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Review

Australia's Ongoing Challenge of Legacy Asbestos in the Built Environment: A Review of Contemporary Asbestos Exposure Risks

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Abstract: Asbestos remains ubiquitous in the Australian built environment. Of the 13 million tonnes of asbestos products installed in earlier decades, an estimated 50% remain in situ today. Because of the extensive past use of asbestos, and the increasing age of these products, the potential for exposure to asbestos fibres in both indoor and outdoor environments remains high, even while the actual asbestos exposure levels are mostly very low. Sources of these exposures include disturbance of in situ asbestos-containing materials (ACMs), for example during renovations or following disaster events such as fires, cyclones and floods. Our understanding of the risk of asbestos-related disease arising from long-term low-level or background exposure, however, is poor. We provide the most up-to-date review of asbestos exposure risks currently affecting different groups of the Australian population and the settings in which this can manifest. From this, a need for low-level asbestos monitoring has emerged, and further research is required to address whether current exposure monitoring approaches are adequate. In addition, we make the case for proactive asbestos removal to reduce the risk of ongoing asbestos contamination and exposure due to deteriorating, disturbed or damaged ACMs, while improving long-term building sustainability, as well as the sustainability of limited resources.

Keywords: asbestos; asbestos-containing materials (ACMs); asbestos exposure risk; built environment

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1. Introduction: Asbestos in the Built Environment

Asbestos exposure causes diseases like asbestosis, mesothelioma and cancers of the lung, ovary, and larynx [1]. Historically, the most significant source of workplace exposure was from asbestos mining and manufacturing. However, the presence of asbestos in millions of homes and public and commercial buildings across Australia today means workers at the greatest risk of exposure are those who undertake removal, repairs, maintenance, renovations and other work on older buildings. This includes builders, electricians, plumbers and painters. Examples of work involving, or likely to involve, the disturbance of asbestos include removing asbestos-containing floor tiles as part of a renovation, cutting or drilling into an asbestos cement sheet wall, demolishing a structure that contains asbestos, or working on asbestos cement pipes [2].

Past non-workplace exposures arose from living with an asbestos worker or living near an asbestos mine or factory. These exposures have consistently been associated with disease [3]. However, with progressive restrictions commencing in the 1960s on the mining and manufacturing of asbestos and asbestos products, and ultimately after the ban at the end of 2003 in Australia, these exposures became less common. Home renovators are now the most likely at-risk group for non-workplace exposure, since they have little or no training in asbestos handling and removal and are less likely to adopt protective control measures to minimise exposure [4–8].

Asbestos fibres are also released with general deterioration (weathering) and damage to ACMs, as well as damage from disasters such as fires, storms, cyclones and floods. These events can cause short-term increases in airborne fibres, require complex control measures and are expensive to remediate. In some cases, long-term contamination of land with asbestos fragments and fibre bundles remains. Other potential sources of exposure include illegal asbestos disposal, historical fill material and waste recycling (see Section 4). Future exposure risks could also arise from imported goods with asbestos fibres in contravention of the import ban.

This article provides the most up-to-date review of asbestos exposure risks in Australia and the settings in which these can manifest. It also discusses current and future approaches to address these risks and identifies knowledge gaps. To achieve this, we have considered the issues of potential asbestos fibre release from in situ products, the analytical framework for measuring asbestos exposure, current settings for potential asbestos exposure (including case studies) and the evolution of the overarching national framework to prevent asbestos exposure.

2. Potential Fibre Release from In Situ Asbestos Products

Australia was one of the highest per capita users of asbestos in the world until the 1980s. The use of asbestos products in buildings was phased out after this time, and banned by the end of 2003, but most in situ products are much older [9]. Like any building material, as ACMs age, they deteriorate. The level of deterioration caused by general ageing depends on several factors, including how well the products are maintained. There are very low concentrations of asbestos fibres measured in most urban centres in industrialised countries like Australia [10] and asbestos fibres can be found in the lungs of many people who have not had any workplace exposure [11,12]. The simple measure of asbestos consumption has been shown to be associated with asbestos-related disease mortality rates, including in past high-consuming countries like Australia, as well as in developing nations that are relatively new users of ACMs [13].

2.1. Indoor Products

Indoor products are likely to weather at a slower rate than outdoor products, with damage arising because of physical contact (e.g., general wear and tear) and movement of the building (e.g., vibration). Renovation activities can transiently increase indoor airborne fibre concentrations depending on how carefully they are conducted (see Section 4.2). However, airborne asbestos fibre concentrations in buildings where products are not being disturbed are generally not present in measurable quantities or occur at very low levels, similar to outdoor levels [14–16].

In a 2008 study of 752 buildings, including schools, universities, public buildings, and homes, conducted over a ten-year period, Lee and Van Orden [14] found that although indoor concentrations were greater than outdoors, 'in-place ACM does not result in elevated airborne asbestos in building atmospheres approaching regulatory levels and that it does not result in a significantly increased risk to building occupants'. The highest indoor concentrations, on average, were found in schools, which was probably owing to a greater level of activity in these buildings [14].

Ageing, damage and renovation of asbestos products can potentially increase indoor asbestos fibres in the air or dust, while ventilation and ongoing cleaning activities will reduce indoor asbestos fibres. A 2022 study of changes in asbestos fibre concentrations in typical Eastern European buildings found that indoor airborne fibre concentrations are generally low and reduce over time, with ventilation being an important factor in the reductions [17].

2.2. Outdoor Products

Asbestos products that are located outdoors (for instance, external cladding, fences, and roofs) are more likely to be subject to weathering and deterioration than indoor asbestos products. The damage to outdoor products can be highly visible. Cracked and broken ACM fences and wall sheets are common in areas where these products were used extensively. General deterioration is less obvious, but the erosion of ACM can remove cement particles and result in the release of asbestos fibres. The contribution of damaged and weathered materials to urban asbestos pollution is very difficult to determine.

Typical ambient air levels of asbestos fibres in cities are about 0.0001 f/mL, ten-fold higher than in rural areas (remote from any special sources of asbestos) [16]. A factor limiting airborne fibre counts, even for deteriorated products with visible debris, is that the debris and fibre bundles are larger than the respirable size fraction (unpublished; Otness and Franklin), which means they are not measured by the air monitoring methods currently used (see Section 3). The sources of increased concentrations in cities are varied and although fibre release from individual products, even if highly degraded, can be minimal, there are many of these products in the built environment.

Figure 1 shows where asbestos may be found inside and outside the average Australian home [18]. This information can be used by homeowners for awareness and guidance on how to manage asbestos in situ safely.

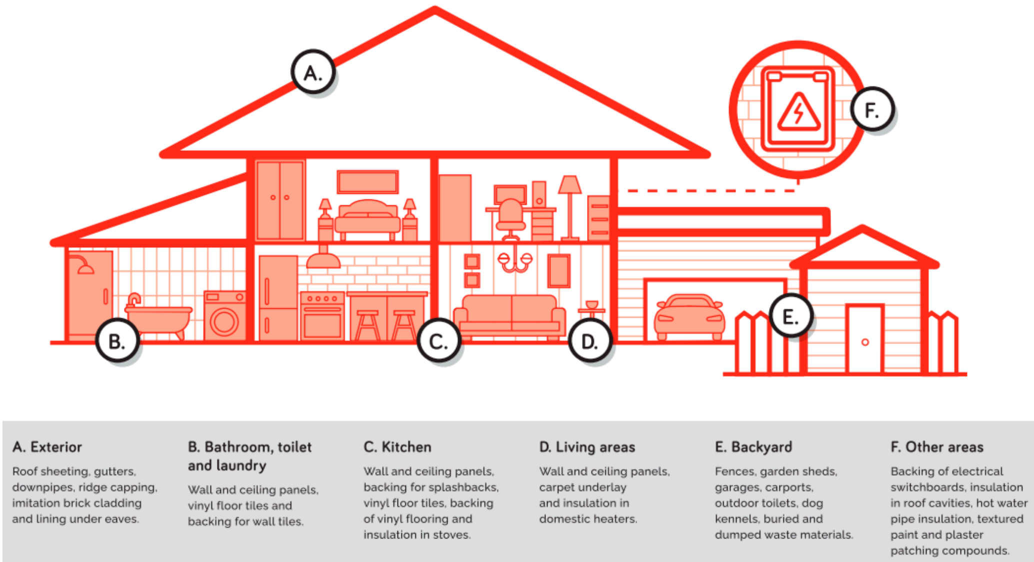


Figure 1. Asbestos locations diagram [18]. A homeowner's guide to identifying potential ACM, to assist with managing it safely.

3. Analytical Techniques for Measuring Asbestos Exposure

In Australia, current asbestos exposure measurement data is primarily based on phase contrast microscopy (PCM) analysis that only includes particle concentrations that meet the World Health Organisation (WHO) critical fibre and countable fibre definition of particles of >5 µm long, <3 µm wide and with a length to width ratio of 3:1 [19]. The choice of a 5 µm cut-off with a 3:1 aspect ratio was an arbitrary one and based on readily available sampling methodology, known to provide an index or estimate of exposure in workplace settings where exposures were relatively high, and the fibre type was known [20]. As such there is a high uncertainty in quantifying risk for the level and type of both workplace and non-workplace exposure concentrations occurring in the present day.

Health researchers [21–24] recommend a standardised method to obtain more reliable data on fibre morphology. This would inform future epidemiological studies that would benefit from exposure-response data for the comparatively low-level exposures to asbestos and other related elongated mineral particles. Advances in artificial intelligence (AI), electron microscopy and integrated software provide a viable solution for developing a standardised methodology in Australia for environmental fibre sampling at the lower limits of current reporting. Such methods allow for the inclusion of lower width (<0.2 μm) or thinner asbestos fibres that are more difficult for a human analyst to observe by PCM but are becoming increasingly relevant for assessing disease risk.

The European Commission has recognised the scientific and technological advancements in fibre measurement [25] and has agreed to amend the Asbestos at Work Directive with a significant, tenfold reduction of the European Union (EU) occupational exposure limit for asbestos (from 0.1 fibres/cm^3 to 0.01 fibres/cm^3), with an optional lower threshold (of 0.002 fibres/cm^3) dependent on the fibre-counting method being used [26]. It forms part of the European Commission's broader strategy to improve the energy performance of existing buildings and achieve healthy indoor environments, including through the removal of hazardous substances like asbestos [27]. In Australia, work health and safety (WHS) laws require duty holders (i.e., those responsible for WHS compliance) to ensure the workplace exposure standard (WES) for asbestos is not exceeded. The current WES for asbestos is a respirable fibre level of 0.1 fibres/mL (0.1 f/mL, equivalent to 0.1 f/cm^3) of air measured in a person's breathing zone and expressed as a time-weighted average fibre concentration calculated over an eight-hour working day [28]. For air monitoring related to the removal of friable asbestos, a limit of 0.01 f/mL at the asbestos removal area also applies [29,30].

4. Current Settings for Potential Asbestos Exposure

There are 5 different settings of concern for high-risk asbestos exposure groups in Australia—demolition; renovation; illegal asbestos disposal; disaster and emergency events; and contaminated sites (see Figure 2). This aligns with the broader global consensus of potential asbestos exposure pathways, especially given the clear shift in recent years towards implementation of total asbestos bans [31]. While the circumstances contributing to potential asbestos exposure in each of these settings differ, the common concern is that exposure can and does occur, notwithstanding the existence of control measures that should be in place. The factors influencing potential asbestos exposure in the different settings in the Australian context are discussed in more detail below.

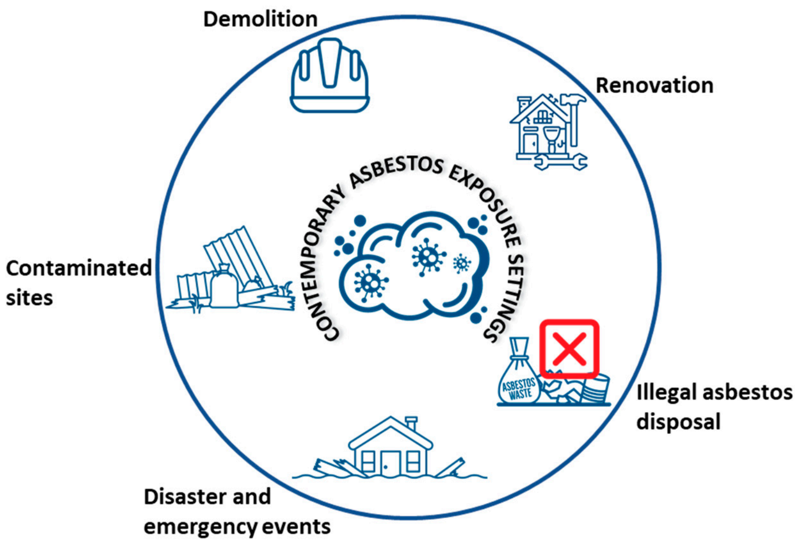


Figure 2. Contemporary asbestos exposure risks arise from different settings in the Australian built environment.

4.1. Demolition

Non-compliant asbestos removal work or building demolition is a potential source of both short-term elevated airborne asbestos fibres and long-term asbestos contamination of the soil. In Australia, the Model WHS Regulations contain specific provisions in relation to asbestos removal. Specifically, the demolition and refurbishment of structures and plants constructed or installed before the 2003 asbestos ban includes the duty to identify and remove, so far as is reasonably practicable, all asbestos before demolition (Part 8.6, r452) [29]. However, despite these laws, poor asbestos management during demolition remains an ongoing problem e.g., [32–34]. This is likely to remain a problem for some time owing to the large number of buildings that still contain ACMs and that many of these ACMs are reaching the end of their product life [9].

There are few published data on airborne asbestos fibres generated by demolition. Perkins et al. in 2007 found very low levels of airborne asbestos fibres in the demolition of whole buildings when proper practices were observed, even in buildings that still contained significant amounts of asbestos [35]. Where there are no attempts to reduce dust levels during demolition, airborne asbestos fibre levels can be high [36,37]. For asbestos removal work in Australia to comply with the Model WHS Regulations, the respirable asbestos fibre level using the Membrane Filter Method must not exceed 0.01 f/mL and work must stop if levels are recorded above 0.02 f/mL (Part 8.8, r476) [29].

4.2. Renovation

Renovations that do not include precautions for asbestos are one of the greatest contemporary risks of uncontrolled exposure to airborne asbestos fibres. Indeed, of all the current exposures, renovation and removal are the most likely to be associated with disease [38–42]. These activities are a major source of non-workplace exposure because of the large number of homes that are renovated, particularly older homes that are likely to contain ACMs. Exposure can either be accidental (for example, a homeowner or tradesperson being unaware of existing asbestos in a building) or result from unsafe work practices.

Home renovation has been [43–45], and remains [5–7], a common activity in Australia. Based on the most recent home improvement awareness survey undertaken by the Asbestos Safety and Eradication Agency [5], 67% of respondents across Australia were considered 'home improvers', split evenly between DIY renovators (51% of home improvers) and those who outsource most or all of the renovation (49% of home improvers). In 2020 and 2021, the 'stay at home' instructions throughout the COVID-19 pandemic saw a boom in DIY home improvement projects, giving rise to concerns of increased asbestos exposure risk. As a proportion of the total home improvement projects undertaken in the last five years, at least a third began during the early COVID-19 restrictions in Australia (i.e., March to June 2020), and a significantly higher proportion (46–69%) commenced in 2021 [5–7]. A more detailed analysis of home improvers has shown distinct cohorts exist based on clustering of similar demographic, socioeconomic, behavioural and attitudinal traits, providing even further insight on how to target risk management information appropriately based on their levels of asbestos awareness and knowledge [8].

Renovation activities, particularly those involving the use of power tools, can produce short-term high concentrations of asbestos fibres, and major renovation works may temporarily increase background fibre concentrations in the medium term, contributing to increased cumulative exposure [16]. It should be noted that destructive work practices that increase the proportion of respirable dust fraction in the air (e.g., high-speed power tools, high-pressure water or compressed air, the use of manual brooms or brushing) are not recommended when working with asbestos. In studies that have simulated renovation/removal activities and measured airborne asbestos fibre concentrations, it has been demonstrated that fibre concentrations can be very high, exceeding, in the short-term at least, the WES for asbestos of 0.1 f/mL (8 h time-weighted average). Table 1 provides a summary of airborne asbestos fibre concentrations measured in these studies [16,46]. While it is difficult to compare these results directly with the WES, as the sampling periods used in these studies are much shorter than the 8 h workplace limit, these high short-term concentrations are consistent with expectations and seem to be sufficient to cause disease [38–42].

Table 1. Airborne asbestos fibre concentrations (f/mL) measured during selected renovation activities (based on [16,46]).

Activity	Concentration (f/mL)	Time	Exposure Adjusted to 8-h Exposure for Each Task [1]
Workplace exposure standard	0.1 [2]	8-h (time-weighted average)	0.1
Removal of vinyl tiles by scraping	0.004–0.014	Short-term [3]	
Asbestos-cement sheet Hand saw Jigsaw Circular saw	 1–4 2–100 10–20	 Short-term [3] Short-term [3] Short-term [3]	
Removal of AC corrugated external roof sheeting in dry conditions	0.215 [4]	18 min	0.008 f/mL
Removal of AC flat external wall sheeting in dry conditions	0.213 [4]	31 min	0.012 f/mL
Removal of small sections of AC flat sheet to create penetrations	13.231 [4]	5 min	0.140 f/mL
Drilling and screwing into AC sheet	0.062 [4]	15 min	0.002 f/mL
Removal of AC wall panels in bathrooms	0.663 [4]	15 min	0.021 f/mL
Cleanup after task	0.898 [4]	35 min	0.065 f/mL
Removal of a small outdoor shed constructed of flat and corrugated AC sheeting	0.124 [4]	108 min	0.030 f/mL

[1] Assumes no other exposure to asbestos fibres during the 8 h for each task and exposure is measured without consideration of personal protective equipment (PPE). [2] A licenced removalist must stop asbestos removal work when the recorded personal respirable asbestos fibre level exceeds 0.02 f/mL. The removalist cannot resume removal work until area air monitoring shows that the recorded respirable asbestos fibre level is below 0.01 f/mL. [3] Time was not specified but 'short-term' monitoring is usually 30 min (but can be shorter). [4] These were personal samplers. All results from personal sampling were considerably greater than area sampling.

4.3. Illegal Asbestos Disposal

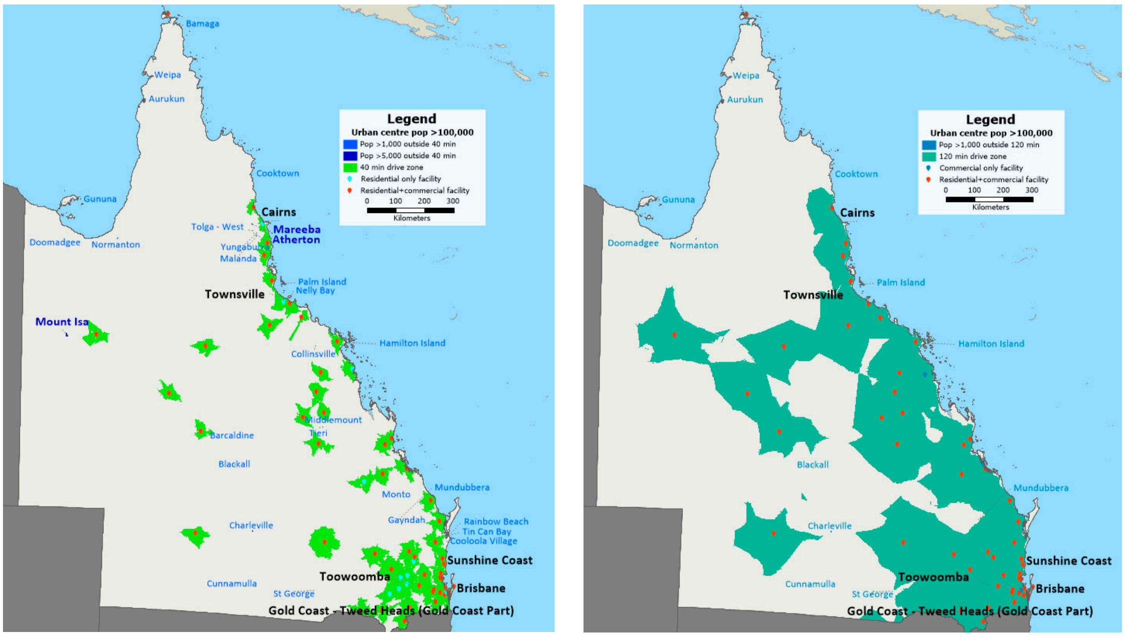
Illegal disposal of ACMs from both commercial and domestic sites is a problem across Australia. It affects not only local government and private landowners who typically bear the cleanup costs but also regulatory authorities who bear the responsibility for investigation and law enforcement of major incidents; individuals (e.g., workers and the general public) exposed to it who may bear risks to their future health; and government in terms of long-term health care costs. The biggest immediate impact is in the cost of cleanup and site remediation. In a 2016 review, it was estimated that across Australia, about 6300 tonnes of ACM is dumped each year, and the cost of cleanup is around $A11.2 million per annum [47]. These were crude estimates based on numerous assumptions, as the volumes or weight of illegally disposed ACMs and the costs of cleaning up these materials are not systematically recorded by local or state governments.

Household renovators, building contractors, and asbestos removalists are considered the main culprits responsible for most incidents of illegally disposed ACMs [47]. In recent asbestos awareness surveys of 'DIYers' or 'home improvers' who have worked on a property with asbestos risk (i.e., built before 1990), about one-third (28–35%) of those who have encountered asbestos in the past admit to inappropriate (illegal) disposal—mostly in their own or a neighbour's household bin [5–7]. In surveys of members of the New South Wales (NSW) community specifically, one quarter reported improper methods of disposal when dealing with asbestos including commonly leaving it on-site once it had been removed [48]. Larger volumes of asbestos waste are often dumped in urban bushland or vacant blocks of land, but there have been numerous press reports of dumping in public open spaces like roadsides and next to school grounds [47]. Illegally disposed asbestos is generally ACM sheeting but can also include other asbestos-containing materials, including friable material, and can be co-located in mixed construction and demolition or commercial/industrial waste. More egregious illegal behaviour included a scam that involved delivery of a new free large storage shed in exchange for receiving tonnes of asbestos-contaminated soil that was prepared as the footing for the shed [49].

The motivations to illegally dispose of ACMs include issues around a lack of awareness of what to do, cost and accessibility [5–7,34,47,48,50]. A willingness to take risks to remain competitive or to make higher profits (for example, commercial operators illegally disposing ACMs even when their client has been charged the full cost of legal disposal), and an apathy and/or a perception that dealing with ACMs properly is too difficult are additional factors [47,48]. Analysis of aspects related to cost (waste levies) and accessibility (drive times) of ACM disposal has recently been undertaken [unpublished; ASEA]. While waste levies for disposal of wrapped asbestos likely represent a small proportion of the overall removal cost, ranging from $0 up to $146; other cost factors need to be considered and include removal, transportation and gate fees at asbestos waste facilities—all charged based on commercial decisions made by the professionals undertaking this work. The availability of suitably trained asbestos professionals is also a cost consideration, especially for regional and remote areas of Australia.

On the accessibility issue of asbestos waste facilities, a metric of 40-min and 120-min travel times for small/domestic (under 10 m^2) and large/commercial loads, respectively, was used as a reflection of convenient travel times [unpublished; ASEA]. Figure 3 showcases an example of the findings from this research for the state of Queensland, in north-east Australia (population over 5.3 million). Here, 2.3% of the population lives more than 40 min from a waste facility that accepts domestic asbestos waste (small loads), and 0.7% lives more than 120 min from a waste facility that accepts commercial asbestos waste (large loads or friable asbestos waste). Nationwide, it was calculated that on average 2.8% (range 0–15.4%) of the total Australian population lives more than 40 min from a waste facility that accepts domestic asbestos waste (small loads), and just 0.4% (range 0–13.5%) of the Australian population lives more than 120 min from a waste facility that accepts commercial asbestos waste (large loads/friable asbestos waste). Regional and remote areas were most affected by longer travel times to asbestos waste facilities, with actual travel times to an asbestos waste facility for some localities in the mostly remote Northern Territory (NT) being up to 34 h [unpublished; ASEA]. Licensed asbestos waste facilities not accepting asbestos waste is another factor affecting accessibility [51].

Dumped asbestos remains a cause of significant community concern, particularly if found in public open spaces or on vacant blocks in residential areas. Dumped ACM, even if non-friable/bonded, can include broken and/or weathered fragments, but there is not likely to be a large release of fibres. Problems may occur when the land where asbestos has been dumped is being developed. If the ACM is not identified early and adequately removed it can be crushed by heavy equipment or mixed with cleared vegetation and mulched, allowing fibres to become airborne. The number of fibres released into the air will not be high and the subsequent risk of disease will be extremely low, although it will not be zero.



(**a**) (**b**)

Figure 3. Travel times—(**a**) within 40 min and (**b**) within 120 min—to a licensed asbestos waste facility for the state of Queensland.

There are ongoing efforts by governments and others to ensure safe asbestos waste disposal becomes easier and cheaper for the whole community by making it a strategic focus of current and future actions [51,52], including investigation of alternative asbestos waste technologies in addition to landfills [53].

4.4. Disaster and Emergency Events—Fires, Storms, Cyclones and Floods

Preventing asbestos exposure following disaster and emergency events requires ACMs to be identified early and then maintained in a safe state or undisturbed until they can be appropriately removed. The large scale of recent disaster and emergency events in Australia has required coordinated government-led action to assist early in the initial cleanup phase. This is because different types of fires (e.g., bushfires and other fire incidents), storms, cyclones, or floods can all disturb previously safely contained materials. The main concern is the destruction and spread of asbestos from the event and the risk of exposure when accessing a property and disturbing materials during and after the event and as part of the removal and cleanup [54]. There is a lack of evidence that disaster and emergency events involving damage to asbestos products cause significant public exposures during the event [54]. However, each of these events has the capacity to create considerable asbestos contamination that can lead to exposure when accessing and disturbing contaminated materials, significant community disquiet, costly cleanup, and the potential for future exposure from any residual contamination.

Bushfires typically occur more regularly than other disaster events in Australia and often impact regional areas. However, this is where older asbestos-containing buildings are present in significant proportions and access to resources (e.g., licensed asbestos assessors and removalists, asbestos waste facilities) for cleanup may be limited, making the implications for asbestos management complex. Confined fire events typically occur in cities and densely populated metropolitan areas, posing a different set of asbestos management challenges, namely controlling asbestos exposure risk for a bigger proportion of the population. A comparison of the impact of different fire event types is provided in Table 2. Irrespective of the fire event type, compared with other disasters, fires are more likely to liberate asbestos fibres from non-friable/bonded asbestos products and can cause considerable release and dispersion of these asbestos fibres. Fires cause the cement matrix of ACM to break and 'spall'. Spalls are flakes of material that are broken off the larger body because of the surface failure of that material. For asbestos cement products, water held within the matrix expands under heat causing a differential pressure build-up within the cement matrix that results in spalling, sometimes explosively [55]. The dominant (free) fibre emissions during a fire are associated with the spalling process [55]. Despite the spalling that occurs during fires, airborne asbestos fibre concentrations are generally quite low during and immediately after a fire event [56]. The reason is likely to be that high volumes of air drawn into the fire area would significantly dilute fibre concentrations. However, the free fibres and fibre bundles can travel and be deposited beyond the fire site [57].

As with other instances of damage to asbestos products, contamination of the surrounding materials and environment is a major problem. Soil, vegetation, and hard surfaces in and around the fire scene can be contaminated with fibres, fibre bundles and ACM fragments. Most asbestos will be deposited as large pieces or fragments of ACM, predominantly within or immediately about the area of the fire scene. Smaller quantities of asbestos fibre bundles and free asbestos fibre are liberated from their non-friable/bonded form as a result of spalling and are deposited in measurable concentrations within the immediate vicinity of, and to a lesser extent beyond, the fire scene [55,57].

Table 2. Asbestos management in recent disaster and emergency events (based on [58–68]).

Event Type	Incident Details	Management Details (e.g., Extent of Damage, ACM Type, Parties Involved in Cleanup, Estimated Costs)
Large scale fire	Black Summer bushfires State of NSW Spring (September) 2019 to Summer (February) 2020	• a protracted drought from 2017, combined with Australia's hottest and driest year in 2019, led to the most severe fire season ever recorded in NSW • 5.5 million hectares of land was burnt across NSW; 26 lives lost; 2476 homes, 284 facilities and 5469 outbuildings destroyed; 1013 other homes, 194 facilities and 2042 outbuildings damaged—40% estimated to contain ACMs • NSW Rural Fire Service (RFS) led the fire-fighting efforts with support from Fire and Rescue NSW, the National Parks and Wildlife Service, the Forestry Corporation of NSW, the State Emergency Service, the NSW Police Force and over 5000 interstate and overseas fire and emergency service personnel • the NSW Bushfire Clean-up Program was set up by the NSW Government Public Works Authority, who engaged a managing contractor (Laing O'Rourke) to clear debris from fire-damaged properties across NSW and make communities safe as quickly as possible—cleanup commenced January 2020 and was completed by July 2020, with 340,000 tonnes of waste cleared and all asbestos-contaminated waste deemed as friable • the Australian Government committed $2 billion to assist individuals and communities impacted by the fires; insurance claims for NSW totaled $1.88 billion
Confined fire	Wickham Wool Store fire City of Newcastle, NSW 1 March 2022	• industrial storage facility with asbestos cement roof caught fire • asbestos containing debris travelled to neighbouring areas as a result of the fire's smoke plume • Local Recovery Committee (City of Newcastle Council, NSW Environmental Protection Authority, Public Works Advisory, NSW Health, SafeWork NSW) established to coordinate the cleanup of areas impacted by the fire • asbestos cleanup, including active air monitoring for asbestos fibres, from March to July 2022; involved 687 homes and public areas like a local school, parks, footpaths, roads, playgrounds, community gardens, sporting fields • $13 million AUD cleanup cost repaid by landowner to government

Table 2. *Cont.*

Event Type	Incident Details	Management Details (e.g., Extent of Damage, ACM Type, Parties Involved in Cleanup, Estimated Costs)
Cyclone	Cyclone Seroja Mid-west region, WA 11–12 April 2021	• severe category 3 tropical cyclone, impacted a 770 km stretch of coastline, affecting 16 local government areas, in particular the holiday towns of Kalbarri and Northampton—biggest disaster in WA history • no human lives lost, but significant building damage to 70% of all buildings in Kalbarri and Northampton, mostly lost roofs but also other structures destroyed (10% completely)—many of the damaged properties contained ACMs • a coordinated whole-of-government response led by the Department of Fire and Emergency Services (DFES) via the Seroja State Recovery Operations team, with additional support from the Australian Defence Force Army and Royal Australian Air Force • longer-term support by the State Recovery Coordination Group (made up of 23 additional agencies and partner organisations) and five Community Recovery Officers to support the impacted local governments • cleanup involved removal of large amounts of asbestos and DFES established a separate Asbestos Risk Management Division; an Asbestos Management Plan was developed in collaboration with the Department of Water and Environmental Regulation and the Department of Health, and contractors were engaged to execute the plan including atmospheric monitoring, identifying and securing asbestos-contaminated debris by the application of sealant to prevent the release of asbestos fibres, followed by removal and disposal • insurance claims of approximately $400 million dollars AUD
Flood	River Murray flood event Riverlands and Murraylands, SA November 2022 to January 2023	• a combination of wet weather events in northern states in the preceding months and years led to the highest river flows for some decades • a variety of ACMs in flood-affected residences and businesses, including older asbestos holiday shacks • South Australian State Emergency Services led the response and recovery efforts, with support from Green Industries SA (GISA; a statutory corporation of the Government of SA) • GISA appointed Johns Lyng Disaster Management Australia (a contractor) to coordinate the ongoing clean-up, including free asbestos removal, with more than 1100 tonnes of waste collected to date (April 2023) • approximately 4000 hectares of agricultural land and 4000 homes affected (10% primary residences)

Abbreviations—NSW: New South Wales; AUD: Australian dollars; SA: South Australia; WA: Western Australia.

Storms, cyclones and floods also lead to the damage and spread of asbestos material. The main concern with these disasters is also the contamination that will occur in the aftermath of the event and the risk of exposure during cleanup [54]. When these events occur, it is necessary to prevent homeowners and community members from entering properties to ascertain the extent of damage and salvage any remaining belongings before any emergency cleanup response is organised. This is because without sufficient awareness and knowledge of asbestos, and in haste to move on from the disaster or while waiting for organised support, personal cleanup efforts can include ad hoc removal and demolition of damaged building materials including asbestos, and the mixing of asbestos and non-asbestos waste. There is a risk of exposure to asbestos fibres for all people involved, especially without proper preparation (e.g., at minimum PPE such as disposable coveralls and gloves, a properly fitted class P2 respirator or P2 face mask, fully enclosed shoes without laces that can be easily cleaned or disposal shoe covers, protective eyewear). Furthermore, the removal or movement of damaged building materials and debris can extend the potential asbestos contamination boundaries (e.g., to waste facilities not licensed to accept asbestos).

Recent examples of different types of disaster and emergency events in Australia are presented in Table 2, contextualising the large-scale impact on different communities, government agencies and industry experts involved in the cleanups. In all instances, irrespective of the event type, relative scale or location; the presence of legacy asbestos significantly increased the recovery and remediation efforts, and entailed additional resources specifically for asbestos management. The approaches to asbestos management were tailored to suit the incidents, and involved multidisciplinary cooperation, with assistance required from across geographical boundaries, including interstate and even internationally. This highlights the significant socioeconomic costs associated with a reactive approach to managing legacy asbestos, which could be much improved if proactive action is given precedence. With the increasing frequency of such events, there has been an improved ability to mobilise and more efficiently accomplish the physical cleanup, but the post-disaster impact involves a long-term recovery process that often takes years and given the latency of asbestos-related disease onset [42], the consequences of any asbestos exposure will not be known for some time.

4.5. Contaminated Sites

All of the above can lead to soil contamination and expensive cleanup. Contamination of soil can also result from former asbestos factory sites and surrounding areas (e.g., the James Hardie legacy sites across Australia, e.g., [69]); former asbestos mines, shipping and railyards; or from historical waste burial either within landfills or as infill, prior to the regulation of asbestos. Asbestos contamination can present an ongoing exposure risk beyond the initial activity if its presence is unknown and sites are disturbed, e.g., during redevelopment activities. It does not necessarily pose a risk to human health or the environment if the sites are identified as asbestos-contaminated early, the contamination is inaccessible and undisturbed, or effective asbestos management plans are put in place (e.g., memorial on title and restriction of site uses).

The cost of remediation of contaminated soil can be hundreds of thousands of dollars [34], up to an order of magnitude higher for former industrial sites, can take many months to complete, and unnecessarily creates tonnes of hazardous waste that needs to be disposed of at licensed waste facilities.

Environment protection laws dealing with contaminated land are designed to manage risks to human health and to the environment. These laws differ in the states and territories across Australia, however, the main factors that need to be considered for site contamination are:

- the amount of asbestos in soil
- how exposure to airborne asbestos may occur
- the risk of material or serious environmental harm, as defined in the relevant environment protection law.

Except in Victoria, environment protection laws rely on the health screening levels (HSL) for asbestos in the National Environment Protection (Assessment of Site Contamination) Measure 1999 (the ASC NEPM; [70]) to assist land users in determining if action is required under environmental regulations. In Victoria, the obligation to report contamination is triggered where a person is, or is likely to be, exposed to airborne asbestos fibre levels of above 0.01 f/mL by means of inhalation.

The ASC NEPM is based on guidance material developed and recently updated by the WA government—Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia [71]. Asbestos is a common reason for a site to be officially classified as contaminated. For example, in WA in 2019, there were 2346 classified contaminated sites and in over 50% of sites, asbestos was present (unpublished; Otness and Franklin).

The human health risk from asbestos-contaminated soil varies depending on the form of asbestos (friable or non-friable), the fibre type (crocidolite, amosite or chrysotile—noting all asbestos fibre types cause debilitating and fatal diseases including asbestosis, lung cancer, mesothelioma, and cancers of the larynx and ovary [1,72]), its quantity, and the exposure situation, for example, the type and level of activity on the contaminated land.

Contaminant asbestos can be in a range of forms, sizes, and degrees of deterioration and includes: bonded, non-friable ACM that may be in sound condition, although possibly broken or fragmented; fibrous asbestos (FA), which is friable asbestos material in origin or material that has become friable; and asbestos fines (AF), which is smaller sized non-friable and friable material including free fibres of asbestos, small fibre bundles and small fragments of debris. Different HSL apply depending on the form of asbestos and the land-use (i.e., residential, recreational, commercial or industrial) [70,71]. The need to report contamination under environmental regulation and take action is based on the likelihood of exposure, not just soil concentrations. Remediation includes in situ management, asbestos removal or removal of the soil, depending on the nature of the contamination, the depth and spread of contamination and the potential for exposure for current and future land-uses.

As asbestos is a banned and controlled substance, management may be required even where there is no increased potential risk to human health. For minor contamination that does not require reporting under environmental regulation, contamination may still need to be managed to be compliant with jurisdictional WHS and public health legislation.

5. Framework for National Action to Prevent Asbestos Exposure

The Australian Government Asbestos Safety and Eradication Agency (ASEA) was set up in 2013 [73] following a 2012 whole-of-government review (The Asbestos Management Review) that recommended urgent, systematic, nationwide action was needed to deal with Australia's asbestos legacy and that a national strategic plan would be an appropriate tool to focus and coordinate asbestos-related actions by governments across Australia [74]. It also recommended a staged removal of all ACMs from government and commercial buildings by 2030. The newly formed Asbestos Safety and Eradication Agency developed the National Strategic Plan for Asbestos Management and Awareness 2014–2018 (i.e., the first phase Asbestos National Strategic Plan) [75], which incorporated a number of recommendations of the 2012 Asbestos Management Review [74].

This first phase Asbestos National Strategic Plan was focused on building an evidence base to inform future actions. It included extensive research to identify gaps in knowledge, challenges in asbestos management and removal, as well as best practice approaches. Annual progress reports were published which detailed the activities undertaken by governments during this period [76–78]. A final evaluation identified opportunities for greater collaboration and that a clearer articulation of the roles and responsibilities was needed, with more targeted actions to demonstrate commitment and accountability [79].

The second phase plan (the 2019–2023 Asbestos National Strategic Plan) was developed taking into account the lessons learned from the first phase, but with a stronger focus placed on risk-based asbestos removal. 'Prioritised' removal involves the planned, staged removal of ACMs based on the level of risk that the material poses, as opposed to only removing the ACM once it has become damaged or when a property is refurbished or renovated. This is consistent with duties under WHS laws which require duty holders to work through a hierarchy of control when managing risk (see Figure 4). Specifically, the most effective and reliable level of protection is to eliminate the hazard (i.e., airborne asbestos fibres) and this must be considered first. The lowest level of protection involves minimising exposure by using administrative controls (i.e., asbestos warning labels and asbestos registers) or personal protective equipment. Proactive and planned removal is the most effective control to eliminate the risk of asbestos exposure. Strategic actions of the second phase Asbestos National Strategic Plan required all jurisdictions to have schedules and processes for the prioritised safe removal and safe disposal of ACMs from public buildings and infrastructure [52].

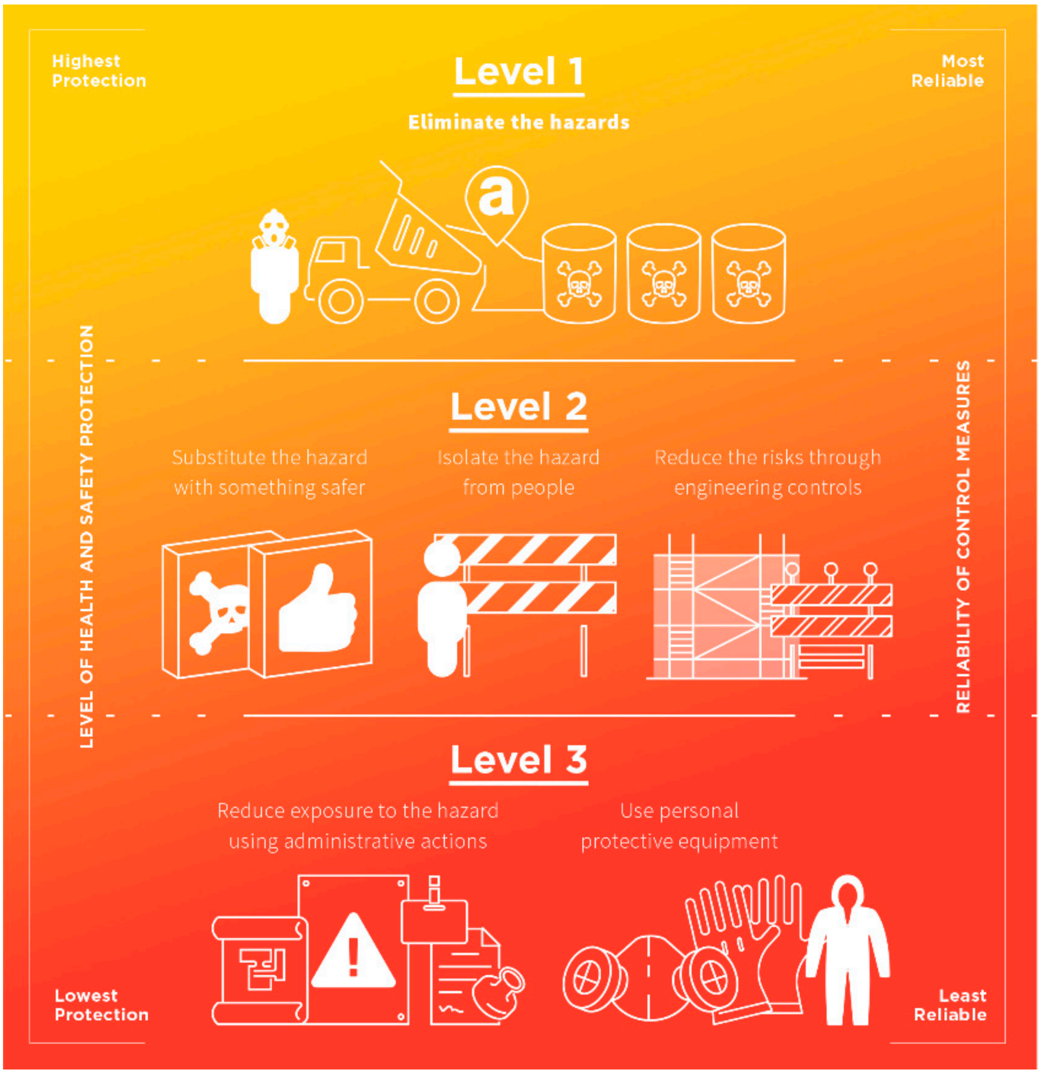


Figure 4. Hierarchy of controls for asbestos hazards. [Image courtesy of the Victorian Asbestos Eradication Agency or VAEA].

There are a number of reasons why the third phase of the Asbestos National Strategic Plan needs to focus on proactive asbestos removal options—not only in public buildings and infrastructure, but also in the commercial and residential sectors.

As outlined above, the increasing frequency and intensity of disaster events in Australia is also increasing the risk of exposure to asbestos fibres as ACMs become damaged during these events [80]. The subsequent cleanup is more dangerous, time-consuming and costly, regardless of how well the ACM was maintained. Earlier research examining the return on investment to support safe prioritised asbestos removal noted 'a median 20% cost difference between planned asbestos removal and urgent removal of asbestos, indicating significant cost savings if early intervention occurs against unplanned and accordingly urgent removal' [81]. More chronic climate change factors (e.g., temperature and humidity extremes) may also increase the rate of deterioration of existing asbestos-containing infrastructure in Australia and, therefore, shift more ACMs to waste flows sooner [80], than what might otherwise be expected to occur passively [9].

In addition to the health risks of potential exposure to asbestos fibres if ACM is deteriorating, disturbed or damaged, leaving ACMs in place in the built environment is not cost-free. For workplaces, the costs of in situ management include regular inspections to monitor ACM condition; ongoing treating and maintaining ACMs (e.g., sealing or encapsulating [82]); as well as retaining and updating asbestos registers and management plans to comply with WHS laws [83]. Investment in the proactive removal of ACMs will help to alleviate ongoing assessment requirements, resulting in net operating benefits. Conversely, maintaining ACMs such as cement sheeting by encapsulating or over-cladding rather than removing, can additionally create further asbestos exposure risks [84].

Furthermore, ACMs that remain in situ continue to present a liability for all property owners, whether they be residential, commercial or government property owners. In the case of commercial and government property owners, McGregor et al. (2021) note that 'entities in both public and private sectors are failing to recognise or appropriately measure liabilities related to asbestos and that the implications of asbestos for assets and expenses in financial statements are rarely reported'. The authors conclude that 'Good governance requires a much more proactive stance to identify objectively whether exposure exists and to document processes employed in that identification. Implicit in this is that exposure extends beyond existing and known civil claims for compensation for asbestos exposure, to include the removal of asbestos and the restoration and rehabilitation of associated assets [85]. In the commercial sector, the timing of asbestos removal has been shown to play a significant role in the property's value [86].

Large-scale removal, however, requires careful planning and industry preparation. In a report by Australia's National Science Agency, the CSIRO [80], it was observed that 'as asbestos in the built environment continues to age the nature of work with asbestos will need to shift from managing in-situ to removal and disposal' and that there is 'potential for the rate of removal to increase beyond the industry's capacity to manage, posing a risk of exposure to untrained workers, as well as renovators and the wider community. There is a need to ensure that the availability of skilled workers grows in parallel with the need to remove ageing asbestos. These issues are not insurmountable, as evidenced by programs of prioritised asbestos removal from Victorian government buildings by the Victorian School Building Authority (VSBA) and the Victorian Asbestos Eradication Agency (VAEA). In 2015 the VSBA inspected 1712 government school sites and found high-risk asbestos at 497 schools and by 2016, removed all high-risk asbestos. By the end of 2020, the VSBA had removed asbestos which might pose a future risk from 1287 schools [87]. The VAEA has developed and begun to execute a long-term plan for the removal of ACMs from government-owned buildings [88].

Another example of a large-scale government-funded asbestos removal program is the ACT Government's Loose Fill Asbestos Insulation Eradication Scheme [89]. It was designed to address asbestos exposure arising from 'Mr Fluffy'—the commonly used name for the friable asbestos insulation material installed between 1968 and 1979 in more than 1000 homes across Canberra and the surrounding region. Between 1989 and 1993 the Commonwealth and ACT Governments undertook a jointly funded program to remove visible and accessible loose-fill asbestos insulation from affected homes, but this program failed to remove all loose-fill asbestos insulation. In 2014 the ACT Government determined that demolition of houses affected by loose fill asbestos insulation was the only enduring solution to the health risks as well as the social, practical and financial consequences being faced by owners of affected properties. The Asbestos Response Taskforce was established to deliver and manage the Loose Fill Asbestos Insulation Eradication Scheme from 25 June 2014 through to 30 June 2022. Supported by a $1 billion loan from the Australian Government, the Scheme involved a voluntary buyback and demolition program of affected Canberra homes. Of the 1048 properties identified as affected by loose-fill asbestos insulation, 1020 properties have been demolished (as of 30 June 2022) [90].

Asbestos removal and disposal work across Australia is regulated by both WHS and environment protection regulators. Asbestos removal work requires licensing, supervision, notification to WHS regulators and the issue of an independent clearance certificate to confirm an area is safe to re-enter once work has been completed. These requirements reduce the risk of untrained or inexperienced operators entering the industry. The licensed asbestos removal and disposal industry have demonstrated the resilience and capacity to accommodate changes and fluctuations in asbestos removal demand in response to prioritised removal programs, as well as cleanup of asbestos-contaminated waste after fires, floods and cyclones [91].

There are a range of human health and environmental benefits to be derived from proactive asbestos removal, which will be explored in greater detail in the third phase of the Asbestos National Strategic Plan. Past, present and key actions of the Asbestos National Strategic Plan are summarised in Figure 5, showing the transition from passive efforts and knowledge gathering, to inform the current and future shift into prioritised and proactive asbestos removal.

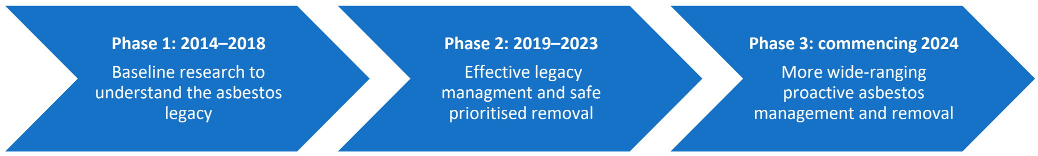


Figure 5. A summary of the key actions of the 3 phases of the Australian Government Asbestos National Strategic Plan.

6. Case Studies

The following case studies describe how specific legacy ACMs (i.e., asbestos cement roofs and pipes) still remaining in situ in Australia pose an asbestos exposure risk to the public or those tasked with their ongoing management.

6.1. Asbestos Cement Roofs

Asbestos cement roofing represented approximately 2% of the 13 million tonnes of ACMs that were dispersed in the Australian built environment [9]. In a small-scale proof-of-concept study, different remote sensing imageries, combined with advanced analytics, machine learning (ML) and AI, were used to detect asbestos cement roofing in the Australian built environment [92]. Over 23,000 tonnes or nearly 1.5 million m^2 of asbestos cement roofing was detected in targeted study localities covering 770 km^2 of the Australian residential build environment, pointing to the need for planning and action in these hotspots [unpublished; ASEA].

Although asbestos cement roofing represents a smaller share of the overall residential asbestos legacy, it poses a disproportionately higher public health risk. The risk factors related to asbestos cement roofing that contribute significantly to the potential for asbestos exposure are:

- Age—Most existing roofs are beyond their product life. An aged asbestos cement roof is prone to increased structural weakness due to physical changes. Sheet thickness has been estimated to reduce with degradation at a rate of 0.01–0.02 mm/year [93], making it weak and brittle and therefore prone to collapse from forces such as walking on it during maintenance or removal or other forces such as strong winds, hail or falling branches from overhanging trees. Weakened roofs can also shatter explosively in fires, causing widespread contamination of surrounding areas [20,94].
- Maintenance—Roofs are much harder to maintain than wall cladding, making upkeep more costly and likely not done adequately or appropriately. Contaminated run-off of asbestos fibres into gutters, stormwater systems or the surrounding ground surface can occur without maintenance (e.g., due to the action of rain), and more widespread contamination arises from illegal maintenance practices. Potential asbestos stabilisation practices such as encapsulation add additional load to a roof and are only suitable if the underlying structure and supporting systems are also in good condition, making repetitive applications unviable [82]. Conversely, illegal high-pressure cleaning of asbestos cement roofs is a large problem for regulators and other government agencies tasked with managing the emergency response [95–98].
- Weathering—By virtue of its position, roofing is more exposed than other outdoor products to the effects of sun, rain, wind, hail, air pollution and salt. Asbestos cement

roofs can also be damaged by moss/lichen growth. Surface degradation exposing an asbestos-enriched layer can occur, resulting in fibre release in the range of 10^6 to 10^8 fibres/$m^2 \cdot h$ [16,94]. The fibres not only become airborne (approximately 20% dispersed to air) but can also be washed out by rainwater (approximately 80%) resulting in soil contamination [21,87].

- Disaster events—Contamination from asbestos cement roof destruction can be widespread, and unforeseen costs after such events are higher than for planned removal. This includes the cost of a new roof; cleaning and disposal of the asbestos-impacted soils and other contaminated materials in the surrounding areas; as well as additional inspection, sampling and validation required for clearance certificates to confirm that the remediation has been undertaken appropriately.
- Incident management—Asbestos cement roof incidents and non-compliant management and removal work burden asbestos waste facilities with increased waste volumes arising from asbestos-contaminated materials. This poses an increased exposure risk and overall cost to the general community and the asbestos professionals tasked with the cleanup, in the immediate vicinity and beyond, as the higher volume of contaminated waste (now including more debris than just whole pieces of asbestos) needs to be safely collected, transported and disposed.
- Effect of innovation—Increased domestic uptake of products such as rooftop solar, rainwater tanks and satellite dishes are incompatible with an asbestos cement roof. The roof building material and condition upon which such systems are installed are not always considered, despite code of practices issued from regulatory bodies suggesting otherwise. The additional load, ongoing maintenance and repair work, and operation can result in non-compliant activity and elevate asbestos exposure risk to homeowners, workers and the general community even further. Internationally, planned initiatives to improve asbestos management (i.e., proactively remove it) are linked with the transition to sustainable environmental practices (e.g., in the EU [27,99–101]).

6.2. Asbestos Cement (AC) Pipes

Asbestos cement (AC) pipes represented approximately 34% of the 13 million tonnes of ACMs that were used in the Australian built environment [9]. In 2018, it was estimated that 40,000 km remained in situ across Australia and that 90% would need remediation or replacement by 2033 [102]. While many of these AC pipes remain in use, as they near the end of their usable lifespan (estimated to be 60–80 years), the focus now turns to management of these assets in ways that eliminate or minimises the release of asbestos fibres. A collaboration between ASEA and representatives from industry, state and territory WHS regulators, environment protection regulators and trade unions resulted in best practice guidelines being developed, to assist water and/or sewerage service providers in eliminating or minimising the risk of exposure to asbestos fibres released from AC pipes [103].

In managing AC pipes, particular challenges arise when ageing pipes fail or leak, as water and sewerage service providers (water agencies) must take remedial action while maintaining undisrupted water and sewer service delivery to the community. Current and emerging technologies for AC pipe removal and remediation enable safe and sustainable management of this infrastructure. AC pipes that are decommissioned but remain in situ require ongoing monitoring and management to prevent future exposure.

There are various methods for managing AC water and sewer pipes that are compliant with WHS and environment protection laws, some of which involve managing pipes in situ. Figure 6 shows the common management methods in a hierarchy, based on how effective the method is for eliminating or minimising exposure to airborne asbestos fibres while the work is being carried out and for any future work on that site. Options include:

- Removal and replacement—This represents the only AC pipe management method that completely eliminates future asbestos exposure risks at the site. A new pipe can be laid in the trench from which the AC pipe has been removed. This is the most expensive AC pipe rehabilitation option, as full excavation is required and asbestos must be removed, transported and buried at an approved waste facility in accordance with WHS and environment protection laws.

- By-passing and construction of a new alignment—This represents the most common approach used and involves making an AC pipe section redundant by disconnecting it and installing a brand-new service pipeline alongside. The redundant AC pipe section remains buried in situ and although decommissioned, it remains the responsibility of the water agency to manage the risks associated with it (e.g., including it in an asbestos register and management plan, as well as recording it in all asset information requests).
- Slip-lining and curing-in-place pipe lining—Involves using plant to pull through a smaller diameter pipe inside the existing AC pipe or lining an existing AC pipe with a resin-saturated fabric tube to extend the life of water and sewer assets. The Water Services Association of Australia (WSAA) is a key industry body in Australia and has worked in collaboration with researchers from Australian universities on the Smart Linings for Pipe and Infrastructure project to produce standards, codes of practice and decision tools on the use of pipe liners.
- Pipe reaming—Involves pumping drilling fluid into the existing AC pipe and as the reaming tool attaches, the new pipe comes forward and the existing pipe is broken. The pipe fragments of the redundant AC pipe are captured in the drilling fluid along with some of the soil. This asbestos waste is then flushed down stream to a receiving pit where it is collected. It must all be disposed of as asbestos waste in accordance with WHS and environmental protection laws.
- Pipe bursting or splitting—Involves machinery that is pushed up the AC pipe section to expand, split or break the pipe, creating a cavity for a replacement pipe to be inserted into the void. A disadvantage is that removing all the fragments of the AC pipe from the surrounding soil is difficult to achieve with current technologies, and generally requires excavation, remediation, and validation by sampling to meet cleanup requirements. This method is only chosen if no other methods are reasonably practicable, as there are significant regulatory requirements.

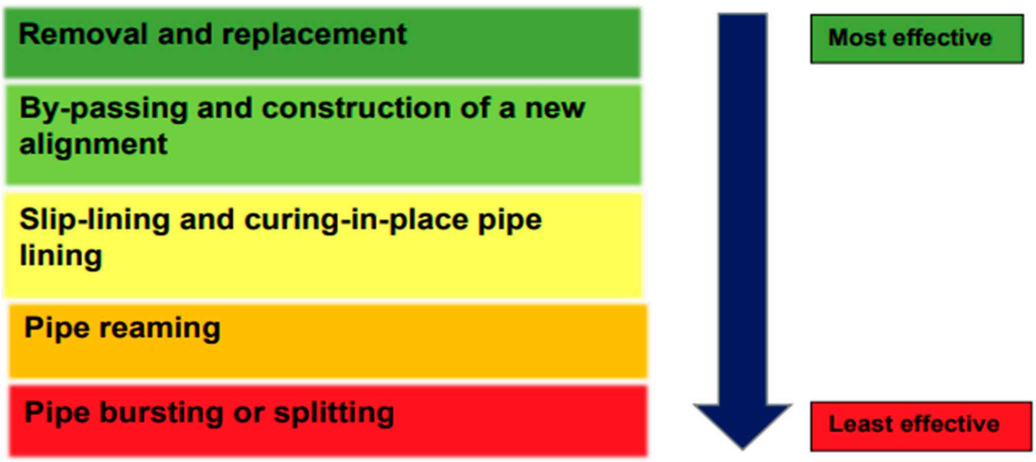


Figure 6. Hierarchy of AC pipe management methods.

Alongside the above measures, new trenchless methods (i.e., methods that do not require the digging of trenches to remove AC pipe) for both managing decommissioned AC pipes and rehabilitating ageing AC pipes so they can continue to be used are currently being explored. These include pipe pull and split processes, in situ encapsulation of broken AC pipe, lining by die reduction and spirally wound unplasticised polyvinylchloride techniques [92].

7. Conclusions

It has been almost 20 years since Australia completely banned the importation, supply and use of asbestos, but its legacy lives on not only in our workplaces but also in our homes and the environment. The fervent use of asbestos products for over 100 years and their purported longevity means they are still widespread in the built environment and without proactive intervention, are likely to remain there for many more years. This does not include the unknown asbestos contamination that may also exist, for which eradication may never be possible, such as for buried material managed in situ (including land development over former approved waste facilities).

The risk posed by in situ asbestos still in use is hard to quantify but there is evidence that activities such as renovation and removal can cause short-term high-level exposure to asbestos fibres if not undertaken safely. This presents a risk of asbestos-related disease, particularly mesothelioma, in an expanded proportion of the population.

Our understanding of the risk of asbestos-related disease from long-term low-level or background exposure that could occur from the scenarios described in this article, however, is poor. What is known is that the number of people exposed to in situ asbestos in Australia is probably very large. Therefore, we need to improve our understanding of the disease risks associated with exposure to non-workplace sources of asbestos. Specifically, we need more information about exposure levels, including ambient levels in the general community and from activities that are likely to release airborne fibres above ambient levels. We also need to keep filling our knowledge gaps of the history of Australia's ACM use and how it differed across the country, to inform and take advantage of emerging technologies that model where we might expect ACMs to remain and in what quantities.

As well as the targeted asbestos cement roof pilot study already undertaken (see Section 6.1), ML and AI have also been used to develop a national-scale residential asbestos heatmap for Australia. This has mapped the probability of asbestos presence by geographic area, with the use of limited asbestos data combined with publicly available predictor variables [unpublished; ASEA]. Both these pieces of research form a significant program of work implementing Target 9 of the 2019–2023 Asbestos National Strategic Plan [51]. Furthermore, this research has been undertaken to facilitate the commencement and ongoing complex management required of asbestos in different segments of the built environment. However, continued efforts in the form of upscaling, updating and practical use of such research are now needed to better plan how to appropriately manage the asbestos exposure risk now and into the future.

Few epidemiological studies or clinical reports with supporting environmental data are available in the low-level exposure range that must be considered for current and future exposure risks. A strategic approach is needed, involving toxicology, geology, exposure assessment, epidemiology and analytical professionals in developing a more sensitive standardised air sampling method to improve data collection for low-level exposure, and report on fibre morphology distributions in samples. The collection of good-quality exposure data will provide information that can be used to address outstanding questions. This would not prohibit PCM equivalent fibre concentration from continuing to be calculated and reported against current regulatory exposure standards. Instead, additional data and research may lead to a review of the Australian workplace exposure standard.

Knowledge on contemporary exposure scenarios is needed to better understand the exposure-response relationship between low-dose asbestos exposure and the future burden of asbestos-related disease. This will provide insight into how to apply sustainable and proportionate management of the remaining in situ asbestos in Australia, including proactive asbestos removal. The coordinated approach to asbestos management in Australia, which has been ongoing for nearly 10 years, has made significant advancement towards these efforts but will be required for years to come.

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References

1. International Agency for Research on Cancer (IARC). Arsenic, Metals, Fibres and Dusts. Monographs on the Evaluation of Carcinogenic Risks to Humans Volume 100C: Asbestos (Chrysotile, Amosite, Crocidolite, Tremolite, Actinolite and Anthophyllite). 2012. Available online: http://publications.iarc.fr/120 (accessed on 12 January 2023).
2. Australian Government, Safe Work Australia. Model Code of Practice: Construction Work. 2018. Available online: https://www.safeworkaustralia.gov.au/doc/model-codes-practice/model-code-practice-construction-work (accessed on 12 January 2023).
3. Noonan, C.W. Environmental asbestos exposure and risk of mesothelioma. *Ann. Transl. Med.* **2017**, *5*, 234. [CrossRef]
4. Park, E.-K.; Yates, D.H.; Hyland, R.A.; Johnson, A.R. Asbestos exposure during home renovation in New South Wales. *Med. J. Aust.* **2013**, *199*, 410–413. [CrossRef] [PubMed]
5. Australian Government, Asbestos Safety and Eradication Agency (ASEA); SEC Newgate Research. DIY Home Renovations Research. 2020. Available online: https://www.asbestossafety.gov.au/research-publications/newgate-diy-covid-research (accessed on 12 January 2023).
6. Australian Government, ASEA; SEC Newgate Research. Asbestos Safety and Home Improvement Research—Quantitative Survey. 2021. Available online: https://www.asbestossafety.gov.au/sites/default/files/documents/2021-11/2021%20Home%20Improvement%20Survey%20-%20Report%20-%20Newgate%20-%20November%202021.PDF (accessed on 12 January 2023).
7. Australian Government, ASEA; ThinkPlace. Asbestos Safety and Home Improvement Research—Qualitative Interviews and Focus Groups. 2021. Available online: https://www.asbestossafety.gov.au/sites/default/files/documents/2022-02/2021%20Home%20Improvement%20Qualitative%20Research%20-%20Report%20-%20December%202021_0.PDF (accessed on 12 January 2023).
8. Khamhing, K.; McArdle, S.; Ross, J. Awareness and Profiling of High-Risk Asbestos Exposure Groups in Australia. *Sustainability* **2023**, *15*, 5806. [CrossRef]
9. Brown, B.; Hollins, I.; Pickin, J.; Donovan, S. Asbestos Stocks and Flows Legacy in Australia. *Sustainability* **2023**, *15*, 2282. [CrossRef]
10. Australian Government, Australian Safety and Compensation Council. Literature Review of Asbestos Fibre Release from Building Materials Following Weathering and/or Corrosion. 2008. Available online: https://www.safeworkaustralia.gov.au/system/files/documents/1702/literaturereview_airborneasbestosfibres_2008_pdf.pdf (accessed on 12 January 2023).
11. Casali, M.; Carugno, M.; Cattaneo, A.; Consonni, D.; Mensi, C.; Genovese, U.; Cavallo, V.; Somigliana, A.; Pesatori, A.C. Asbestos lung burden in necroscopic samples from the general population of Milan, Italy. *Ann. Occup. Hyg.* **2015**, *59*, 909–921. [CrossRef]
12. Gilham, C.; Rake, C.; Burdett, G.; Nicholson, A.G.; Davison, L.; Franchini, A.; Carpenter, J.; Hodgson, J.; Darnton, A.; Peto, J. Pleural mesothelioma and lung cancer risks in relation to occupational history and asbestos lung burden. *Occup. Environ. Med.* **2016**, *73*, 290–299. [CrossRef]
13. Rath, E.M.; Yuen, M.L.; Odgerel, C.-O.; Lin, R.-O.; Soeberg, M.; Nowak, A.K.; Takahashi, K. The Ecological Association between Asbestos Consumption and Asbestos-Related Diseases 15 Years Later. *Environ. Health Perspect.* **2022**, *130*, 057703. [CrossRef] [PubMed]
14. Lee, R.J.; Van Orden, D.R. Airborne asbestos in buildings. *Regul. Toxicol. Pharmacol.* **2008**, *50*, 218–225. [CrossRef]
15. Bardsley, A. Asbestos Exposure in New Zealand: Review of the Scientific Evidence of Non-Occupational Risks. A Report on Behalf of the Royal Society of New Zealand and the Office of the Prime Minister's Chief Science Advisor. 2015. Available online: https://royalsociety.org.nz/assets/documents/Asbestos-exposure-in-New-Zealand-April-2015.pdf (accessed on 12 January 2023).
16. Brown, S.K. Asbestos. In *Indoor Air Quality Handbook*; Spengler, J.D., Samet, J.M., McCarthy, J.F., Eds.; McGraw-Hill Professional: New York, NY, USA, 2001; pp. 38.1–38.17.
17. Obminski, A. The natural reduction of threat in selected systems of old buildings containing asbestos. *Sci. Rep.* **2022**, *12*, 2580. [CrossRef]

18. Australian Government, ASEA. Asbestos Locations Diagram. 2022. Available online: https://www.asbestossafety.gov.au/find-out-about-asbestos/asbestos-home#where-can-asbestos-be-in-the-home (accessed on 12 January 2023).
19. International Programme on Chemical Safety & World Health Organization. Asbestos and Other Natural Mineral Fibres. *World Health Organization*. 1986. Available online: https://apps.who.int/iris/handle/10665/37190 (accessed on 12 January 2023).
20. Kottek, M.; Yuen, M.L. Public health risks from asbestos cement roofing. *Am. J. Ind. Med.* **2022**, *65*, 157–161. [CrossRef]
21. Eastern Research Group Inc. Report on the Expert Panel on Health Effects of Asbestos and Synthetic Vitreous Fibers: The Influence of Fiber Length. Prepared for the US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. 2003. Available online: https://www.atsdr.cdc.gov/hac/asbestospanel/finalpart1.pdf (accessed on 12 January 2023).
22. Berman, D.W.; Crump, K.S. A meta-analysis of asbestos-related cancer risk that addresses fiber size and mineral type. *Crit. Rev. Toxicol.* **2008**, *38* (Suppl. S1), 49–73. [CrossRef] [PubMed]
23. US Department of Health and Human Services; Centers for Disease Control and Prevention; National Institute for Occupational Safety and Health. Current Intelligence Bulletin 62—Asbestos Fibers and Other Elongate Mineral Particles: State of the Science and Roadmap for Research. 2011. Available online: https://www.cdc.gov/niosh/docs/2011-159/pdfs/2011-159.pdf (accessed on 12 January 2023).
24. European Chemicals Agency (ECHA); Committee for Risk Assessment (RAC). Opinion on Scientific Evaluation of Occupational Exposure Limits (OELs) for Asbestos. 2021. Available online: https://echa.europa.eu/rac-opinions-on-scientific-evaluations-of-oels (accessed on 12 January 2023).
25. European Commission. Proposal for a Directive of the European Parliament and of the Council Amending Directive 2009/148/EC on the Protection of Workers from the Risks Related to Exposure to Asbestos at Work. 2022. Available online: https://ec.europa.eu/social/main.jsp?langId=en&catId=89&furtherNews=yes&newsId=10418#navItem-relatedDocuments (accessed on 12 January 2023).
26. European Commission. Better Protection of Workers from Asbestos. Commission Welcomes Political Agreement to Revise EU Rules. 2023. Available online: https://ec.europa.eu/commission/presscorner/detail/en/IP_23_3557?utm_source=miragenews&utm_medium=miragenews&utm_campaign=news (accessed on 12 January 2023).
27. Proposal for a Directive of the European Parliament and of the Council on the Energy Performance of Buildings (Recast). 2021. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1641802763889 (accessed on 12 January 2023).
28. Australian Government, Safe Work Australia. Workplace Exposure Standards for Airborne Contaminants. 2022. Available online: https://www.safeworkaustralia.gov.au/doc/workplace-exposure-standards-airborne-contaminants-2022 (accessed on 12 January 2023).
29. Australian Government, Safe Work Australia. Model WHS Regulations. 2022. Available online: https://www.safeworkaustralia.gov.au/doc/model-whs-regulations (accessed on 12 January 2023).
30. National Occupational Health and Safety Commission. *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres*, 2nd ed.; [NOHSC:3003(2005)]; Australian Government: Canberra, Australia, 2005. Available online: https://www.safeworkaustralia.gov.au/sites/default/files/2021-11/guidancenote_membranefiltermethodforestimatingairborneasbestosfibres_2ndedition_nohsc3003-2005_pdf.pdf (accessed on 12 January 2023).
31. Berry, T.-A.; Belluso, E.; Vigliaturo, R.; Gieré, R.; Emmett, E.A.; Testa, J.R.; Steinhorn, G.; Wallis, S.L. Asbestos and Other Hazardous Fibrous Minerals: Potential Exposure Pathways and Associated Health Risks. *Int. J. Environ. Res. Public Health* **2022**, *19*, 4031. [CrossRef]
32. Victorian State Government, WorkSafe Victoria. Media Release December 2020. Available online: https://www.worksafe.vic.gov.au/news/2020-12/company-fined-after-unsafe-demolition (accessed on 12 January 2023).
33. Queensland Government, WorkSafe Queensland. Media Release November 2020. Available online: https://www.worksafe.qld.gov.au/news-and-events/news/2020/$16000-fine-for-dodgy-demolition-of-house-with-asbestos-containing-material (accessed on 12 January 2023).
34. Government of Western Australian (WA), Department of Health. Survey of Local Government and Other Regulators Experience with Asbestos Incidents in the Public Sector. 2011. Available online: https://ww2.health.wa.gov.au/Articles/A_E/About-asbestos (accessed on 12 January 2023).
35. Perkins, R.A.; Hargesheimer, J.; Fourie, W. Asbestos release from whole-building demolition of buildings with asbestos-containing material. *J. Occup. Environ. Hyg.* **2007**, *4*, 889–894. [CrossRef]
36. Brown, S.K. Asbestos exposure during renovation and demolition of asbestos-cement clad buildings. *Am. Ind. Hyg. Assoc. J.* **1987**, *48*, 478–486. [CrossRef]
37. Kakooei, H.; Meshkani, M.; Azam, K. Ambient monitoring of airborne asbestos in non-occupational environments in Tehran, Iran. *Atmos. Environ.* **2013**, *81*, 671–675. [CrossRef]
38. Landrigan, P.J. The third wave of asbestos disease: Exposure to asbestos in place. Public health control. Introduction. *Ann. N. Y. Acad. Sci.* **1991**, *643*, xv–xvi. [CrossRef]
39. Olsen, N.J.; Franklin, P.J.; Reid, A.; de Klerk, N.H.; Threlfall, T.J.; Shilkin, K.; Musk, B. Increasing incidence of malignant mesothelioma after exposure to asbestos during home maintenance and renovation. *Med. J. Aust.* **2011**, *195*, 271–274. [CrossRef] [PubMed]

40. Armstrong, B.; Driscoll, T. Mesothelioma in Australia: Cresting the third wave. *Public Health Res. Pract.* **2016**, *26*, 2621614. [CrossRef] [PubMed]
41. Australian Government; Australian Institute of Health and Welfare (AIHW). Australian Mesothelioma Registry (AMR) Annual Reports and Publications (2011–2020). Available online: https://mesothelioma-australia.com/publications-and-data/publications (accessed on 12 January 2023).
42. Mahoney, K.; Driscoll, T.; Collins, J.; Ross, J. The Past, Present and Future of Asbestos-Related Diseases in Australia: What Are the Data Telling Us? *Sustainability* **2023**, *15*, 8492. [CrossRef]
43. Australian Government, ASEA. National Benchmark Asbestos Awareness Survey. 2014. Available online: https://www.asbestossafety.gov.au/research-publications/national-benchmark-asbestos-awareness-survey-2014 (accessed on 12 January 2023).
44. Australian Government, ASEA. National Benchmark Survey of Awareness and Attitudes to Asbestos. 2016. Available online: https://www.asbestossafety.gov.au/research-publications/asbestos-safety-research/national-benchmark-survey-awareness-and-attitudes-asbestos-2016 (accessed on 12 January 2023).
45. Australian Government, ASEA. National Benchmark Survey of Awareness and Attitudes to Asbestos. 2018. Available online: https://www.asbestossafety.gov.au/research-publications/national-benchmark-survey-awareness-and-attitudes-asbestos-2018 (accessed on 12 January 2023).
46. Australian Government, ASEA. Measurement of Asbestos Fibre Release during Removal Works in a Variety of DIY Scenarios. 2016. Available online: https://www.asbestossafety.gov.au/research-publications/measurement-asbestos-fibre-release-during-removal-works-variety-diy-scenarios (accessed on 12 January 2023).
47. Australian Government, ASEA; ACIL Allen. Illegal Asbestos Dumping: Review of Issues and Initiatives—Discussion Paper. 2016. Available online: https://www.asbestossafety.gov.au/research-publications/illegal-asbestos-dumping-review-issues-and-initiatives-discussion-paper (accessed on 12 January 2023).
48. NSW State Government; Environment Protection Authority (EPA); Heartward Strategic. Social Research to Improve Asbestos Management—Asbestos Safety Part 2: Asbestos Waste. 2021. Available online: https://www.epa.nsw.gov.au/publications/asbestos/asbestos-safety-part-2-asbestos-waste (accessed on 12 January 2023).
49. NSW State Government. EPA—Media Release February 2020. Available online: https://www.epa.nsw.gov.au/news/media-releases/2020/epamedia200212-dont-be-misled-by-the-free-shed-epa-warns-residents-about-dirty-fill-deal (accessed on 12 January 2023).
50. Gray, C.; Carey, R.N.; Reid, A. Current and future risks of asbestos exposure in the Australian community. *Int. J. Occup. Environ. Health* **2016**, *22*, 292–299. [CrossRef]
51. Victorian State Government, Sustainability Victoria. Asbestos Disposal Management Plan. 2021. Available online: https://www.sustainability.vic.gov.au/about-us/our-mission/our-strategies/asbestos-disposal-management-plan (accessed on 12 January 2023).
52. Australian Government, ASEA. National Strategic Plan for Asbestos Awareness and Management 2019–2023. Available online: https://www.asbestossafety.gov.au/what-we-do/national-strategic-plan (accessed on 12 January 2023).
53. Frangioudakis Khatib, G.; Hollins, I.; Ross, J. Managing Asbestos Waste Using Technological Alternatives to Approved Deep Burial Landfill Methods: An Australian Perspective. *Sustainability* **2023**, *15*, 4066. [CrossRef]
54. Environmental Health Standing Committee (enHealth). *Management of Asbestos in the Non-Occupational Environment*; Environmental Health Standing Committee: Canberra, Australia, 2005.
55. Government of WA, Department of Health. Guidance Note on the Management of Fire Damaged Asbestos. 2015. Available online: https://www.agric.wa.gov.au/sites/gateway/files/Management%20of%20fire%20damaged%20asbestos.pdf (accessed on 12 January 2023).
56. Victorian State Government, Department of Human Services; Noel Arnold & Associates. Report on the Investigation of the Effect of Fire on Asbestos Fibre Contamination. 2006. Available online: https://www.health.vic.gov.au/publications/report-on-the-investigation-of-the-effect-of-fire-on-asbestos-fibre-contamination (accessed on 12 January 2023).
57. Bridgman, S. Community health risk assessment after a fire with asbestos containing fallout. *J. Epidemiol. Community Health* **2002**, *55*, 921–927. [CrossRef]
58. NSW State Government, EPA. NSW State of the Environment 2021 Report. 2021. Available online: https://www.soe.epa.nsw.gov.au/all-themes/land/fire (accessed on 18 April 2023).
59. Australian Government; National Emergency Management Agency; Australian Institute for Disaster Resilience. Bushfires. Black Summer, New South Wales, July 2019–March 2020. Available online: https://knowledge.aidr.org.au/resources/black-summer-bushfires-nsw-2019-20/ (accessed on 18 April 2023).
60. NSW State Government. NSW Bushfire Clean-Up Program. Available online: https://www.nsw.gov.au/regional-recovery-programs/bushfire-recovery/nsw-bushfire-clean-up-program (accessed on 18 April 2023).
61. O'Rourke, L. NSW Bushfire Clean-Up. Available online: https://www.laingorourke.com/projects/australia/nsw-bushfire-clean-up/ (accessed on 18 April 2023).
62. City of Newcastle Local Government. Wickham Fire Incident. Available online: https://newcastle.nsw.gov.au/about-us/news-and-updates/emergencies/wickham-fire-incident (accessed on 18 April 2023).

63. Newcastle Herald. Wickham Warehouse Fire. 2023. Available online: https://www.newcastleherald.com.au/story/8033442/landowner-pays-13m-bill-for-wickham-fire-clean-up/?src=rss (accessed on 18 April 2023).
64. Australian Government, Bureau of Meteorology. Severe Tropical Cyclone Seroja. Available online: http://www.bom.gov.au/cyclone/history/seroja.shtml (accessed on 18 April 2023).
65. Government of WA, Department of Fire and Emergency Services. Tropical Cyclone Seroja. Available online: https://www.dfes.wa.gov.au/annualreport2021/tropical-cyclone-seroja/ (accessed on 18 April 2023).
66. Australian Government; National Emergency Management Agency; Australian Institute for Disaster Resilience. Tropical Cyclone Seroja, Western Australia 11–12 April 2021. Available online: https://knowledge.aidr.org.au/resources/cyclone-tropical-cyclone-seroja-western-australia-2021/ (accessed on 18 April 2023).
67. South Australian State Emergency Service. River Murray Flood Information. 2022. Available online: https://www.ses.sa.gov.au/incidents-and-warnings/sases-2022-river-murray-flood-information/ (accessed on 18 April 2023).
68. Government of South Australia (SA), Green Industries SA. River Murray Region Floods 2022–2023. Available online: https://www.greenindustries.sa.gov.au/flood-disaster-waste-management (accessed on 18 April 2023).
69. James Hardie legacy Sites. Available online: https://www.cityofparramatta.nsw.gov.au/jh-sites (accessed on 12 January 2023).
70. Australian Government, National Environment Protection Council. National Environment Protection (Assessment of Site Contamination) Measure. 2013. Available online: http://www.nepc.gov.au/nepms/assessment-site-contamination (accessed on 12 January 2023).
71. Government of WA, Department of Health. Guidelines for the Assessment, Remediation and Management of Asbestos Contaminated Sites. 2021. Available online: https://ww2.health.wa.gov.au/Articles/A_E/Asbestos-contaminated-sites/Guidelines-asbestos-contaminated-sites (accessed on 12 January 2023).
72. World Health Organization (WHO). Chrysotile Asbestos. 2014. Available online: https://apps.who.int/iris/bitstream/handle/10665/143649/9789241564816_eng.pdf;jsessionid=F66052EB1D7FF84946BF5DBC13CEEB18?sequence=1 (accessed on 12 January 2023).
73. Asbestos Safety and Eradication Agency Act 2013. Available online: https://www.legislation.gov.au/Details/C2016C0041 (accessed on 12 January 2023).
74. Australian Government, Department of Education. Employment and Workplace Relations—Safety and Compensation Policy Branch. Asbestos Management Review: Report 2012. Available online: https://www.asbestossafety.gov.au/find-out-about-asbestos/asbestos-safety-information/brochures/asbestos-management-review-report (accessed on 12 January 2023).
75. Australian Government, ASEA. National Strategic Plan for Asbestos Management and Awareness 2014–2018. Available online: https://www.asbestossafety.gov.au/what-we-do/national-strategic-plan/National%20Strategic%20Plan%202014-2018 (accessed on 12 January 2023).
76. Australian Government, ASEA. National Strategic Plan for Asbestos Management and Awareness 2014–2018: Progress Report 2015–16. Available online: https://www.asbestossafety.gov.au/what-we-do/national-strategic-plan/national-strategic-plan-progress-report-2015-16 (accessed on 12 January 2023).
77. Australian Government, ASEA. National Strategic Plan for Asbestos Management and Awareness 2014–2018: Progress Report 2016–17. Available online: https://www.asbestossafety.gov.au/what-we-do/national-strategic-plan/national-strategic-plan-progress-report-2016-17 (accessed on 12 January 2023).
78. Australian Government, ASEA. National Strategic Plan for Asbestos Management and Awareness 2014–2018: Progress Report 2017–18. Available online: https://www.asbestossafety.gov.au/what-we-do/national-strategic-plan%20%20/National%20Strategic%20Plan%20Progress%20Report%202017-18 (accessed on 12 January 2023).
79. Australian Government, ASEA. National Strategic Plan for Asbestos Management and Awareness 2014–2018: Final Report. Available online: https://www.asbestossafety.gov.au/what-we-do/national-strategic-plan/National%20Strategic%20Plan%20for%20Asbestos%20Management%20and%20Awareness%202014%20-%202018%20Final%20Report (accessed on 12 January 2023).
80. Quezada, G.; Devaraj, D.; McLaughlin, J.; Hanson, R. *Asbestos Safety and Eradication Agency (ASEA) Report: Asbestos Safety Futures: Managing Risks and Embracing Opportunities for Australia's Asbestos Legacy in the Digital Age*; CSIRO: Canberra, Australia, 2018. Available online: https://www.asbestossafety.gov.au/research-publications/asbestos-safety-futures-report (accessed on 12 January 2023).
81. Australian Government. ASEA Report: Return on Investment to Enable Safe Prioritised Asbestos Removal in Australia. 2019. Available online: https://www.asbestossafety.gov.au/research-publications/return-investment-enable-safe-prioritised-asbestos-removal-australia (accessed on 12 January 2023).
82. Australian Government, ASEA; Sustainable Buildings Research Centre, University of Wollongong. A Review of Asbestos Stabilisation and Containment Practices. 2017. Available online: https://www.asbestossafety.gov.au/research-publications/review-asbestos-stabilisation-and-containment-practices-final-report (accessed on 12 January 2023).
83. Australian Government. ASEA Report: Case Studies of Significant Asbestos Removal Projects. 2018. Available online: https://www.asbestossafety.gov.au/research-publications/case-studies-significant-asbestos-removal (accessed on 12 January 2023).
84. NSW State Government. SafeWork NSW—Position Paper: Cladding over Asbestos Containing Materials. Available online: https://www.safework.nsw.gov.au/resource-library/asbestos-publications/position-paper-cladding-over-asbestos-containing-materials (accessed on 12 January 2023).

85. McGregor, W.; Potter, B.; Soderstrom, N.; Stevenson, K. Asbestos Contamination: Governance and Financial Reporting Issues in the Public, Private and Not-for-profit Sectors. *Aust. Account. Rev.* **2021**, *31*, 307–320. [CrossRef]
86. Fisher, J.D.; Lentz, G.H.; Tse, K.S.M. Valuation of the Effects of Asbestos on Commercial Real Estate. *J. Real Estate Res.* **1992**, *7*, 331–350. Available online: https://econpapers.repec.org/article/jreissued/v_3a7_3an_3a3_3a1992_3ap_3a331-350.htm (accessed on 12 January 2023). [CrossRef]
87. Victorian State Government; Victorian School Building Authority (VSBA). Asbestos Safety Program in Schools. Available online: https://www.schoolbuildings.vic.gov.au/asbestos-safety-program (accessed on 12 January 2023).
88. Stevenson, S.P.; Barron, O.; Pakenham, A.; Hashinaka, M. Understanding and Ending the Lethal Asbestos Legacy. *Sustainability* **2023**, *15*, 2507. [CrossRef]
89. ACT Government. Asbestos Response Taskforce Report—Long Term Management of Loose Fill Asbestos Insulation in Canberra Homes. 2014. Available online: https://www.loosefillasbestos.act.gov.au/__data/assets/pdf_file/0007/2014828/Long-term-management-of-loose-fill-asbestos-insulation-in-canberra-homes.pdf (accessed on 12 January 2023).
90. ACT Government. Asbestos Response Taskforce Report—Implementation of the Loose Fill Asbestos Insulation Eradication Scheme (1 January—30 June 2022), Presented the Legislative Assembly for The Australian Capital Territory Tenth Assembly. Available online: https://www.parliament.act.gov.au/__data/assets/pdf_file/0006/2063562/Implementation-of-the-Loose-Fill-Asbestos-Insulation-Eradication-Scheme-1-January-30-June-2022-Half-Yearly-Report.pdf (accessed on 12 January 2023).
91. IBISWorld Industry Research Reports Australia—Waste Remediation and Materials Recovery Services in Australia: Market Research Reports. 2022. Available online: https://www.ibisworld.com/au/industry/waste-remediation-materials-recovery-services/5025/ (accessed on 12 January 2023).
92. Hikuwai, M.V.; Patorniti, N.; Vieira, A.S.; Frangioudakis Khatib, G.; Stewart, R.A. Artificial Intelligence for the Detection of Asbestos Cement Roofing: An Investigation of Multi-Spectral Satellite Imagery and High-Resolution Aerial Imagery. *Sustainability* **2023**, *15*, 4276. [CrossRef]
93. Spurny, K.R. On the release of asbestos fibers from weathered and corroded asbestos cement products. *Environ. Res.* **1989**, *48*, 100–116. [CrossRef]
94. Government of WA, Department of Health. Guidance Note on Asbestos Cement Roofs. 2016. Available online: https://ww2.health.wa.gov.au/-/media/Files/Corporate/general-documents/Asbestos/PDF/GuidanceNoteonAsbestosCementRoofs20162-1.pdf (accessed on 12 January 2023).
95. NSW State Government. SafeWork NSW—Safety Alert. Pressure Cleaning of Asbestos Roofs Safety Alert. 2017. Available online: https://www.safework.nsw.gov.au/safety-alerts/safety-alerts/pressure-cleaning-of-asbestos-roofs#:~:text=In%20April%202017%2C%20a%20contractor,of%20inhaling%20airborne%20asbestos%20fibres (accessed on 12 January 2023).
96. Government of WA, Department of Mines. Industry Regulation and Safety—Safety Alert 12/2018. High Pressure Water Cleaning of Asbestos Cement Prohibited. Available online: https://www.commerce.wa.gov.au/publications/safety-alert-122018-high-pressure-water-cleaning-asbestos-cement-prohibited (accessed on 12 January 2023).
97. Queensland Government, WorkSafe Queensland. Alert. High Pressure Water Spray on Asbestos Roof. 2018. Available online: https://www.worksafe.qld.gov.au/news-and-events/alerts/incident-alerts/2018/high-pressure-water-spray-on-asbestos-roof (accessed on 12 January 2023).
98. Government of SA, SafeWork SA. Safety Alert. High-Pressure Cleaning Leads to Asbestos Contamination. 2023. Available online: https://www.safework.sa.gov.au/news-and-alerts/safety-alerts/incident-alerts/2023/high-pressure-cleaning-leads-to-asbestos-contamination (accessed on 12 January 2023).
99. European Commission. Questions and Answers: Towards an Asbestos-Free Future. 2022. Available online: https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_5678 (accessed on 12 January 2023).
100. European Commission. European Green Deal. 2020. Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 12 January 2023).
101. European Commission. Renovation Wave Strategy. 2020. Available online: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1835 (accessed on 12 January 2023).
102. Australian Government, ASEA. Case Studies of Asbestos Water Pipe Management Practices. 2018. Available online: https://www.asbestossafety.gov.au/research-publications/asbestos-cement-water-and-sewer-pipe-management-case-studies (accessed on 12 January 2023).
103. Australian Government, ASEA. Asbestos-Cement Water and Sewer Pipe Management Guidelines. 2022. Available online: https://www.asbestossafety.gov.au/research-publications/asbestos-cement-water-and-sewer-pipe-management-guidelines (accessed on 12 January 2023).