sustainability

MDPI

Review

Mitigation of Contamination and Health Risk: Asbestos Management and Regulatory Practices

Achyut Aryal [1,2,3,4,*] and Craig Morley [5]

[1] AKA Education Group, Auckland College of Tertiary Studies, Auckland 1010, New Zealand
[2] Institute of Forestry, Tribhuvan University, Kathmandu 40618, Nepal
[3] Centre for Compassionate Conservation, TD School, University of Technology Sydney, Sydney, NSW 2007, Australia
[4] AGI Education, Auckland 1010, New Zealand
[5] Toi Ohomai Institute of Technology, Marine and Environmental Management, Mokoia Campus, Rotorua 3015, New Zealand; craig.morley@toiohomai.ac.nz
* Correspondence: achyut.aryal@aka.ac.nz or savefauna@gmail.com or achyut.aryal@uts.edu.au

Abstract: Asbestos is a naturally occurring mineral renowned for its exceptional tensile strength, chemical resistance, and low thermal and electrical conductivity. Due to these properties, it has been widely used in various industries. However, asbestos exposure is strongly linked to severe health conditions, including lung cancer, mesothelioma, and asbestosis. Although over 70 countries have banned asbestos-containing materials, significant health risks persist due to ongoing use and poor management practices in many regions. To mitigate these risks, robust occupational health measures are essential. These include safe removal protocols, comprehensive worker training, proper use of personal protective equipment (PPE), regular exposure monitoring, rigorous compliance checks, and severe penalties for non-compliance. Moreover, effective asbestos waste management and the development of advanced disposal technologies are essential to reducing risks. Public awareness campaigns, regulatory enforcement, and a global ban on asbestos production, use, and export are also necessary, particularly in countries where asbestos is still in use. Lessons from asbestos management in Australia and New Zealand provide valuable insights for nations currently dealing with asbestos issues. This paper reviews current practices in asbestos surveying, removal, and disposal, comparing them to the stringent regulatory frameworks in Australia and New Zealand. It highlights strategies that can be adopted globally to ensure safer management and complete elimination of asbestos.

Keywords: New Zealand; Australia; health-asbestos-related diseases; construction; asbestos; asbestos management; survey; regulatory impact

check for updates

Citation: Aryal, A.; Morley, C. Mitigation of Contamination and Health Risk: Asbestos Management and Regulatory Practices. *Sustainability* **2024**, *16*, 9740. https://doi.org/10.3390/su16229740

Academic Editors: Lotfi Aleya and Wen-Hsien Tsai

Received: 13 September 2024
Revised: 30 October 2024
Accepted: 4 November 2024
Published: 8 November 2024

1. Introduction

Asbestos is a naturally occurring mineral that has long been valued for its versatility in construction and textiles. Its strong, flexible fibres are highly resistant to chemicals and electrical conductivity [1–4]. However, despite these beneficial properties, exposure to asbestos has led to a global health crisis, causing life-threatening conditions such as lung cancer, mesothelioma, and asbestosis resulting from inhalation of its fibres [1,2,5,6].

The fire and heat resistance that contributed to asbestos's widespread use in various industries have resulted in millions of deaths, particularly in developing countries [1,7–9]. The first official death related to asbestosis was reported in the UK in 1931 [10]. Unfortunately, asbestos-related diseases often appear after a latency period of 10–50 years. Although restrictions on asbestos began in the 1970s, the UK fully banned its use in 1999 [11]. Australia followed suit with a comprehensive ban on 31 December 2003 [12], and New Zealand implemented the Health and Safety at Work [Asbestos] Regulations in 2016 [12–14].

Australia's 1984 Asbestos Regulations, under the Occupational Health and Safety Act, introduced strict measures to minimise workplace exposure to asbestos. Employers were required to conduct assessments, provide training, and ensure proper protective measures [2]. The ban mandated that only licenced companies could remove asbestos, while independent accredited assessors were responsible for ensuring safe removal practices. A national awareness programme was also initiated to educate the public about the risks and management of asbestos. Despite these efforts, asbestos remains a significant health threat in Australia and New Zealand due to its presence in buildings constructed before 2000 and ongoing soil contamination [14–17].

The widespread health crisis caused by asbestos continues to affect countries across Europe, China, Canada, Australia, the UK, Africa, Russia, and India, particularly in regions where asbestos has been extensively used. In response to the dangers, over seventy countries have prohibited using and importing asbestos [18]. Nevertheless, major producers such as Russia, China, Brazil, and Kazakhstan continue to manufacture and export asbestos, perpetuating asbestos-related deaths, especially in developing nations that are slow to implement bans. These nations often resist international calls to halt this trade [3,7].

This paper explores current practices in asbestos surveying, removal, and disposal in Australia and New Zealand, assessing their sustainability, environmental impact, and effectiveness in reducing health risks. These findings can provide valuable insights and guidance for countries considering asbestos bans or implementing safer practices following a ban.

2. Asbestos Removal and Management Practice in Australia and New Zealand

Australia and New Zealand have demonstrated a strong commitment to addressing asbestos-related challenges through comprehensive bans and the establishment of dedicated task forces. Both countries have developed the national asbestos Codes of Practice as part of these initiatives (Table 1). These codes provide clear guidelines for the construction and demolition industries to ensure safer asbestos management [15,19]. In Australia, Safe Work Australia is responsible for overseeing asbestos regulations, while WorkSafe New Zealand performs a similar role, implementing regulatory mechanisms for asbestos removal and management. Both countries are also actively involved in research and development to improve the safety of asbestos removal processes, particularly in the construction sector [20].

Despite these efforts, significant challenges remain, especially concerning soil and water contamination. Damaged asbestos roofs can release fibres into the environment, posing serious risks. A study in Western Australia found that soils surrounding houses with asbestos roofs contained higher concentrations of asbestos fibres than those without [21]. Additionally, asbestos-containing materials, such as cement pipes, were widely used in drainage systems built before 1980, leading to the detection of asbestos fibres in sediment samples from urban stormwater drains [4,22]. Similarly, asbestos-fibre contamination has been found in soil samples near New Zealand residential buildings with asbestos cement sewer lines. These findings highlight the urgent need for more effective asbestos removal practices to mitigate environmental risks.

The regulation of hazardous materials, including asbestos, is tightly controlled in Australia and New Zealand, with both countries implementing similar management practices. The stringent regulatory framework emphasises the importance of the safe removal and disposal of asbestos. Under the Work Health and Safety (WHS) Regulations, a Person Conducting Business or Undertaking (PCBU) is prohibited from performing asbestos removal unless carried out by a licenced removalist, except in cases where specific exemptions apply. Licenced removal companies in both countries are required to hold a Class A licence for friable asbestos removal, allowing them to handle and remove both friable and non-friable asbestos. A Class B licence is required for non-friable asbestos work, except for projects involving less than 10 m^2 of asbestos materials (Tables 2 and 3) [14]. Similarly, there is no requirement to hold such a removal licence for the following:

1. Research, laboratory tests, and analysis
2. Sampling and identification
3. Maintenance or service
4. Transportation and disposal of asbestos
5. Education, training, demonstrations, display preparations, removing 10 m^2 or less than 10 m^2 of non-friable asbestos

Table 1. Timeline history—Asbestos Removal and Management in the UK, Australia, and New Zealand [12,14–16,18,19].

Year	New Zealand	Australia	UK
1931	-	-	Official confirmation of Asbestosis disease.
1965	-	-	Introduction of the Asbestos Regulations for Management and Use.
1980s	Asbestos awareness levels increased, with the use of asbestos beginning to decline	-	Banned in Brown (amosite) and Blue (crocidolite) asbestos.
1984	Banned in Brown and Blue asbestos.	-	-
1992	Guidelines for the Management and Removal of Asbestos issued.	-	Control of Asbestos at Work Regulations introduced.
1999	Health and Safety in Employment (Asbestos) Regulations introduced.	Import, supply, and use of all types of asbestos were banned.	A complete ban on the import, supply, and use of all types of asbestos.
2003	-	Asbestos regulations were introduced, including licensing requirements for asbestos removal.	Asbestos Licensing Regulations introduced.
2006	Asbestos Regulations updated to align with international standards.	Asbestos-containing materials (ACMs) in workplaces were required to be identified and managed.	Revised Control of Asbestos Regulations introduced.
2016	Asbestos Regulations enacted in New Zealand prohibiting the import and use of asbestos.	-	-
2018	The Asbestos Removal Licensing Scheme (ARLS) was established.	Asbestos regulations updated to include more substantial penalties for non-compliance.	Asbestos: The Hidden Killer campaign was launched to raise awareness.
2021	Health and Safety at Work (Asbestos) Regulations implemented.	-	-
-	Asbestos Licensing Unit (ALU) established.	-	-
-	Asbestos regulations are continually updated and enforced, focusing on safe removal practices.	Asbestos-containing material (ACM) assessment and management are required before demolition or renovation.	Control of Asbestos Regulations revised.

Table 2. Comparison of Asbestos management, removal, and disposal practice in Australia, New Zealand, and the UK [6,12,14–19].

Asbestos Removal & Disposal Practices	Australia	New Zealand	UK
Friable Asbestos Removal (Class A)	Class A method: Removal by a Class A licenced removalist.	Class A method: Removal by a Class A licenced removalist.	Class A method: Removal by a licenced contractor with appropriate training and experience.
Non-Friable Removal (Class B)	Class B method: Removal by a licenced removalist.	Class B method: Removal by a licenced removalist.	Class B method: Removal by a licenced contractor or trained workers following specific regulations.
Air Monitoring	Air monitoring is not mandatory for non-friable asbestos removal, but it is recommended as a best practice.	Air monitoring is recommended to verify the effectiveness of control measures during removal.	Air monitoring is required to assess fibre release and ensure the effectiveness of control measures.
Enclosure for Class A and B	Class A: Enclosed removal methods with specialised enclosures, negative air pressure units, and appropriate personal protective equipment (PPE).	Class A: Enclosed removal methods with specialised enclosures, negative air pressure units, and appropriate PPE.	Enclosed are removal methods with appropriate enclosures, negative pressure units, and proper PPE for Class A and B removal.
	Class B: Enclosed removal methods with appropriate enclosures, negative air pressure units, and PPE.	Class B: Enclosed removal methods with appropriate enclosures, negative air pressure units, and PPE.	Enclosed are removal methods with proper enclosures, negative pressure units, and PPE for Class A and B removal.
	Class A Enclosure Requirements:	Class A Enclosure Requirements:	Class A and B Enclosure Requirements:
	- Use of airtight enclosures with solid walls, floors, and ceilings to prevent the escape of fibres.	Use of airtight enclosures with solid walls, floors, and ceilings to prevent the escape of fibres.	Use of airtight enclosures with solid walls, floors, and ceilings to prevent the escape of fibres.
	- Proper sealing of openings, joints, and connections to ensure containment.	Proper sealing of openings, joints, and connections to ensure containment.	Proper sealing of openings, joints, and connections to ensure containment.
	- Ventilation systems with HEPA filters to maintain negative air pressure inside the enclosure and control fibre release.	Ventilation systems with HEPA filters to maintain negative air pressure inside the enclosure and control fibre release.	Ventilation systems with HEPA filters to maintain negative air pressure inside the enclosure and control fibre release.
	Can remove – up to 10 m^2 of non-friable asbestos or ACM – ACD that is ■ associated with the removal of less than 10 m^2 of non-friable asbestos or ACM ■ not associated with removing friable or non-friable asbestos and is only a minor contamination.		
Decontamination Process	Mandatory decontamination facilities and processes for workers and equipment involved in removal.	Decontamination facilities and processes are required for workers and equipment involved in removal.	Mandatory decontamination facilities and processes for workers and equipment involved in removal.
Disposal Methods	Asbestos waste must be double-bagged, labelled, and disposed of at approved disposal facilities.	Asbestos waste must be double-bagged, labelled, and disposed of at authorised disposal facilities.	Asbestos waste must be properly packaged, labelled, and disposed of at licenced waste disposal sites.

Table 2. *Cont.*

Asbestos Removal & Disposal Practices	Australia	New Zealand	UK
Transportation Methods	Asbestos waste must be transported by a licenced waste carrier in accordance with specific regulations.	Asbestos waste must be transported by a licenced waste carrier in accordance with specific regulations.	Asbestos waste must be transported by a licenced waste carrier following specific regulations and packaging requirements.
Asbestos in Soil	Guidelines and regulations are in place for managing and remediation of asbestos-contaminated soil.	Guidelines and regulations are in place for managing and remediation of asbestos-contaminated soil.	Guidelines and regulations are in place for managing and remediation of asbestos-contaminated soil.

Table 3. Licence requirements for asbestos removal work [6,12,14–19].

Type of Licence	What Asbestos Can Be Removed?
Class A	Can remove any amount or quantity of asbestos or ACM, including – any amount of friable asbestos or ACM – any amount of ACD – any amount of non-friable asbestos or ACM.
Class B	Can remove – any amount of non-friable asbestos or ACM – any amount of ACD associated with removing non-friable asbestos or ACM.
No licence required	Can remove: – up to 10 m^2 of non-friable asbestos or ACM – ACD that is ■ associated with the removal of less than 10 m^2 of non-friable asbestos or ACM ■ not associated with removing friable or non-friable asbestos and is only a minor contamination.

3. Asbestos Survey

An asbestos survey is essential for effectively managing and removing asbestos in Australia and New Zealand (Table 4). Before any removal work begins, the PCBU must develop a comprehensive asbestos-removal control plan (ARCP). This plan should include detailed information about the type, condition, and location of asbestos to ensure informed decisions can be made regarding repair, removal, or management strategies for asbestos-containing materials (ACMs).

The asbestos survey report serves as the foundation for a comprehensive management strategy, which includes precise locations of asbestos. This report is mandatory before any refurbishment or demolition activities occur (Tables 2–4). Surveyors must be well-versed in asbestos materials, associated hazards, and proper sampling techniques. They should also have a strong understanding of building construction methods, fire protection, and structural applications, as these factors influence the use of asbestos in both standard and industrialised buildings (Tables 2–4).

Table 4. ACMs (Asbestos Contaminated Materials) comments and sampling strategy [6,12,14–19].

ACM	Comments and Sampling Strategy
Bulk, encapsulated, and spray coatings	It is usually homogenous. When uniform, two samples from each end of the sprayed surface are sufficient. If the installation is large (>100 m^2), sample every 25–30 m^2. Repair and alteration patches should be sampled.
Thermal/pipe insulation	Composition often changes. Color, size, texture, and healed regions cause variations. Variations and planned tasks determine sample numbers and location. Sample undamaged areas. Take one sample of each 3 m pipe run, paying attention to layers. One sample per 6 m works for extended pipelines (>20 m). Even similar pipes should be sampled because it is hard to prove asbestos-free. Valves, hatches, and repaired areas near access routes are unlikely to contain asbestos, but discretionary sampling may be needed. Repair and alteration patches should be sampled.
Insulating board/tiles	The board is homogeneous but may have repaired or replaced boards and tiles. One 3–5 cm^2 sample per room or 25 m^2 usually works. If there are multiple panel types, take representative samples. Since amosite is easily detected, smaller samples may be sufficient for visually consistent AIB materials.
Asbestos cement (AC) materials	Homogeneous materials include corrugated and flat sheets or other moulded items. Most pre-formed exterior cement sheets installed before 1990 in older structures contain asbestos, thus only a limited sample is needed. Falling through flimsy AC roofs may limit sampling. Without sampling, AC content can often be assumed. This excludes asbestos soffits, which should be sampled or deemed AIB. Sampling AC flues may release dangerous gases. If sampling is needed, take one sample of each sheet or product (e.g., downpipes).
Other asbestos suspects	One or two samples from each material type are usually enough. If the material is more than a few square metres, take two samples. Roofing felts, ornamental coatings, and plasters are examples.
Debris	Debris can be sampled by selecting fragments that look like ACMs or have visible fibres. Debris from recent ACM damage may be under the source. The less accessible regions may still have debris from installation, maintenance, or removal (e.g., loft spaces, floor voids, cable trays, suspended ceiling tiles, or high-level surfaces).
Rocks and minerals	Homogeneous or non-homogeneous rocks and minerals exist. Homogeneous commercial ACMs can be sampled as solid or loose homogeneous materials. Samples should be representative for non-homogeneous rocks and minerals. The sample should show layers, colours, and mineral veins, such as in marble. The sample size should contain all obvious non-homogeneities.

4. Asbestos Surveying Planning

Careful planning is vital for large sites with multiple buildings, such as schools, hospitals, and factories. The complexity and size of these buildings require effective coordination between the PCBU and the asbestos surveyor to ensure compliance with health and safety regulations under the Health and Safety at Work Act 2015. The survey process typically follows four stages, which may overlap depending on the site's size, complexity, history of fire damage, or cases involving pre-purchase surveys (Table 4). Site-specific assessments and work plans are necessary, as asbestos sampling can disrupt the site's operation.

5. Four Stages of Asbestos Survey Planning

Step 1: Gather Data for Planning the Survey

Data collection can be quick and interactive. It involves pre-site meetings, walk-throughs, and feedback from building owners. This process is customised based on the complexity of the building (Table 4). For extensive or multi-property surveys, where pre-survey visits are impractical, data be collected through correspondence or walkthroughs.

Step 2: Desktop Study

Surveyors then review the building plans and data to design the survey. This includes assessing the necessary resources, equipment, work schedules, bulk sampling strategies, and site layout. The desktop study helps identify the potential presence of asbestos and outlines the appropriate type of survey to conduct, particularly for refurbishment and demolition work.

Step 3: Plan Survey and Data Collection

This step focuses on the complexity of the site and involves developing a primary survey plan, which serves as the foundation for any PCBU contracts (Table 4). Key components include the following:

(a) The survey scope, including external areas, and known asbestos-containing material or ACMs;
(b) Sampling methods, the expected number of samples, procedures for addressing disturbed areas, work timelines, signage, access, and parameters for material assessment;
(c) Personnel and safety requirements, including security measures, emergency safety protocols to prevent asbestos disturbance, emergency procedures, and worker decontamination;
(d) Reporting methods, detailing how data will be presented, stored, accessed, and updated, along with handling photographic or video evidence.

Step 4. Risk Assessment of the Survey

Risk assessment is integral to asbestos surveys for refurbishment and demolition. This process ensures that all potential hazards are identified and mitigated, effectively managing and removing asbestos while safeguarding public health and the environment.

6. Asbestos Sampling and Limitation

Surveyors follow a four-step planning process to conduct a risk assessment, ensuring that their work does not interfere with the client's PCBU or pose risks to others. Surveyors use personal protective equipment (PPE) to minimise exposure and often pre-wet the sample and the survey area to reduce the release of fibres. When wetting is unsafe or ineffective, shadow vacuuming is recommended.

Sampling should take place during removal work to help control and minimise risk. The process must consider geographical factors, dust discharge, and future activities to prevent asbestos spread. This includes restricting access to sampling areas, providing appropriate warnings and minimising asbestos disturbance is vital. Tools should be cleaned between samples to avoid cross-contamination, using wet-wiping methods or Class H vacuum cleaners on asbestos-protected polythene sheets. For safety, each sample must be sealed and wrapped in a bag or container, and surveyors are responsible for disposing of asbestos-containing materials. Sealing sample points with tape, fillers, or paint is essential to prevent the release of asbestos fibres.

When collecting bulk asbestos samples, it is important to account for material variation, ensuring that representative samples of 3–5 cm^2 are taken. Samples should be collected from both inner and less accessible areas, particularly where asbestos might be present. However, sampling from obvious or potentially harmful areas, such as the edges of tiles, boards, or previously repaired areas, may not be necessary (Table 4).

The effectiveness of an asbestos survey can be compromised if the scope or methods are restricted by the client/PCBU or the surveyor. Such limitations can delay the identification of asbestos-containing materials, potentially increasing the complexity and cost of asbestos management. Surveyors must have unrestricted access to all building areas, and the PCBU should assist by identifying restricted areas and arranging access during the planning phase.

7. Airborne Fibre—Survey and Monitoring

Monitoring airborne fibre levels is essential for complying with contamination standards and assessing the effectiveness of control measures during asbestos removal or encapsulation projects. The monitoring method used will depend on specific conditions related to these activities. Protecting health is the primary goal, and quality control monitoring is integral to ensuring safety and regulatory compliance. A certified asbestos assessor or qualified worker must conduct air monitoring using membrane filter technology. This method is widely accepted globally and endorsed by WorkSafe New Zealand, as it measures airborne fibre levels in the work environments during asbestos-related activities.

Air monitoring is necessary for certain situations, determined by factors such as the type and condition of asbestos, whether work occurs within an enclosure, and whether it occurs indoors, outdoors, or in public areas. It is particularly critical for Class A (friable asbestos) removal, although it is not mandatory for Class B (non-friable asbestos) removal activities. Licenced asbestos assessors or competent individuals must implement rigorous air monitoring protocols for Class A asbestos removal [14]. For Class A asbestos removal, pre- and post-surveillance of removal activities is mandatory when it is likely that respirable asbestos fibres will exceed trace thresholds. Suppose air monitoring reveals respirable asbestos levels exceeding the specified action levels (>0.02 fibres/mL). In that case, immediate action must be taken by qualified asbestos removal specialists, with notification to the relevant authorities [14].

Safe asbestos removal requires maintaining airborne contamination levels below 0.01 asbestos fibres per millilitre of air over eight hours. This trace level must be adhered to in workplaces. Additionally, asbestos-contaminated soil and related removal activities must also meet this standard, with a strong emphasis on pre-removal air monitoring [14].

8. Standard Operating Procedures for Removing Asbestos and Cleaning Sites

The five key stages in asbestos removal and clean-up are assessment, planning, removal, decontamination, and disposal.

First, asbestos surveyors identify the type and quantity of asbestos through thorough surveys. Then, a detailed removal or management plan is prepared, outlining the scope of work, procedures, tools, materials, and safety precautions required for removal. This includes the preparation of an Asbestos Removal Control Plan (ARCP).

Qualified, licenced asbestos removal contractors carry out the removal process and are equipped with the appropriate tools and protective equipment (e.g., respirators, overalls or protective suits, and gloves). Depending on whether the asbestos is friable or non-friable, the work area must be isolated or sealed to prevent asbestos fibres from spreading. When necessary and applicable, wetting agents or suppression systems are used to control airborne fibres, and Negative Pressure Units (NPU) are explicitly used to remove friable asbestos.

Following the removal process, decontamination occurs. This includes the use of HEPA vacuums, NPUs, and wet cleaning methods. Workers involved in removal must adhere to decontamination procedures, which include the removal of PPE and showering to eliminate residual asbestos fibres. Finally, asbestos waste is then disposed of at approved sites.

9. Problems with Removing Asbestos and Cleaning It Up

Despite well-established procedures for asbestos removal, significant challenges persist. Many building owners and managers are unaware of the dangers of asbestos, leading to inadequate clean-up and disposal methods that can result in airborne asbestos fibres. Additionally, the high costs of asbestos removal, particularly for large projects, create financial constraints that delay necessary actions, putting employees and the public at risk [22–31]. While asbestos removal regulations are strict, some contractors still fail to comply, engaging in unsafe practices that could have fatal consequences. These issues underscore the need for greater awareness, enhanced training, and strict adherence to safety standards in asbestos management [31].

10. Disposal: Is Landfill the Solution and Practice Globally?

Environmental protection regulations for asbestos disposal vary worldwide. In countries like New Zealand, Australia, the UK, Canada, and Europe, strict laws mandate that only qualified professionals handle asbestos, which is typically disposed of in certified landfills. However, in countries with fewer regulations and limited funds, improper disposal methods, such as burning or open-pit dumping, pose significant environmental and health hazards as asbestos fibres can be released into the air [21].

Efforts are being made to explore more environmentally friendly disposal methods, such as recycling or encapsulation, to prevent airborne fibre release. Although these methods are expensive, they offer long-term solutions. Improving asbestos disposal practices requires establishing standards for handling and disposal, staff training, and compliance inspections.

While landfill disposal of asbestos is common in many industrialised nations, it is not considered a sustainable solution by everyone. Disposal methods must consider environmental, social, and economic impacts, which necessitates exploring alternative approaches [23]. Safe asbestos disposal is crucial for public health, and the debate over landfill disposal emphasises the need to balance its advantages and disadvantages while promoting the development of sustainable and safe asbestos management solutions.

11. Landfill Asbestos Disposal Advantages

Landfills are designated sites for the disposal of hazardous asbestos waste. Asbestos materials are stored in specified areas within landfills, which consist of specially constructed cells covered with soil. This design helps prevent the release of fibres into the air and soil [24]. The handling, transportation, and disposal of asbestos in approved landfills must be carried out by trained personnel, following the guidelines and regulations set by the Environmental Protection Agency (EPA) and various countries. Unlike incineration, landfill disposal is generally more cost-effective for large-scale asbestos disposal, making it an economical alternative [24,25,32,33].

12. Landfill Asbestos Disposal Drawbacks

While landfill disposal is common practice, it poses significant environmental risks. Asbestos is a long-lasting carcinogen, and its decomposition time is unknown. Even when stored in landfills, asbestos can create environmental hazards. For example, cracks or leaks from landfill cells could contaminate groundwater, affecting nearby populations. Additionally, landfills close to residential areas increase the likelihood of environmental and health injustices, contributing to broader societal impacts [32,33].

13. Alternate Means of Asbestos Disposal

In addition to landfilling, there are alternative disposal methods for asbestos. Incineration is one option where asbestos is burned at high temperatures; however, this method can be expensive and may release toxic gases into the atmosphere. Another alternative is recycling asbestos for use in new products, but only specific types of asbestos can be recycled. While landfilling remains the most common disposal method, it is crucial to carefully consider these alternatives to minimise environmental, social, and economic impacts [23,25].

14. Safe Disposal of Asbestos

A comprehensive approach is essential for the safe disposal of asbestos to minimise its risks to human health and the environment. Governments must enact and strictly enforce legislation, ensuring that only licenced professionals handle asbestos-containing materials and that disposal occurs in approved landfills. Research into environmentally friendly disposal methods, such as encapsulation and recycling, should be prioritised. Additionally, educating workers on safe disposal techniques and using personal protective equipment (PPE) is crucial to reducing exposure risks. Regulating authorities should also implement proper monitoring programmes in these sectors. Developing nations could adopt safer disposal methods with international cooperation and financial support. Public awareness campaigns will also enhance the safety and sustainability of asbestos disposal. Strengthening legislation, investing in research, training personnel, engaging with international organisations, and raising public awareness are vital [11,31]

15. Asbestos Management in Australia and New Zealand

Due to its extensive historical use, Australia and New Zealand face significant challenges in managing asbestos. Although removing asbestos is critical, a lack of awareness about its risks, high removal costs, and a shortage of qualified contractors often lead to unsafe practices. Illegal dumping and insufficient enforcement further exacerbate the issue. To tackle these problems, comprehensive education campaigns, more affordable removal services, stricter regulations, and improved public communication are needed. Coordination among government agencies, businesses, and the public is essential for effectively enforcing asbestos removal laws and managing waste disposal [6,11,12,14,17–20,31].

16. Global Asbestos Management

Many industrialised countries have implemented advanced asbestos disposal, such as high-temperature incineration and plasma gasification, ensuring safe disposal without harming the environment. For example, Sweden maintains a national asbestos register and strictly enforces removal legislation. The Netherlands controls asbestos through a national register, licenced removal firms, and a cooperative effort between the government, businesses, and the public. Switzerland enforces strict legislation and licensing for removal firms, ensuring safe management through cooperation among the government, industry, and the public. Japan focuses on raising public awareness and trains certified asbestos removal workers.

Countries like the United States and Canada regulate asbestos through comprehensive national frameworks like the Environmental Protection Agency (EPA) guidelines, the Asbestos Hazard Emergency Response Act (AHERA), and the Toxic Substances Control Act (TSCA). In the U.S., the Consumer Product Safety Commission and the Occupational Safety and Health Administration regulate asbestos exposure from household products and occupational exposure, respectively [17–20,31].

Canada mandates safe handling and removal through legislation, maintains a national inventory, monitors asbestos, conducts research, and promotes education initiatives [34].

While Russia has legislation for asbestos management, enforcement remains challenging. China, the largest user of asbestos, also struggles to enforce its regulations [35–37]. The United Kingdom has established a comprehensive asbestos management programme, which includes licensing, risk assessments, strict removal rules, and a centralised database for safe management and removal [6,11,12,14,17–20,31].

17. Advanced Asbestos Disposal Practices

The UK's recent strides in asbestos disposal, such as establishing a plasma gasification plant in Swindon in 2019 and a high-temperature incinerator in the West Midlands in 2020, bring significant environmental benefits. These facilities, with advanced filtration systems, represent a departure from traditional landfill disposal methods [26]. The plasma gasification plant, with its capacity to process up to 70,000 tonnes of hazardous waste annually, and the incinerator, capable of handling 40,000 tonnes, offers more environmentally friendly alternatives for asbestos disposal [27–29]. By reducing harmful emissions and mitigating the risks associated with asbestos-containing materials (ACMs) in landfills, these innovations pave the way for a greener future [25–27].

In addition to the UK's progress, Japan has piloted plasma gasification to transform asbestos into inert substances while simultaneously generating electricity. Similarly, Norway has successfully used high-temperature incineration for asbestos disposal since the 1990s, employing state-of-the-art facilities [26–29]. High-temperature incineration operates between 800 and 1200 °C, breaking down asbestos fibres and neutralising hazardous chemicals [26]. Advanced filtration systems ensure that harmful particles and odours are not released into the atmosphere.

Plasma gasification, a more advanced method, operates at over 10,000 °C and utilises an electric arc to ionise gases, transforming asbestos into carbon and silicon [26–29]. The resulting solid residue is safely disposed of in hazardous waste landfills. Both technologies incorporate sophisticated filtration and scrubbing systems, offering efficient and environmentally conscious solutions for asbestos disposal. However, these technologies' high cost and technical complexity limit widespread adoption. Strict regulations over the handling, transport, and disposal of asbestos remain essential to avoid health and environmental hazards.

18. Advantages and Disadvantages of These Advanced Methods

High-temperature incineration and plasma gasification offer numerous advantages for asbestos disposal. Both methods ensure the complete breakdown of asbestos fibres and the neutralisation of harmful chemicals, preventing the release of dangerous particles and odours into the environment. Additionally, plasma gasification recycles energy during the process, making it a potentially more sustainable option.

However, these technologies also come with notable drawbacks. They are expensive to implement, requiring specialised equipment and expertise, reducing their widespread use. Furthermore, constructing and operating such facilities near residential areas can raise safety concerns. Therefore, while these methods provide secure and effective solutions for asbestos disposal, they should be reserved for situations where traditional measures, such as landfilling, pose substantial health and environmental risks [25,26]. Moreover, it is crucial to maintain strict regulations for the handling, transport, and disposal of asbestos. Compromising these regulations would undermine public health and environmental safety [27,28].

19. Future Innovation to Manage Asbestos

Cutting-edge technologies are revolutionising asbestos management by providing safer and more efficient methods for handling ACMs. Robotic arms and tools are now used to cut and remove asbestos pipes, significantly reducing worker exposure to dangerous fibres. Encapsulation techniques, which seal ACMs, also prevent fibre release, especially in older structures and industrial facilities [26,28].

Plasma gasification, which converts asbestos into non-toxic gases, is a viable alternative to landfilling. This process not only neutralises harmful fibres but also helps recycle energy. Another promising development is microencapsulation, where asbestos fibres are encased in resin, making them safer for transportation and disposal without costly removal procedures [28,29].

Additionally, advanced mapping technologies, such as drones and satellite imagery, are now used to identify and map areas contaminated with asbestos. These innovations improve the efficiency of asbestos management and removal processes, reduce worker exposure to hazardous materials, and enhance public access to data through local councils [27,29]. As innovation advances, we can expect even more effective and protective solutions to emerge, further safeguarding workers and the environment.

20. Strategies for the Sustainable Management of Asbestos

(1) Awareness campaigns educate people and organisations on asbestos risks, safe handling, removal techniques, and regulatory compliance.
(2) Training programmes enhance the skills of building inspectors, engineers, and professionals in managing asbestos-containing products.
(3) Consistent regulations prevent confusion and maintain standards across Australia and New Zealand.
(4) Smaller enterprises can get help managing asbestos-containing materials through asbestos awareness programmes at the local level.
(5) Regular inspections and maintenance of old infrastructure can detect and address asbestos threats early.
(6) Increased research investment can lead to innovative asbestos disposal and containment methods.

21. Recommendations

A more robust framework is needed to ensure workers' safety when handling asbestos and protect the public, including comprehensive training, enhanced regulatory measures, and innovative technological solutions. Mandatory and standardised training for all personnel involved in asbestos removal and handling is essential. This training should cover the entire process, from safe handling to disposal, ensuring workers have the necessary skills to minimise exposure risks. Sharing this knowledge across industries, particularly those working with aging infrastructure, is pivotal for preventing hazardous exposure.

Governments should also implement financial incentives to encourage property owners to undertake asbestos removal projects, particularly in countries like Australia and New Zealand, where many aging buildings contain significant amounts of asbestos. Financial support will promote compliance with safety regulations and increase asbestos removal efforts. Regular monitoring and strict enforcement of asbestos regulations must be prioritised alongside financial measures. Regular inspections and imposing stringent penalties for non-compliance will help ensure safe practices are followed, particularly in regions where asbestos use has historically been prevalent.

An important step in managing asbestos is developing and promoting advanced asbestos-disposal technologies. High-temperature incineration and plasma gasification provide safer, more environmentally sustainable landfill alternatives. Governments should prioritise adopting of these methods, as they significantly reduce the environmental risks associated with asbestos-containing materials. Additionally, comprehensive nationwide assessments are necessary, including testing gutter and soil samples around structures that contain asbestos, to fully understand exposure risks. Environmental impact assessments should be mandatory for projects involving disturbing asbestos-containing materials. This ensures that potential contamination is identified and addressed before it becomes a health threat.

International collaboration is also vital in the global effort to manage asbestos. By working with major asbestos-producing and using countries like Russia, China, Brazil, and Kazakhstan, we can facilitate the sharing of best practices and develop coordinated safety regulations for effective asbestos management across borders. Moreover, investment in research and innovation is essential to continue improving asbestos detection, handling, and remediation. Collaborations between academia and industry should focus on utilising advanced technologies, such as Artificial Intelligence (AI) and machine learning, for asbestos detection while also exploring alternatives to asbestos-containing products.

Technological advancements such as blockchain and the Internet of Things (IoT) can significantly improve asbestos management by providing transparent tracking and control of asbestos-containing materials throughout their lifecycle. These technologies can help prevent illegal dumping and ensure all materials are safely managed and disposed of. Public awareness campaigns are equally important. Governments and organisations should engage in widespread education efforts to inform property owners, workers, and businesses about the dangers of asbestos exposure, while promoting the adoption of safer alternative building materials.

Finally, stricter regulations and a complete global ban on asbestos are essential to eliminating future risks. Governments must strengthen and enforce regulations that prohibit using, manufacturing, and recycling of asbestos, updating their legislative frameworks to reflect current best practices. By adopting these measures, nations can work together to mitigate the dangers of asbestos, protect public health, and ensure a safer, asbestos-free future.

Author Contributions: All authors have equal contribution. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Aryal, A.; Morley, C. Call for a global ban policy on and scientific management of asbestos to eliminate asbestos-related diseases. *J. Public Health Policy* **2020**, *41*, 279–285. [CrossRef] [PubMed]
2. Thives, L.P.; Ghisi, E.; Júnior, J.J.T.; Vieira, A.S. Is asbestos still a problem in the world? A current review. *J. Environ. Manag.* **2022**, *319*, 115716. [CrossRef] [PubMed]
3. Tran, T.H.; Egilman, D.S.; Bird, T.; Clancy, K. The Definition of Asbestos—A Manufactured Defense to Avoid Regulation and Victim Compensation. *Med. Res. Arch.* **2022**, *10*. [CrossRef]
4. Hendrickx, M. Naturally occurring asbestos in eastern Australia: A review of geological occurrence, disturbance and mesothelioma risk. *Environ. Geol.* **2009**, *57*, 909–926. [CrossRef]
5. Furuya, S.; Chimed-Ochir, O.; Takahashi, K.; David, A.; Takala, J. Global Asbestos Disaster. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1000. [CrossRef]
6. IHME. *Global Burden of Disease (GBD)*; The Institute for Health Metrics and Evaluation (IHME) at the University of Washington: Seattle, WA, USA, 2018. Available online: https://www.healthdata.org/gbd (accessed on 10 February 2024).
7. Ou, Z.; Li, X.; Cui, J.; Zhu, S.; Feng, K.; Ma, J.; Wu, K.; Chen, Y.; Su, Y.; Tang, S.; et al. Global, regional, and national burden of asbestosis from 1990 to 2019 and the implications for prevention and control. *Sci. Total Environ.* **2023**, *904*, 166346. [CrossRef]
8. van Zandwijk, N.; Reid, G.; Frank, A.L. Asbestos-related cancers: The 'Hidden Killer' remains a global threat. *Expert Rev. Anticancer. Ther.* **2020**, *20*, 271–278. [CrossRef]
9. Frank, A.L.; Joshi, T.K. The global spread of asbestos. *Ann. Glob. Health* **2014**, *80*, 257–262. [CrossRef]
10. Tweedale, G.; Hansen, P. Protecting the workers: The medical board and the asbestos industry, 1930s–1960s. *Med. Hist.* **1998**, *42*, 439–457. [CrossRef]
11. Berry, T.A.; Belluso, E.; Vigliaturo, R.; Gieré, R.; Emmett, E.A.; Testa, J.R.; Steinhorn, G.; Wallis, S.L. Potential exposure pathways and associated health risks include asbestos and other hazardous fibrous minerals. *Int. J. Environ. Res. Public Health* **2022**, *19*, 4031. [CrossRef]
12. Government of Australia. Asbestos Code of Practice: Model Code of Practice: How to Safely Remove Asbestos. 2020. Available online: https://www.safeworkaustralia.gov.au/sites/default/files/2020-07/model_code_of_practice_how_to_safely_remove_asbestos.pdf (accessed on 8 February 2024).
13. Stevenson, S.P.; Barron, O.; Pakenham, A.; Hashinaka, M. Understanding and Ending the Lethal Asbestos Legacy. *Sustainability* **2023**, *15*, 2507. [CrossRef]
14. WorkSafe New Zealand. Asbestos Management in Workplaces: Approved Code of Practice. 2016. Available online: https://www.worksafe.govt.nz/dmsdocument/1235-asbestos-management-in-workplaces-acop (accessed on 23 February 2024).
15. ASEA—Asbestos Safety and Eradication Agency. National Asbestos Profile for Australia 2017. Available online: https://www.asbestossafety.gov.au/sites/asea/files/documents/2017-12/ASEA_National_Asbestos_Profile_interactive_Nov17.pdf (accessed on 23 February 2024).
16. Safe Work Australia. Managing the Risks of Asbestos in Workplaces Code of Practice. 2020. Available online: https://www.safeworkaustralia.gov.au/system/files/documents/1902/managing-risks-asbestos-workplaces-cop.pdf (accessed on 8 February 2024).
17. Safe Work Australia. Code of Practice for the Safe Removal of Asbestos. 2021. Available online: https://www.safeworkaustralia.gov.au/codes-practice/safe-removal-asbestos (accessed on 8 February 2024).
18. International Ban Asbestos Secretariat. Current Asbestos Ban. *Retrieved from Current Asbestos Bans.* Available online: https://www.ibasecretariat.org (accessed on 13 September 2024).
19. Department of Prime Minister and Cabinet (DPMC). Asbestos Exposure in New Zealand: Review of the Scientific Evidence of Non-Occupational Risks-April 2015-Office of the Prime Minister's Chief Science Advisor 2015. Available online: https://www.dpmc.govt.nz/sites/default/files/2021-10/pmcsa-Asbestos-exposure-in-New-Zealand_9April15.pdf (accessed on 7 March 2024).
20. Australian Asbestos Network. Available online: https://www.australianasbestosnetwork.org.au/asbestos-about/asbestos-research/ (accessed on 18 July 2024).
21. Khalaf, G.; Alam, M.S.; Megharaj, M. Soil contamination by asbestos fibres: A review of current status and prospects for remediation. *Sci. Total Environ.* **2020**, *701*, 134690. [CrossRef]
22. Ho, K.J.; Vieth-Hillebrand, A.; Chan, Y.K.; Wallis, C.J. Asbestos fibres in sediments of urban stormwater drains. *Environ. Monit. Assess.* **2017**, *189*, 525. [CrossRef]
23. Bolan, S.; Kempton, L.; McCarthy, T.; Wijesekara, H.; Piyathilake, U.; Jasemizad, T.; Padhye, L.P.; Zhang, T.; Rinklebe, J.; Wang, H.; et al. Sustainable management of hazardous asbestos-containing materials: Containment, stabilisation and inertization. *Sci. Total Environ.* **2023**, *881*, 163456. [CrossRef]
24. Ander, E.L.; Cave, M.R.; Johnson, C.C.; Palumbo-Roe, B. *Normal Background Concentrations of Contaminants in the Soils of England: Available Data and Data Exploration*; British Geological Survey: Nottingham, UK, 2021; 112p, CR/11/145N. Available online: https://nora.nerc.ac.uk/id/eprint/19958/ (accessed on 18 July 2024).
25. Wallis, S.L.; Emmett, E.A.; Hardy, R.; Casper, B.B.; Blanchon, D.J.; Testa, J.R.; Menges, C.W.; Gonneau, C.; Jerolmack, D.J.; Seiphoori, A.; et al. Challenging global waste management–bioremediation to detoxify asbestos. *Front. Environ. Sci.* **2020**, *8*, 20. [CrossRef]

26. Vergani, F.; Galimberti, L.; Marian, N.M.; Giorgetti, G.; Viti, C.; Capitani, G.C. Thermal decomposition of cement–asbestos at 1100 °C: How much "safe" is "safe"? *J. Mater. Cycles Waste Manag.* **2022**, *24*, 297–310. [CrossRef]
27. Abdulkarim, B.I.; Hassan, M.A.; Ali, A.M. Thermal plasma treatment of municipal solid waste incineration residue: A review. *Asian J. Eng. Technol.* **2016**, *4*, 92–101.
28. Abdul Halim, S. Biomass Pyrolysis Using Microwave Technology. Ph.D. Dissertation, University of Sheffield, Sheffield, UK, 2016.
29. Panepinto, D.; Tedesco, V.; Brizio, E.; Genon, G. Environmental performances and energy efficiency for MSW gasification treatment. *Waste Biomass Valoriz.* **2015**, *6*, 123–135. [CrossRef]
30. Hernández-Blanquisett, A.; Álvarez-Londoño, A.; Martínez-Ávila, M.C.; Covo-Camacho, S.; Quintero-Carreño, V. Asbestos and cancer in Latin America and the Caribbean: We may have won some battles, but not the war. *J. Public Health Res.* **2022**, *11*, jphr-2021. [CrossRef]
31. Heefner, C.S. The Right to an Environment Free from Toxic Pollution & State Obligations to Eradicate Asbestos-Now Is the Time. *E. Cent. Eur. J. Envtl. L.* **2020**, *27*, 79.
32. Durczak, K.; Pyzalski, M.; Brylewski, T.; Juszczyk, M.; Leśniak, A.; Libura, M.; Ustinovičius, L.; Vaišnoras, M. Modern Methods of Asbestos Waste Management as Innovative Solutions for Recycling and Sustainable Cement Production. *Sustainability* **2024**, *16*, 8798. [CrossRef]
33. Wallis, S.; Lemckert, C.; Hardy, R.; Berry, T.A. Disposal or Treatment: Future considerations for solid waste from the construction and demolition industry. *WIT Trans. Ecol. Environ. Wessex Waste Manag. Southhampton UK* **2020**, *247*, 171–183.
34. Meek, M.E.; Armstrong, V.C. The assessment and management of industrial chemicals in Canada. In *Risk Assessment of Chemicals: An Introduction*; Springer: Dordrecht, The Netherlands, 2007; pp. 591–621.
35. Coggiola, N. The rough path to the compensation of asbestos damages in China. *Sustainability* **2017**, *9*, 1431. [CrossRef]
36. Qian, X.; Zhou, W.; Nakagami, K. An international comparative study on the regulation policy of asbestos usage in China. *Ritsumeikan J. Asia Pac. Stud.* **2012**, *31*, 81–89.
37. Harris, L.V.; Kahwa, I.A. Asbestos: Old foe in 21st century developing countries. *Sci. Total Environ.* **2003**, *307*, 1–9. [CrossRef]