challenge and should be used in conjunction with approved standard methods
- Automated (AI-assisted) asbestos fibre counting methods on microscope images for airborne respirable fibre analysis should be considered in parallel to standard procedures using Phase Contrast Microscopy. This can assist in the accuracy, speed and capacity/throughput of analysis. Advances in microscopy also allow for on-site airborne fibre counting and potentially even continuous monitoring.
- AI-assisted image recognition for asbestos types is a nascent, yet potentially encouraging field of research. Under certain constraints, e.g. environments with a consistently known variety of mixed wastes, this approach could be feasible at low cost.

- Near infrared spectroscopy shows a great deal of promise for asbestos detection from a compact device. Care needs to be taken in ensuring the device achieves enough spectral resolution to differentiate asbestos minerals from their non-asbestos counterparts.
- Hyperspectral imaging in the short-wave infrared is an emerging technique that may be able to be part of a mixed waste sorting system. Despite the challenges associated with varying surface conditions, signal processing techniques may allow suitable performances.

There are new technologies currently in development which show promise for real-time detection of asbestos. The accuracy of the technique may not fully be realised yet but the NSSN Paper SD3 attempts to map their technology readiness, limitations and eventual impacts of application. These technologies include advanced microscopy methods, macroscopic imaging (hyperspectral), spectroscopy techniques (Near-IR and Raman), light detection and ranging (LIDAR), Laser induced breakdown spectroscopy (LIBS) and Novel Fluorescence. These emerging technologies, their technology readiness level (TRL) and application are mapped across the asbestos value chain shown in Figure 15.

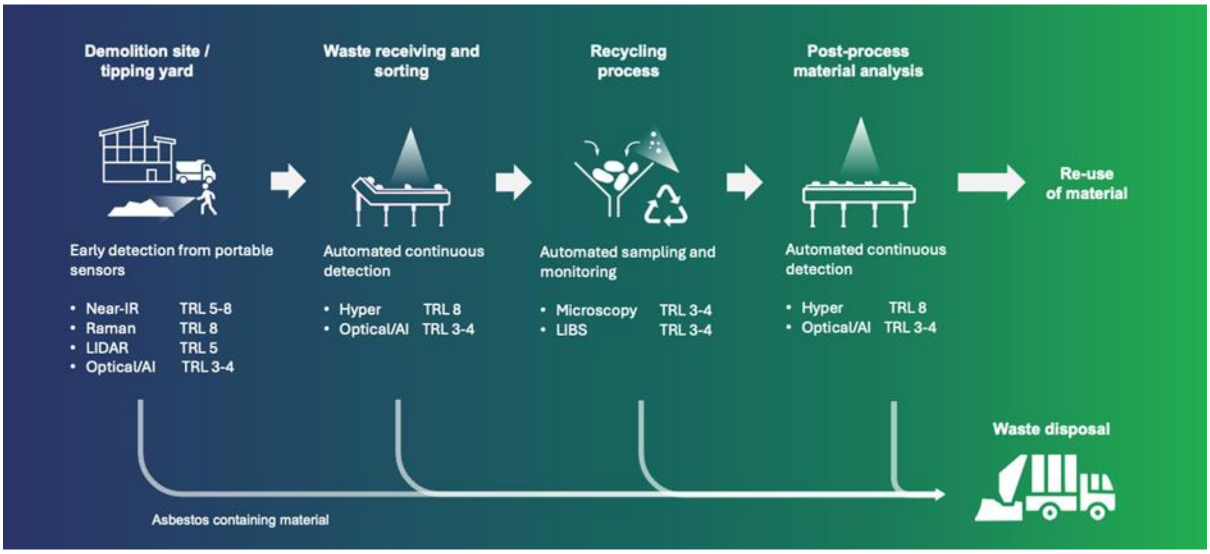

Figure 15: Summary of relevant emerging sensing technologies for asbestos detection and airborne fibre counting, across various points in the recycling process (NSSN paper). Note that microscopy technologies in this figure are for airborne fibre counting.

Government support of asbestos detection technology innovation and development

The Commonwealth Government has provided support in the form of grant funding to develop innovative solutions for asbestos detection. One of the grants provided was through the Business Research Innovation Initiative Program (BRII)[37] – Regulatory Technology Round (Asbestos Challenge) in 2021, after a successful submission made by ASEA.

The BRII Asbestos Challenge not only examined single detection technology but also new systems that might include a range of solutions and methods to improve the effectiveness of existing asbestos detection and control measures (e.g. asbestos in building materials, or asbestos in the air), and to remove time-consuming steps, such as sending material to a lab for testing. An important requirement

[37] The Business Research and Innovation Initiative Program provides startups and small to medium enterprises with grant funding to develop innovative solutions for government policy and service delivery challenges. BRII is administered by the Australian Government through the Department of Industry, Science and Resources. BRII Program funds project in two phases – feasibility studies and then proof-of-concept studies, receiving $100,000 and $1million funding respectively. https://business.gov.au/grants-and-programs/business-research-and-innovation-initiative

for the BRII Asbestos Challenge was that any solution must improve the efficiency and effectiveness of asbestos testing in-situ and in real time. Materials testing must deliver a solution that is non-destructive (i.e. not removing or disturbing the materials to test) and it must meet regulatory requirements of the duty holder under the health and safety regulations.

Five applicants to BRII Asbestos Challenge were successful for the three-month feasibility study phase in 2022 and two of the applicants progressed to the proof-of-concept phase in 2023, receiving an additional $1 million funding each from BRII to further develop their technologies over 15 months (Table 12).

Table 12. BRII Asbestos Challenge grantee

Grantee	Project	BRII Phase
Portable Analytical Solutions Pty Ltd	In situ detection of six asbestos types in bulk and airborne filter samples	Feasibility study only
Urban Analytics and Complex Systems (UACS) Consulting Pty Ltd	Asbestos Vision, a smart phone app to identify asbestos and connect people	Feasibility study only
Alemir International Pty Ltd	ALERT, for a real-time monitoring and warning device for airborne asbestos	Feasibility study only
Flawless Photonics Pty Ltd	A hand-portable in-situ real-time non-contact asbestos sensor	Feasibility study and proof-of-concept
Predictive Analytics Group (PAG) R&D Pty Ltd	In situ detection of asbestos in wall panelling using microwave technology	Feasibility study and proof-of-concept

The Australian Research Council recently awarded a Linkage grant to University of Adelaide which previously partnered with Flawless Photonics in BRII Asbestos Challenge. The university has partnered with several organisations including ASSEA to develop a portable device for reliable, real-time detection of asbestos (ARC, 2024). The technique utilises new optics and fluorescence detection techniques along with machine-learning analysis. The device can be used to detect asbestos where it may be encountered, such as within homes, workplaces, customs inspections, material and mulch recycling centres, and mining operations.

5.5 Coordination

The NSW Asbestos Coordination Committee (NACC) and the Asbestos Taskforce are examples of coordination and collaboration between NSW Government agencies to tackle asbestos issues within the state. However, adopting the through-chain risk-based approach to managing asbestos will demand broader, whole-of-sector coordination between all levels of government, industry stakeholders and businesses.

A staged pilot program to scale coordination

A successful risk-based through-chain approach depends on a thoughtfully designed system, which could start in the form of a staged pilot program. The design of the pilot program should incorporate best practices from NSW, other regions and industries, tailoring them to the specific needs of NSW's stakeholders. With some industry players and council areas already applying elements of the through-chain risk-based approach (See Section4.3. and Section5.1.1), the pilot program could leverage their experience and learning, using existing methodologies as a starting point while refining the framework for broader applications.

A staged pilot program offers a controlled environment and a manageable size of supply chain to evaluate the framework's effectiveness and refine its design. A pilot approach also enables a gradual rollout, allowing for validating assumptions in specific, manageable scenario testing and active redesign to reflect stakeholder feedback. By piloting in targeted locations, waste facilities or within certain waste categories, NSW can focus on high-priority high-risk areas and apply resources more effectively. This controlled deployment will help identify challenges and areas for improvement before scaling up to a state-wide approach, ensuring that the system is robust and adaptable to diverse conditions across NSW.

The staged design of the pilot program will provide opportunities for evaluation and improvement. Mechanisms such as stage gate reviews and audits should be put in place to assess pilot program results and outcomes. The purpose of the reviews and audits are not to assess compliance, but to ensure transparency and provide assurance and data. Audits will also assess whether or not pilot programs are attaining the objectives and results expected of them, leading to iterative improvements in future programs. The data generated from the initial stage on resource requirements, cost savings, health risk reductions and operational efficiency improvements could inform the design of later stages of the program. Such a staged pilot approach builds a strong case for wider adoption, ensuring stakeholders across the supply chain see clear value in scaling the system as well as reducing the risks for unexpected disruption with a new approach.

National coordination

Looking at a broader picture, a national approach for managing asbestos in recovered materials and fines would require support from coordinating agencies at the Commonwealth, state and territory levels. The Asbestos National Strategic Plan 2024-2030 highlights several key actions to be implemented by lead agencies that are supported by government and non-government partners, including unions and employer representatives. Key actions include developing guides on asbestos contamination in C&D waste and asbestos safety for waste facility operators and workers to ensure safe and effective transport and disposal (Priority 3) (ASSEA, 2024b). A national risk-based threshold should be considered, as the end product will be transported and used in different states and territories across various businesses. Coordinating agencies also play an important role in delivering consistent messaging on risk communication and awareness if a threshold for the end product is adopted. There is also an opportunity for a coordinated efforts on data and intelligence gathering between the agencies and the industries.

5.6 Recommendations

Recommendation 1:

NSW Government implement a coordinated, through-chain risk-based approach to managing asbestos in recovered materials, incorporating a suite of specific recommendations on the application of thresholds, sampling and analysis designed to ensure that potential risks are understood and mitigated at each step in the value chain. Individual recommendations should not be considered in isolation.

Recommendation 2:

NSW Government considers implementing a threshold for asbestos in recovered fines and materials for beneficial reuse. The threshold should:

- Be based on the current criteria of 0.001% w/w (asbestos in any form) as described in the Western Australia Guideline: Managing asbestos at construction and demolition waste recycling facilities and meet all the requirements below:
    - no visible ACM,
    - below 10 mg/kg weight of total asbestos/weight of product (i.e. 0.001 % w/w) and
    - asbestos not detected using AS 5370.
- Support a through-chain risk-based approach to managing asbestos in recovered fines and materials for beneficial reuse

- Apply to the end product ready for reuse in non-contact scenarios, although the threshold could also be used as an in-process standard to verify the efficacy of processing steps.

Recommendation 3:

NSW EPA develops material acceptance, inspection, sampling and analysis guidelines for asbestos in recovered materials to assess product quality against the set threshold in consultation with industry stakeholders. The sampling and analysis guidelines should:

- Support a through-chain risk-based approach to managing asbestos in recovered fines and materials for beneficial reuse
- Consider the nature of different materials and processing chains
- Be validated by the results from a staged pilot program.

Recommendation 4:

NSW EPA updates Standards for managing construction waste in NSW to include a through-chain risk-based approach by adopting WA Waste Guideline: Managing asbestos at construction and demolition waste recycling facilities.

Recommendation 5:

NSW Government considers a staged pilot program of a through-chain risk-based approach to design, test and validate findings and recommendations from this report.

Recommendation 6:

NSW Government engages with other jurisdictions to work towards a consistent approach and outcomes (including legislation) in managing asbestos in recovered fines and materials for beneficial reuse.

Recommendations 7:

NSW Government considers stronger support for better source separation at demolition sites, including residential premises, through the identification of industry best practice with clear and consistent guidance, training and competency around robust asbestos identification and handling for all workers handling asbestos prior to disposal.

NSW Government evaluates the delivery of small grants funding for council-run programs to date to inform the design of a more systematic funding model.

NSW Government improves and standardises data collection, collation and analysis procedures to better inform and adapt management as part of a through-chain approach.

Recommendations 8:

NSW Government remains aware of emerging technologies that can assist with asbestos detection and considers supporting the development and trialling of technologies that have high potential through a new NSW business research challenge program.

Recommendations 9:

NSW Government facilitate development of national competency-based training for waste industry.

NSW Government liaise with industry professional bodies to develop competency-based training for laboratory analysts, asbestos assessors/environmental auditors/occupational hygienists who consult or work with the waste industry.

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References

ACGIH. (2001). *Documentation of the Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) - Asbestos, All Forms.* The American Conference of Governmental Industrial Hygienists.

Addison, J., Davies, L., Roberson, A., & Willey, R. (1988). *Release of dispersed asbestos fibres from soils.* Edinburgh: Institute of Occupational Medicine. Retrieved April 10, 2024, from https://assets.publishing.service.gov.uk/media/65fd678e65ca2f001b7da88c/CD1.3.MS3_IOM__1988._The_release_of_dispersed_asbestos_fibres_from_soils__Addison_J__Davies_LST__Roberson_A__Willey_RJ__Historical_Research_Report_TM_88_14__Institute_of_Occupational

AIHW. (2024). *Mesothelioma in Australia 2023.* Australian Institute of Health and Welfare. Retrieved November 11, 2024, from https://www.aihw.gov.au/reports/cancer/mesothelioma-in-australia-2023/related-material

ARC. (2024). *Funded Projects - Linkage Projects 2024 round 1*. Retrieved November 20, 2024, from Australian Research Council: https://rms.arc.gov.au/RMS/Report/Download/Report/1b0c8b2e-7bb0-4f2d-8f52-ad207cfbb41d/269

Ascend Waste and Environment. (2021). *Hazardous Waste in Australia 2021.* Retrieved from https://www.dcceew.gov.au/sites/default/files/documents/hazardous-waste-in-australia-2021.pdf

ASEA. (2021). *Asbestos waste data in Australia: 2020-21 Annual Update.* Retrieved from https://www.asbestossafety.gov.au/sites/default/files/documents/2021-12/Asbestos%20waste%20data%20in%20Australia%20-%202020-21%20Annual%20Update_0.pdf

ASEA. (2022). *Asbestos safety for householders and home renovators.* Retrieved December 6, 2024, from Guidance for householders and home renovators: https://www.asbestossafety.gov.au/sites/default/files/documents/2022-03/Asbestos%20safety%20for%20householders%20and%20home%20renovators_0.pdf

ASEA. (2023a). *Asbestos waste data in Australia: 2021-22 Annual Update.* Retrieved from https://www.asbestossafety.gov.au/sites/default/files/documents/2023-01/Asbestos%20waste%20data%20in%20Australia%20-%202021-22%20Annual%20Update.PDF

ASEA. (2023b). *Action on illegal disposal of asbestos: A Guide for Local Government.* ASEA. Retrieved November 12, 2024, from https://www.asbestossafety.gov.au/sites/default/files/documents/2023-03/NSP19-23%20Rsch%20-%20Illegal%20asbestos%20disposal%20-%20Guide%20for%20Local%20Govt%20-%20Factsheet%201%20%28Barriers%20to%20safe%20and%20lawful%20disposal%20-%20COM-B%29%20-%20Mar23

ASEA. (2023c). *Asbestos National Strategic Plan: Progress Report 2021-2022.* Asbestos Safety and Eradication Agency. Retrieved from https://www.asbestossafety.gov.au/sites/default/files/documents/2023-08/NSP%20Annual%20Progress%20Report%202021-22%20-%20FINAL-%20Accessible%20-%206%20July%202023.PDF

ASSEA. (2024a). *Asbestos waste in Australia: 2022-23 Annual Update.* Retrieved from https://www.asbestossafety.gov.au/sites/default/files/documents/2024-03/Asbestos%20waste%20data%20in%20Australia%20-%202022-23%20Annual%20Update%20-Infographic.PDF

ASSEA. (2024b). *Phase Three: Asbestos National Strategic Plan 2024-2030.* Retrieved November 8, 2024, from Asbestos and Silica Safety and Eradication Agency: https://www.asbestossafety.gov.au/sites/default/files/documents/2024-

03/Phase%20Three%20Asbestos%20National%20Strategic%20Plan%202024-2030%20-%20January%202024_0.PDF

ASSEA. (2024c). *Asbestos waste data in Australia*. Retrieved March 15, 2024, from https://www.asbestossafety.gov.au/research-publications/asbestos-waste-australia-0

Australian Institute of Food Safety. (n.d.). *What is HACCP?* Retrieved November 13, 2024, from Australian Institute of Food Safety: https://www.foodsafety.com.au/haccp-programs/what-is-haccp

CDC. (2018). *Appendix C - Supplementary Exposure Limits*. Retrieved November 11, 2024, from The National Instutite for Occupational Safety and Health (NIOSH): https://www.cdc.gov/niosh/npg/nengapdxc.html

Darnton, L. (2024). The Hodgson and Darnton Approach to Quantifying the Risks of Mesothelioma and Lung Cancer in Relation to Asbestos Exposure. In A. Korchevskiy, J. Rasmuson, & E. Rasmuson (Eds.), *Health Risk Assessment for Asbestos and Other Fibrous Minerals* (p. 233). Hoboken: John Wiley & Sons, Inc.

Driece, H. A. (2010). Assessment of cancer risks due to environmental exposure to asbestos. *Journal of Exposure Science & Environmental Epidemiology, 20*, 278-485. Retrieved from https://www.nature.com/articles/jes200956

Driscoll, T. (2013). *The use of asbestos-contaminated soils on Barangaroo.* Sydney, NSW: Sydney School of Public Health. Retrieved from https://www.environment.nsw.gov.au/resources/clm/barangaroo/BarangarooAsb.pdf

DTSC. (2024). *Sampling Objectives*. Retrieved November 11, 2024, from Department of Toxic Substances Control: https://dtsc.ca.gov/sampling-objectives/

Dutch Government. (2018). *Overheid.nl Wettenbank*. Retrieved November 5, 2024, from Productenregeling asbest: https://wetten.overheid.nl/BWBR0018026/2018-11-30

Dutch Government. (2024). *Productenbesluit asbest (Asbestos Products Decree)*. Retrieved October 10, 2024, from Overheid.nl: https://wetten.overheid.nl/BWBR0017778/2024-01-01#Paragraaf2

Dutch Government. (n.d.). *Staatscourant van het Koninkrijk der Nederlanden*. Retrieved November 5, 2024, from Overheid.nl: https://zoek.officielebekendmakingen.nl/stcrt-2015-3498.html

ECETOC. (1990). *Technical Report No. 38: A Guide to the Classification of Preparations Containing Carcinogens, Mutagens and Teratogens.* Brussels: European Chemical Industry Ecology and Toxicology Centre. Retrieved November 4, 2024, from https://web.archive.org/web/20240626073349/https://www.ecetoc.org/wp-content/uploads/2021/10/ECETOC-TR-038.pdf

ECHA RAC. (2021). *Opinion on scientific evaluation of occupational exposure limits for Asbestos.* European Chemicals Agency Committee for Risk Assessment. Retrieved April 10, 2024, from https://echa.europa.eu/documents/10162/30184854/OEL_asbestos_Final_Opinion_en.pdf/cc917e63-e0e6-e9cd-86d2-f75c81514277#:~:text=OEL%20as%208%2Dhour%20TWA%3A%20Asbestos%20is%20a%20non%2D,in%20the%20air%20is%20derived.

Edge Environment Pty Ltd. (2011). *Construction and demolition waste guide: recycling and re-use across the supply chain.* Retrieved from https://www.dcceew.gov.au/sites/default/files/documents/case-studies.pdf

EEA. (2022). *Early warning assessments related to the 2025 targets for municipal waste and packaging waste: Belgium.* European Environment Agency. Retrieved November 5, 2024, from European Environment Agency: https://www.eea.europa.eu/publications/many-eu-member-states/belgium

Emmett, E. A. (2021). Asbestos in High-Risk Communities: Public Health Implications. *International Journal of Environmental Research and Public Health, 18*, 1579.

enHealth. (2021). *enHealth Risk Communication Guidance: Risk Communication Principles.* Environmental Health Standing Committee. Retrieved from https://www.health.gov.au/sites/default/files/documents/2022/07/enhealth-guidance-risk-communication-principles.docx

EPA Ireland. (2023). *National End-of-Waste Decision EoW-N001/2023.* Retrieved December 6, 2024, from Licensing & Permitting: Waste Publications: https://www.epa.ie/publications/licensing--permitting/waste/Final-Decision---National-End-of-Waste-Criteria-N001-2023.pdf

EPA Victoria. (2021). *Waste disposal categories - characteristics and thresholds.* Environment Protection Authority Victoria. Retrieved October 28, 2024, from https://www.epa.vic.gov.au/about-epa/publications/1828-3-waste-disposal-categories

EPA Victoria. (2022). *Broderick Road Clean Up Project Complete.* Retrieved October 24, 2024, from https://www.epa.vic.gov.au/for-community/incidents/broderick-road#:~:text=In%20June%202022%2C%20EPA%20completed,Geelong%20communities%20and%20for%20Victoria.

European Commission. (2000). *Commission Decision 2000/532/EC.* Publications Office of The European Union. Retrieved October 15, 2024, from https://eur-lex.europa.eu/eli/dec/2000/532/2023-12-06

European Commission. (n.d.). *Waste Framework Directive*. Retrieved Nov 15, 2024, from Environment: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

European Commission: Directorate-General for Environment. (2024). *Study on asbestos waste management practices and treatment technologies.* Publications Office of the European Union. Retrieved October 15, 2024, from https://data.europa.eu/doi/10.2779/251640

FIR. (2024). *FIR Factsheet on Recycled Aggregates (Example: The Netherlands)*. Retrieved November 5, 2024, from Fédération IInternationale Du Recyclage: https://www.fir-recycling.com/wp-content/uploads/2024/02/FIR-Factsheet-on-Recycled-Aggregates-Example-The-Netherlands.pdf

Flemish Government. (n.d.). *VLAREMA Onderafdeling 2.3.2. Criteria voor grondstoffen, bestemd voor gebruik als bouwstof (Subsection 2.3.2. Criteria for raw materials intended for use as building materials)*. Retrieved November 5, 2024, from Vlaanderen: https://navigator.emis.vito.be/detail?woId=44119

Foy, S. (2024). Waste is set to overhelm. *Goulburn Post*. Retrieved July 3, 2024

Hillerdal, G. (1999). Mesothelioma: cases associated with non-occupational and low dose exposures. *Occupational and Environmental Medicine, 56*(505), 505-513. doi:10.1136/oem.56.8.505

Hodgson, J. T., & Darnton, A. (2000). The Quantitative Risks of Mesothelioma and Lung Cancer in Relation to Asbestos Exposure. *The Annals of Occupational Hygiene, 44*(8), 565.

Holroyd City Council. (2014a). *Free Asbestos Collection Trial - Holroyd City Council.* Retrieved from https://lgnsw.org.au/common/Uploaded%20files/PDF/Holroyd_City_Council_Case_Study.pdf

Holroyd City Council. (2014b). *Asbestos Collection and Education Program - Holroyd City Council.* Retrieved from https://lgnsw.org.au/common/Uploaded%20files/PDF/asbestos-education-program-holroyd.pdf

Holroyd City Council. (2015). *'Fight the Dust' and 'Asbestos Answers'.* Retrieved from https://lgnsw.org.au/common/Uploaded%20files/PDF/Fight_the_Dust_Holroyd.pdf

Horton, D. K., Bove, F., & Kapil, V. (2008). Select Mortality and Cancer Incidence Among Residents in Various U.S. Communities that Received Asbestos-Contaminated Vermiculite Ore from Libby, Montana. *Inhalation Toxicology, 20*(8), 767-775. doi:https://doi.org/10.1080/08958370801983240

IARC. (2012). *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Arsenic, Metals, Fibres, and Dusts* (Vol. 100 C). Lyon, France: International Agency for Research on Cancer. Retrieved from https://publications.iarc.fr/_publications/media/download/6143/ef2dcba35d394362f6f5346d042bd48e5792ded3.pdf

ICLG. (2024). Environment & Climate Change Laws and Regulations - France 2024. In *Environment & Climate Change Laws and Regulations 2024.* The International Comparative Legal Guides. Retrieved October 15, 2024, from https://iclg.com/practice-areas/environment-and-climate-change-laws-and-regulations/france

Imray, P., & Neville, G. (1993). Approaches to the Assessment and Management of Asbestos Contaminated Soil. In A. Langley, & M. van Alphen, *The Health Risk Assessment and Management of Contaminated Sites, Contaminates Sites Monograph Series No. 2.*

Institute of Medicine (US) Committee on Asbestos: Selected Health Effects. (2006). Biological Aspects of Asbestos-Releated Diseases. In I. o. Effects, *Asbestos: Selected Cancers.* Washington, D.C.: National Academies Press (US). Retrieved October 31, 2024, from https://www.ncbi.nlm.nih.gov/books/NBK20336/#a2000f62errr00249

Jaeger, C., Gordon, M., & Vedelago, C. (2022). *After three years and $71m, Lara's mountain of rubbish is no more.* Retrieved October 24, 2024, from The Age: https://www.theage.com.au/national/victoria/after-three-years-and-71m-lara-s-mountain-of-rubbish-is-no-more-20220629-p5axj8.html

LAGA. (2001). Retrieved from Bund/Länder-Arbeitsgemeinschaft Abfall (LAGA): https://www.laga-online.de/documents/m32_laga_pn98_1503993280.pdf

LAGA. (2022). *LAGA M23 Vollzugshilfe: zur Entsorgung asbesthaltiger Abfälle.* Retrieved September 4, 2024, from Bund/Länder-Arbeitsgemeinschaft Abfall (LAGA): https://www.laga-online.de/documents/m23-ueberarbeitung-konsolidiert-2022-11-29-v3-endfassung-redakt-bereinigt-4_2_1690372365.pdf

Larouzee, J., & Le Coze, J.-C. (2020). Good and bad reasons: The Swiss Cheese model and its critics. *Safety Science, 126*.

NEN. (2017). *NEN 5707: Soil - Investigation and sampling of asbestos in soil and soil stockpiles.* Retrieved from The Royal Netherlands Standardization Institute (NEN): https://www.nen.nl/en/nen-5707-c2-2017-nl-243402

NEPC. (2013). *National Environment Protection (Assessment of Site Contamination) Measure*. Retrieved May 8, 2024, from National Environment Protection Council: https://www.nepc.gov.au/nepms/assessment-site-contamination

NHMRC, NRMMC. (2011). *Australian Drinking Water Guidelines 6 National Water Quality Management Strategy.* Canberra: National Health and Medical Research Council, National Resource Management Ministerial Council.

NICOLE. (2021). *Asbestos in Soil: A pan European perspective.* Network for Industrially Co-ordinated Sustainable Land Management in Europe. Retrieved November 5, 2024, from https://nicole.org/wp-content/uploads/2023/05/Asbestos-in-Soil.pdf

NIOSH. (2002). *Comments of the National Institute for Occupational Safety and Health on the Mine Safety and Health Administration Advanced Notice of Proposed Rulemaking on Measuring and Controlling Asbestos Exposure .*

NIOSH-OSHA Asbestos Work Group. (1980). *Workplace Exposure to Asbestos (Review and Recommendations).* U.S. Department of Health and Human Services. The National Institute for Occupational Safety and Health. Retrieved October 15, 2024, from https://www.cdc.gov/niosh/docs/81-103/pdfs/81-103.pdf?id=10.26616/NIOSHPUB81103

NOHSC. (2001). *National Model Regulations for the Control of Workplace Hazardous Substances [NOHSC:1005(1994)].* Retrieved from https://web.archive.org/web/20040719181435/http://www.nohsc.gov.au/PDF/Standards/WorkplaceHazardousSubstances-model_regs_NOHSC1005_1994.pdf

NOHSC. (2005). *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres 2nd Edition [NOHSC:3003(2005)].* Canberra: National Occupational Healthy and Safety Comission. Retrieved April 10, 2024, from https://www.safeworkaustralia.gov.au/sites/default/files/2021-11/guidancenote_membranefiltermethodforestimatingairborneasbestosfibres_2ndedition_nohsc3003-2005_pdf.pdf

Noonan, C. W. (2017). Environmental asbestos exposure and risk of mesothelioma. *Annals of translational medicine, 5*(11), 234. doi:doi:10.21037/atm.2017.03.74

NSW DPIE. (2021). *NSW Waste and Sustainable Materials Strategy 2041.* NSW Department of Planning, Industry and Environment. Retrieved May 15, 2024, from https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/recycling/nsw-waste-and-sustainable-materials-strategy-2041.pdf

NSW EPA. (2014). *Waste Classification Guidelines. Part 1: Classifying Waste.* Retrieved Nov 12, 2024, from NSW Environment Protection Authority: https://www.environment.nsw.gov.au/resources/wasteregulation/140796-classify-waste.pdf

NSW EPA. (2017). *NSW Waste Avoidance and Resource Recovery Strategy Progress Report 2014-15.* Retrieved from https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/waste/17p0083-warr-strategy-progress-report-2014-15.pdf

NSW EPA. (2018). *NSW Illegal Dumping Strategy 2017-21.*

NSW EPA. (2019a). *Standards for managing construction waste in NSW.* NSW Environmental Protection Authority. Retrieved April 16, 2024, from https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/waste/19p1542-standards-for-managing-construction-waste-in-nsw.pdf

NSW EPA. (2019b). *Waste Avoidance and Resource Recovery Stragey Progress Report 2017-18.* Retrieved from https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/recycling/19p1690-warr-strategy-progress-report-2017-18.pdf

NSW EPA. (2021). *NSW State of the Environment 2021.* Parramatta, NSW: NSW Environmental Protection Agency. Retrieved from https://www.soe.epa.nsw.gov.au/sites/default/files/2022-02/21p3448-nsw-state-of-the-environment-2021_0.pdf

NSW EPA. (2022a). *NSW Illegal Dumping Prevention Strategy 2022-27.* Retrieved from https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/illegaldumping/22p4237-illegal-dumping-prevention-strategy-2022-27-v4.pdf

NSW EPA. (2022b). Outcome of consultation on recovered fines. Retrieved December 6, 2024, from https://www.epa.nsw.gov.au/news/media-releases/2022/epamedia220510-outcome-of-consultation-on-recovered-fines

NSW EPA. (2022c). *Issues paper: NSW resource recovery framework.* Parramatta, NSW: NSW Environmental Protection Agency. Retrieved from https://hdp-au-prod-app-nswepa-yoursay-files.s3.ap-southeast-2.amazonaws.com/8416/4747/1569/22p3625-nsw-resource-recovery-framework-issues-paper.pdf

NSW EPA. (2022d). *Prosecution Guidelines.* Retrieved December 6, 2024, from https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/legislation/22j0619-epa-prosecution-guidelines-january-2022.pdf

NSW EPA. (2022e). *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.* NSW EPA. Retrieved October 30, 2024, from https://www.epa.nsw.gov.au/-

/media/epa/corporate-site/resources/air/22p3963-approved-methods-for-modelling-and-assessment-of-air-pollutants.pdf

NSW EPA. (2022f). *Contaminated Land Guidelines: Samplign design part 1- application.* NSW EPA. Retrieved November 11, 2024, from https://hdp-au-prod-app-nswepa-yoursay-files.s3.ap-southeast-2.amazonaws.com/9116/6027/3560/22p3915-sampling-design-guidelines-part1.pdf

NSW EPA. (2023). *NSW waste and recycling performance data for the 2022-23 financial year*. Retrieved from https://www.epa.nsw.gov.au/your-environment/waste/waste-overview/waste-performance-data

NSW EPA. (2024a). *Contaminated mulch management plan*. Retrieved December 10, 2024, from https://www.epa.nsw.gov.au/working-together/community-engagement/updates-on-issues/rozelle-parkland-asbestos-investigation/contaminated-mulch-management-plan

NSW EPA. (2024b). *Dealing with household asbestos*. Retrieved November 12, 2024, from NSW EPA: https://www.epa.nsw.gov.au/your-environment/household-building-and-renovation/dealing-with-household-asbestos

NSW EPA. (2024c). *Risk-based licensing*. Retrieved from https://www.epa.nsw.gov.au/licensing-and-regulation/licensing/environment-protection-licences/risk-based-licensing

NSW EPA. (2024d). *Tracking asbestos waste using the Integrated Waste Tracking Solution*. Retrieved November 12, 2024, from NSW EPA: https://www.epa.nsw.gov.au/your-environment/waste/transporting-asbestos-waste-tyres/tracking-asbestos-waste-with-iwts

NSW Government. (2016). *Guidance for Regulators to Implement Outcome and Risk-based Regulation.*

NSW Government. (2019). *NSW Asbestos Waste Strategy 2019-21.* State of NSW and NSW Environment Protection Authority. Retrieved from https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/waste/19p1900-nsw-asbestos-waste-strategy-2019-21.pdf

NSW Government. (2021). *Exempt and Complying Development Codes: asbestos material.* Retrieved November 14, 2024, from https://www.asbestos.nsw.gov.au/sites/default/files/2022-09/PS-21-036-Exempt-and-Complying-Development-Codes---asbestos-material.pdf

NSW Government. (n.d.). *Naturally occurring asbestos*. Retrieved December 6 , 2024, from Asbestos in NSW: https://www.asbestos.nsw.gov.au/identify-asbestos/what-is-asbestos/naturally-occurring-asbestos

OECD. (2010). *Risk and Regulatory Policy: Improving the Governance of Risk.* Paris: OECD Publishing. doi:https://doi.org/10.1787/9789264082939-11-en

Office of Local Government. (2015). *Model Asbestos Policy for NSW Councils.* NSW Department of Planning and Environment. Retrieved from https://lgnsw.org.au/Public/Public/Policy/Asbestos.aspx

Otness, Pierina. (2021). Research on Current Nonoccupational Exposure to Asbestos. In J. R. Millette, & J. S. Webber, *Asbestos and Other Elongate Mineral Particles - New and Continuing Challenges in the 21st Century.* ASTM International.

Queensland Government. (2018). *Review of the Regulated Waste Classification and Waste-Related Environmentally Relevant Activity (ERA) frameworks: Decision Regulatory Impact Statement.* Retrieved October 28, 2028, from https://www.legislation.qld.gov.au/view/pdf/published.risras/sl-2018-0154

Queensland Government. (2024a). *End of waste codes*. Retrieved October 28, 2024, from Business Queensland: https://www.business.qld.gov.au/running-business/environment/waste-management/regulated-waste/eow-codes

Queensland Government. (2024b). *Overview of regulated waste categorisation.* Queensland Government. Retrieved October 28, 2024, from https://www.des.qld.gov.au/policies?a=272936:policy_registry/era-is-categorising-regulated-waste.pdf

Rajoria, S., Vashishtha, M., & Sangal, V. (2023). Heavy Metal Ions in Wastewater: A Review on Detection and Toxicity. *Chem Eng Process Tech, 8*(3), 1082. doi:https://doi.org/10.47739/2333-6633/1082

Reid, A., de Klerk, N. H., Magnani, C., Ferrante, D., Berry, G., Musk, A. W., & Merler, E. (2014). Mesothelioma risk after 40 years since first exposure to asbestos: a pooled analysis. *Thorax, 69*(9), 843-850. doi:https://doi.org/10.1136/thoraxjnl-2013-204161

Rijkswaterstaat. (n.d.a). *Besluit stortplaatsen en stort-verboden afvalstoffen (Bssa) [Landfills and Waste Dumping Bans Decree]*. (D. M. Management, Editor) Retrieved October 15, 2024, from Circulaire Economie en Afval: https://www.afvalcirculair.nl/afvalregelgeving/afval-storten/bssa/

Rijkswaterstaat. (n.d.b). *National Waste Management Plan*. Retrieved November 5, 2024, from Landelijk afvalbeheerplan 3: https://lap3.nl/service/english/

Rodilla, J., Cerrada, B. C., Pujadas, C. S., Delclos, G. L., & Benavides, F. G. (2022). Fiber burden and asbestos-related diseases: an umbrella review. *Gaceta Sanitaria, 36*(2), 173-183. doi:https://doi.org/10.1016/j.gaceta.2021.04.001

Safe Work Australia. (2020). *Health monitoring: guide for asbestos.* Retrieved from https://www.safeworkaustralia.gov.au/system/files/documents/2002/health_monitoring_guidance_-_asbestos.pdf

Safe Work Australia. (2024). *Workplace exposure limits for airborne contaminants.* Safe Work Australia. Retrieved November 14, 2024, from https://www.safeworkaustralia.gov.au/doc/workplace-exposure-limits-airborne-contaminants

Safe Work Australia. (n.d.). *Managing risks*. Retrieved November 12, 2024, from Safe Work Australia: https://www.safeworkaustralia.gov.au/safety-topic/managing-health-and-safety/identify-assess-and-control-hazards/managing-risks

SafeWork NSW. (2010). *Management of asbestos in recycled construction and demolition waste - Guide.* Gosford: Safework NSW. Retrieved from https://www.safework.nsw.gov.au/__data/assets/pdf_file/0016/51730/SW08774-Management-of-asbestos-in-recycled-construction-and-demolition-waste-guide.pdf

SafeWork NSW. (2022). *How to safely remove asbestos: Code of Practice.* SafeWork NSW. Retrieved April 24, 2024, from https://www.safework.nsw.gov.au/__data/assets/pdf_file/0015/50082/How-to-safely-remove-asbestos-COP.pdf

SafeWork NSW. (n.d.). *Asbestos notifications*. Retrieved November 20, 2024, from SafeWork NSW: https://www.safework.nsw.gov.au/notify-safework/asbestos-notifications

Shabani, T., Jerie, S., & Shabani, S. (2024). A comprehensive review of the Swiss cheese model in risk management. *Safety in Extreme Environments , 6*, 43-57.

Slooff, W., & Blokzijl, P. J. (1989). *Integrated Criteria Document Asbestos.* Bilthoven, The Netherlands: National Institute of Public Health and Environmental Protection. Retrieved October 10, 2024, from https://www.rivm.nl/bibliotheek/rapporten/758473013.pdf

SoBRA. (2020). *The Distribution of Asbestos in Soil – what can the data mining of sample results held by UK laboratories tell us?* The Society of Brownfield Risk Assessment. Retrieved October 14, 2024, from https://sobra.org.uk/asbestos/the-distribution-of-asbestos-in-soil-what-can-the-data-mining-of-sample-results-held-by-uk-laboratories-tell-us/

SoBRA. (2021). *Variability in UK Laboratory Methods for the Identification and Quantification of Asbestos in Soil.* The Society of Brownfield Risk Assessment. Retrieved October 14, 2024, from https://sobra.org.uk/asbestos/variability-in-uk-laboratory-methods-for-the-identification-and-quantification-of-asbestos-in-soil/

Spurny, K. R. (1989). On the release of asbestos fibers from weathered and corroded asbestos cement products. *Environmental research, 48*(1), 100-16. doi:10.1016/s0013-9351(89)80089-1

Standards Australia. (2024). *Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD) (AS 5370:2024).* Retrieved from https://www.standards.org.au/standards-catalogue/standard-details?designation=as-5370-2024

Stelling, M. A., & Sjerps, M. (2005). Heterogeneity of Contaminants in Solid Waste Materials Sampled. *Environmental Forensics, 6*, 231-239. doi:10.1080/15275920500194373

Sustainability Victoria. (2023). *Guidle to Developing and Managaing ADPs for the Temporary Storage of Non-Friable Asbestos Waste (Pilot Progam).*

Sustainability Victoria. (2024). *Asbestos Disposal Point Grants*. Retrieved November 22, 2024, from https://www.sustainability.vic.gov.au/grants-funding-and-investment/grants-and-funding/asbestos-disposal-point-grants

Swartjes, F. A., & Tromp, P. C. (2008). A Tiered Approach for the Assessment of the Human Health Risks of Asbestos in Soils. *Soil & Sediment Contamination, 17*, 137-149. doi:10.1080/15320380701870484

The CINDERELA Project. (2021). *D 5.5 - End of Waste criteria protocol for waste used as aggregates.* Retrieved October 15, 2024, from https://www.cinderela.eu/The-project/Reports/D5.5-End-of-waste-criteria-protocol-for-waste-used-as-aggregates

Tromp, P., Spaan, S., & ten Brug, B. (2022). *De verwering van asbesthoudende daken en de verspreidingsroutes en blootstellingsrisico's van daarbij vrijkomende asbest(vezels).* [The weathering of asbestos-containing roofs and the distribution routes and exposure risks of asbestos (fibres) released in the process]. TNO. Retrieved October 15, 2024, from https://www.asbestversnelling.nl/site/media/upload/files/tno-2022-r10832.pdf

Turci, F., Favero-Longo, S. E., Gazzano, C., Tomatis, M., Gentile-Garofalo, L., & Bergamini, M. (2016). Assessment of asbestos exposure during a simulated agricultural activity in the proximity of the former asbestos mine of Balangero, Italy. *Journal of hazardous materials, 308*, 321-7. doi:10.1016/j.jhazmat.2016.01.056

UN Environment Programme. (2024). *Value chain including Eco-innovation and circular economy*. Retrieved from UN Environment Programme: https://www.unep.org/explore-topics/resource-efficiency/what-we-do/responsible-industry/value-chains-including-eco

United Nations Environment Programme. (2021). *Catalysing Science-based Policy Action on Sustainable Consumption and Production: The value-chain approach & its application to food, construction and textiles.* Nairobi: United Nations Environment Programme. Retrieved November 11, 2024, from https://www.oneplanetnetwork.org/sites/default/files/from-crm/report_unea5_catalysing_science-based_policy_action_on_scp_-_task_group_irp-one_planet_0.pdf

US EPA. (1993). *Method for the Determination of Asbestos in Bulk Building Materials.* US EPA. Retrieved November 11, 2024, from https://www.nist.gov/system/files/documents/nvlap/EPA-600-R-93-116.pdf

US EPA. (2002). *Draft Technical Guidance about Waste Sampling under the Resource Conservation and Recovery Act (RCRA).* Retrieved October 8, 2024, from United States Environmental Protection Agency: https://www.epa.gov/hw-sw846/draft-technical-guidance-about-waste-sampling-under-resource-conservation-and-recovery-act

US EPA. (2024). *Guidance for Data Quality Assessment*. Retrieved November 11, 2024, from EPA: https://www.epa.gov/quality/guidance-data-quality-assessment

VAEA. (2024). *Risk assessment model*. Retrieved October 15, 2024, from Victorian Asbestos Eradication Agency: https://www.vaea.vic.gov.au/risk-assessment-model

Victorian Government. (2003). Gazette: Special No S 253. Retrieved October 28, 2024, from https://www.gazette.vic.gov.au/gazette/Gazettes2003/GG2003S253.pdf

Victorian Government. (2023). *Find and identify asbestos tool*. Retrieved November 13, 2024, from Asbestos.vic.gov.au: https://www.asbestos.vic.gov.au/about-asbestos/finding-and-identifying/find-and-identify-asbestos-tool

WA DOH. (2021). *Guidelines for the Assessment, Remediation and Management of Asbestos Contaminated Sites in Western Australia.* Retrieved April 10, 2024, from WA Department of Health: https://www.health.wa.gov.au/Articles/A_E/Asbestos-contaminated-sites/Guidelines-asbestos-contaminated-sites

WA DWER. (2021). *Guideline: Managing asbestos at construction and demolition waste recycling facilities* (2021 Update ed.). Western Australia Department of Water and Environmental Regulation. Retrieved April 10, 2024, from https://www.wa.gov.au/system/files/2023-05/guideline-managing-asbestos-at-construction-and-demolition-waste-recycling-facilities.pdf

WA Waste Authority. (2024). *Roads to Reuse: Promoting the use of recycled construction and demolition (C&D) products*. Retrieved November 13, 2024, from WA Waste Authority: https://www.wasteauthority.wa.gov.au/programs/view/roads-to-reuse#:~:text=Roads%20to%20Reuse%20product%20is,rock%20produced%20by%20accredited%20recyclers.

Waste Authority of Western Australia. (2020). *Roads to Reuse pilot project.* Retrieved from https://www.wasteauthority.wa.gov.au/images/resources/files/2021/06/RtR_Pilot_Report.pdf.pdf

WHO. (2000). *Air quality guidelines for Europe* (2nd ed.). World Health Organization. Regional Office for Europe. Retrieved April 15, 2024, from https://www.who.int/publications/i/item/9789289013581

Workplace Health and Safety Queensland. (2011). *Asbestos flooring.* Retrieved November 8, 2024, from https://www.asbestos.qld.gov.au/sites/default/files/asbestos-flooring.pdf

WorkSafe Victoria. (2007). *Recycling construction and demolition material: Guidance on complying with the Occupational Health and Safety (Asbestos) Regulations 2003.* WorkSafe Victoria. Retrieved October 28, 2024, from https://content-v2.api.worksafe.vic.gov.au/sites/default/files/2018-06/ISBN-Recycling-construction-and-demolition-material-2007-01.pdf

WSROC. (2015). *Western Sydney Residential Asbestos Disposal Scheme (WSRADS).* Retrieved from https://lgnsw.org.au/common/Uploaded%20files/PDF/The_Western_Sydney_Residential_Asbestos_Disposal_Scheme_-_LGNSW_case_study_%20-_approved%20(v6).pdf

Appendices

Appendix 1: Terms of Reference

Advice on the management of asbestos in recovered fines and recovered materials for beneficial reuse in NSW

The previous Minister for Environment and Heritage, the Hon. James Griffin MP requested the Office of the Chief Scientist and Engineer (OCSE) to provide advice on the management of asbestos in recovered fines.

Background

Asbestos regulation in NSW

Since 2003, the use or sale of asbestos has been banned in Australia.

Consistent with the national ban on asbestos, section 144AAB of the *Protection of the Environment Operations Act 1997* (POEO Act) makes it an offence to cause or permit asbestos waste in any form to be re-used or recycled. The prohibition applies to all wastes containing any form of asbestos at any concentration. Also, it means asbestos waste cannot be processed, screened or segregated. Therefore, asbestos cement material, for instance, cannot be removed from the waste and all asbestos containing waste must be disposed of to a landfill licensed to receive the waste.

It should be noted that asbestos containing materials managed at the site of their occurrence may not be defined as waste, and different rules can apply to their management and re-use. For example, asbestos-contaminated soil that needs to be processed (generally by excavating the soil and removing the asbestos from it) prior to reuse is considered waste, even if it remains on the same site. If the soil does not need to be processed prior to on-site reuse (generally because contamination levels are extremely low), then it may not be waste, if certain pre-conditions are met.

There will generally be a practical level of exposure below which it is impossible to detect increased risk of asbestos related diseases. This is reflected in the *National Environment Protection (Assessment of Site Contamination) Measure 1999*, which regards levels of asbestos cement material below 0.01% w/w as safe. A more stringent level of 0.001% w/w is applied to fibrous asbestos and asbestos fines due to their greater risk of air borne fibres.

Unlike the national approach for managing asbestos contaminated land, inconsistent approaches exist across jurisdictions in managing asbestos contaminated waste. For instance, in Western Australia where significant efforts are taken to keep asbestos contaminated materials out of construction & demolition waste recycling facilities, it is acceptable to screen and remove asbestos cement material at recycling facilities if it cannot be avoided. Also, the WA guidance on managing asbestos in construction and demolition waste recycling facilities states that to ensure the health of those using or coming into contact with recycled C&D products is protected, the asbestos content (in any form) in any recycled products must not exceed 0.001 % w/w. More information is available on the EPA website.

There is considerable industry confusion around the overlap between the requirements of the contaminated land and waste regulatory frameworks in relation to on-site reuse of asbestos-contaminated soils. The EPA is currently working with industry and other authorities to develop policy and guidance to help clarify this issue, but further advice from the OCSE would be beneficial.

Recovered fines

Recovered fines are the residues remaining after all recyclable construction and demolition waste material has been removed from skip bins. They are reused as a sand/soil substitute in landscaping materials such as turf underlays or construction fill.

Compliance testing by the EPA in 2019 found that around half of all recovered fines produced is high quality clean soils which is of benefit to reuse. However, the other half contained contaminants including asbestos, which may have human health or environmental risks. Other key contaminants were synthetic mineral fibres and plastics and micro-plastics.

Earlier in the year, the EPA commenced consultation with industry and other stakeholders on a proposal to change the rules that apply to the production of recovered fines. This included sampling requirements and the intention to revoke the generic or 'batch' resource recovery orders and exemptions that apply to recovered fines. Skip bin fines would only be able to be reused on a site-by-site basis where high-quality produce could be demonstrated.

The industry raised significant concerns with the proposed changes, as they considered the standards set would be challenging to comply with and could impose significant cost to industry that would be passed onto skip bin customers. They further suggested the proposed changes would see recycling and recovery rates drop significantly and increased illegal dumping.

Industry has separately raised concerns over many years suggesting there is a need for a threshold quantity of asbestos in waste before it is treated as asbestos waste, with the need for a more proportionate approach to risk when dealing with small amounts of bonded ACM. Concerns have also been raised relating to the remediation of contaminated sites, with site auditors seeking greater clarity on what can be done on and off site with soils containing asbestos

Improving the management and beneficial reuse of waste in NSW

The EPA is currently reviewing its approach to the management of asbestos in the context of reuse/recycling and resource recovery to support both a circular waste economy, resource recovery and reuse and explore options for greater consistency between jurisdictions.

The NACC consider there needs to be an improved evidence base on the risk tolerance, health and environmental impacts, technologies and cost-effective methods to inform any future improvements to the safe and effective management of asbestos in recovered fines and in relation to recovered materials / waste intended to be beneficially reused.

Scope of advice

The OCSE will convene a technical panel with relevant experts to address the following:

- Undertake a review of national and international jurisdictions standards and guidelines to determine if asbestos threshold levels (in waste) in an environmental context have been set; where threshold levels exist and what they are; report on the basis (environmental, human health) for determining thresholds and how compliance with those thresholds is achieved.
- Can a tolerable threshold level be set for asbestos in waste intended for beneficial reuse irrespective of its end use? In answering this question, consideration should be given to:
    - What would be a scientifically robust basis for determining the threshold level?
    - Are there controls that could be applied to mitigate environmental and human health risks (including education, regulation, monitoring, reporting etc) to a level where the recovered material could be used in a limited set of circumstances?
    - In what circumstances would it be possible to land apply recovered materials with minimal or controllable/manageable risk (i.e. under infrastructure if capped and sealed), and what would appropriate methods look like? What are the risks of creating legacy issues and how could this be managed?
    - Where should the application of recovered materials be restricted?
    - If no acceptable threshold could be set, what is the scientific basis for maintaining a zero tolerance?
- What is the most appropriate sampling and analytical approach for asbestos in recovered material? In answering this question, consideration should be given to:
    - How many samples to collect and test for a given volume to be fair, cost-effective and representative
    - What test methods would represent best practice, for example, AS4964-2004, NEPM gravimetric and AF/FA sampling or other test methods

    - The technology available in the context of the recommended acceptable thresholds and its accessibility.
- Should a tolerable threshold level for historically asbestos-contaminated soils be different to a tolerable threshold level for asbestos in waste? Is it safe and practical to process asbestos-contaminated soils to reach a threshold level and reuse them on-site.
- Are setting threshold levels the best way to manage asbestos in recovered materials? Or are there better risk-based approaches to achieve these outcomes?
- Are there scientific and risk assessment principles that the EPA should consider when setting threshold levels for asbestos?

Final advice

The OCSE will produce a report to the Minister and the NACC setting out their advice and recommendations on the questions above within 12 months of receiving this terms of reference. The Minister may request that the final report be publicly released. The report and inputs into this review by the OCSE should be treated confidentially in the meantime.

Appendix 2: Site Visits

<table>
<tr><th>Region</th><th>Type</th><th>Facilities</th></tr>
<tr><td rowspan="2">Sydney Metro</td><td>C&D recycling facilities</td><td>Bingo Eastern Creek Ecology Park, Eastern Creek
Concrete Recyclers, Camellia
Bingo Patons Lane RRC, Orchard Hills
Benedict Recycling Centre, Chipping Norton
Boral Recycling, Wetherill Park
Brandown, Cecil Park</td></tr>
<tr><td>Laboratory</td><td>Hibbs, Auburn</td></tr>
<tr><td rowspan="3">Southeast NSW</td><td>C&D recycling facilities</td><td>Breen Resources, Kurnell</td></tr>
<tr><td>Organics recycling facility</td><td>Soilco, Kembla Grange</td></tr>
<tr><td>Local Council (Shellharbour City)</td><td>Dunmore Resources and Recycling Disposal and Depot, Dunmore</td></tr>
<tr><td>Central NSW</td><td>Local Council (Orange)</td><td>Ophir Road Resource Recovery Centre, Orange</td></tr>
</table>

Appendix 3: List of Submissions

Below shows the index of submissions received in response to the OCSE Discussion Paper, in chronological order of receipt:

1. JS Regulatory Services
2. Cleanaway
3. Australasian Land & Groundwater Association (ALGA)
4. Baraja Pty Ltd
5. *Confidential submission*
6. *Confidential submission*
7. Department of Water and Environmental Regulation (Western Australia) (DWER)
8. *Confidential submission*
9. Local Government NSW (LGNSW)
10. *Confidential submission*
11. *Confidential submission*
12. *Confidential submission*
13. *Confidential submission*
14. *Confidential submission*
15. *Confidential submission*
16. Individual submission from Dr Michael Dunbavan
17. Agon Environmental
18. Australian Sustainable Business Group (ASBG)
19. Individual submission from Phillip Foxman
20. Foundation Earth Sciences Pty Ltd
21. *Confidential submission*
22. NSW Health
23. Australian Council of Recycling (ACOR)
24. *Confidential submission*
25. SafeWork NSW
26. Individual submission from Loek Munnichs
27. Asbestos and Silica Safety and Eradication Agency (ASSEA)
28. *Confidential submission*
29. *Confidential submission*
30. Joint submission from the Waste Management and Resource Recovery Association of Australia (WMRR) and the Waste Contractors & Recyclers Association of NSW (WCRA).