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A decision-support framework for asbestos hazard assessment and management in cultural heritage assets

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ABSTRACT

Asbestos is extensively regulated in many countries around the world, both in industrial and construction contexts, due to its well-established health risks. However, its occurrence within cultural heritage remains poorly addressed by existing regulatory and management frameworks. Many artefacts, monuments, and historical materials may contain asbestos as an intentional component, contaminant, or natural constituent, while their conservation value often prevents conventional remediation options such as removal.

This study proposes a decision-support framework for asbestos hazard assessment and management in asbestos-containing cultural heritage items (ACCHI). The framework integrates preliminary screening, hazard identification, stakeholder coordination, laboratory investigation, risk assessment, documentation, and long-term monitoring into a structured workflow. It involves cultural heritage institutions, occupational health and safety services, and accredited asbestos laboratories. It is supported by operational tools, including an Asbestos Survey Report (ASR), a precautionary screening questionnaire, and a dynamic ACCHI Registry.

The framework is designed to support decision-making under uncertainty, particularly before handling, transport, exhibition, or conservation. Within this approach, hazard assessment focuses on asbestos identification and characterization, whereas risk assessment considers fibre release and potential human exposure under specific use scenarios. Periodic re-inspections and registry updates enable adaptive management of asbestos exposure risks while preserving the conservation value and accessibility of heritage assets.

Overall, the framework provides a transferable decision-support model for managing asbestos hazards in heritage-related environments where conventional asbestos regulations do not fully address asset conservation, stakeholder coordination, and long-term monitoring needs.

1. Introduction

Asbestos is a term that was first attributed, several thousand years ago, to a naturally occurring fibrous material found in rocks and easily separable from the host matrix (e.g., Plinio il Vecchio, 77 CE; Strabone, 23 CE). Owing to its mechanical resistance and thermal stability, it was historically used as a binder in the production of terracotta (Lavento and Hornytzkyj, 1996). Because of its heat resistance and its capacity to be woven, asbestos fibres were also used to manufacture cremation cloths (Browne, 2003).

Asbestos refers to six naturally occurring silicate minerals characterised by a fibrous (i.e., asbestiform) habit and a range of distinctive chemico-physical properties (e.g., Directive 2009/148/EC of the European Parliament). These minerals include tremolite asbestos, actinolite asbestos, anthophyllite asbestos, amosite (or grunerite asbestos), crocidolite, and chrysotile (Virta, 2002). Depending on the national legislation, the mining, industrial use, and commercial trade of asbestos are either allowed, regulated, partially restricted, or totally banned. To date, approximately 3500 different types of products have been manufactured using asbestos, many of which remain in situ in buildings and infrastructure worldwide, such as asbestos-cement roofing materials.

Based on the well-established health risk associated with exposure to airborne asbestos, in particular under high dose exposure conditions (Goodman et al., 2025), many countries worldwide have implemented specific monitoring protocols for anthropogenic sources of airborne

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releases (e.g., asbestos-containing materials, ACMs) and for asbestos containing natural sources (e.g., rocks) that may be subject to excavating works. Existing regulations and technical guidelines primarily address occupational and environmental monitoring and, where necessary, the implementation of remediation measures. However, very limited awareness has been given to the presence of asbestos within historical objects and artefacts created in antiquity or during more recent centuries (i.e. 20th century and contemporary art products and objects), which are currently preserved in museums, archives, historical buildings, or private collections (Cortesi et al., 2025). These materials, which may contain asbestos either as an intentional component or as a contaminant, can be collectively defined as Asbestos Containing Cultural Heritage Items (ACCHI) (Petriglieri et al., 2025; Saba et al., 2023).

ACCHI are often subject to periodic handling for routine maintenance and cleaning, and in some cases for conservation and restoration purposes. They may also need to be relocated when interventions are carried out in the rooms or buildings in which they are housed. During the organization of temporary exhibitions, objects are typically moved, packed, transported, unpacked, installed for display, and subsequently handled again in reverse order when returned to storage or to their original location. Any of these operations may result in the release of asbestos fibres into the indoor environment, thereby potentially exposing workers. Recent work on adaptive reuse in heritage context has emphasized the need to incorporate safety priorities and stakeholder perspectives into heritage management processes (Cao et al., 2026). To the best of the author's knowledge, although asbestos is banned in all European countries and in many other jurisdictions worldwide, specific national regulations or technical guidelines addressing the handling of ACCHI, the protection of workers in this context, and the monitoring of asbestos fibres indoors remain limited or absent (Blancquaert and Verreyke, 2025). Unlike asbestos in ACM used in buildings, which can generally be encapsulated, confined or removed, asbestos present within cultural artefacts often constitutes an integral component of the object itself. As such, it forms part of the cultural heritage asset and cannot be removed without adversely affecting its material integrity and historical value (Ruuska-Jauhijärvi, 2025; Spennemann, 2024). Accordingly, ACCHI must be subject to appropriate risk management rather than removal (Petriglieri et al., 2025).

Based on their origin and functional use, ACCHI can be broadly classified into three main categories: (i) artefacts in which asbestos was intentionally incorporated as primary component or additive for functional, structural, partial patches, or aesthetic purposes, including for examples artistic objects, asbestos-cement design pieces, and vehicles (Aceto et al., 2012; Colomban and Kremenović, 2020; Kakoulli et al., 2014; Kulkova and Kulkov, 2016; Saba et al., 2023; Sanpaolesi, 1950); (ii) artefacts in which asbestos is present unintentionally or as a contaminant (Casadio et al., 2013); (iii) objects produced from rocks that naturally contain asbestos minerals, such as sculpture carved from serpentinite rocks or other asbestos-bearing lithologies (Coli et al., 2023; Fratini et al., 2022; Navarro and Rostain, 2023). These categories provide the conceptual basis for the structured framework proposed in this study. They also define the range of heritage-related settings in which asbestos hazard governance requires coordinated decision-making among conservation, health and safety, and analytical actors. Risk-based approaches developed for preventive conservation similarly rely on structured risk identification, prioritisation, documentation, and multidisciplinary decision-making to support the management of collections, buildings, and sites (Pedersoli Jr. et al., 2016; Waller, 2026, Waller, 1994). Hazard-specific decision-support frameworks should build on these general principles while adapting assessment criteria and management pathways to the characteristics of the specific hazard and the heritage context. From this perspective, asbestos represents a specific hazard requiring a tailored application of such decision-support principles. Process-based and tiered assessment frameworks have been proposed to structure problem identification, scale assessment efforts, and support proportionate decision-making under uncertainty in complex environmental management contexts (Smit et al., 2024; Wang et al., 2024).

2. Decision-support rationale and framework objectives

This work proposes a structured decision-making framework for the identification, hazard assessment, and management of asbestos-containing cultural heritage items (ACCHI). The framework is intended to support decision-making under uncertainty by integrating preliminary screening, hazard identification, risk assessment, stakeholder coordination, documentation, and long-term monitoring into a coherent process. It also recommends the adoption of an ACCHI Registry as an adaptive management tool to support periodic re-evaluation and institutional documentation over time.

The proposed framework identifies the roles and interactions of the key actors involved, including Cultural Heritage Institutions (CHI), the Prevention and Protection Service (PPS), used here as a generic term for the entity responsible for occupational health and safety management, and accredited asbestos laboratories. The study also provides a literature-based overview of the principal typologies of ACCHI across different historical periods, considering their historical context, material composition, and technological uses to outline their occurrence within museum collections, historic buildings, and culturally significant sites.

While existing asbestos management approaches primarily address construction materials and industrial settings, they do not account for heritage assets in which asbestos may constitute an integral and non-removable component. This study therefore advances current practice by proposing the first decision-support framework that integrates asbestos hazard assessment, conservation constraints, stakeholder coordination, documentation, and adaptive monitoring for ACCHI.

3. Literature-based evidence of asbestos occurrence in cultural heritage assets

Historical and cultural heritage objects containing asbestos, particularly artefacts and domestic items, have been discovered at numerous archaeological sites worldwide (Bréhier, 1912; Brysbaert, 2008; Colomban and Kremenović, 2020; Hop, 2016; Kulkova and Kulkov, 2016). This section provides a brief literature-based overview of asbestos occurrence in cultural heritage assets. It is not intended as a comprehensive historical review, but as typological evidence for hazard identification and decision-support within the framework proposed in this study. The variability of asbestos-containing cultural heritage items (ACCHI) encountered from antiquity to the modern era is summarised in Table 1.

3.1. Prehistoric period and Ancient Age (up to 5th century CE): potteries and textiles

The use of asbestos during prehistory and antiquity is primarily documented through archaeological findings and a limited number of written sources (e.g., Naturalis Historia by Pliny the Elder, 77–79 CE (Plinio il Vecchio, 77AD)). Ancient civilisations predominantly employed asbestos in the production of pottery and textiles, particularly for garments, funerary shrouds, and candlewicks, in contexts associated with places of worship and imbued with ritual or religious significance (Bianchi and Bianchi, 2015; Yates, 1843). The earliest evidence of asbestos-containing artefacts dates to the prehistoric period, when asbestos was added as a binder in pottery production across a broad region of Eurasia, including Scandinavia, Corsica, Greece, and the Japanese Archipelago.

There is evidence that anthophyllite asbestos was first used in pottery production (i.e., Pit-Comb Ware ceramics) in the Savo region of Finland during the Palaeolithic period, approximately 7•000 to 10•000 years ago. Its use became more widespread in the Paakila district during the Early Metal Age (around 4000 BCE; Hillerdal, 2004). From there,

Table 1
Summary of the principal uses of asbestos as primary or secondary components in cultural heritage items, from prehistory to the present day (references in the full text body).

Historical Period	Asbestos-Containing Cultural Heritage Items
Prehistoric period *Neolithic Age*	Pottery and ceramic vessels.
Ancient Age (up to 5th century CE) *Ancient Greeks and Romans*	Textiles, woven fabrics, shrouds, and candlewicks (especially for burial purposes).
Middle Ages (5th–15th century CE) *Byzantine Art*	Pottery, textiles, and construction materials (e.g., plaster and fresco layers).
Early Modern and Modern Age (15th century CE to present) *Industrial Era, early 20th century*	Civil and religious building materials (e.g., asbestos-cement), murals, wall paintings, sculptures, art plasters and stuccos, natural science museum collections, and modern and contemporary installations. It also includes modern cultural heritage artefacts such as musical instruments, vehicles, historic military furniture (e.g., World War gas masks and helmets), radio and film equipment, decorative ceiling panels, theatre curtains, decorative garden furniture, lamps and safety lamps, interior bookcases, and pinball machines.

anthophyllite asbestos use spread to Sweden, Norway, and adjacent areas of Russia (Kulkova et al., 2012; Kulkova and Kulkov, 2016; Mökkönen and Nordqvist, 2017). Owing to the relatively abundant natural deposits of anthophyllite asbestos in Finland, asbestos from the Paakila region was also exploited in modern times (Hillerdal, 2004; Hiraoka et al., 1998).

Asbestos textiles have been discovered in ancient burial sites across Southeast and East Asia in the Neolithic and Iron Ages and early centuries CE. Cameron et al. reported the archaeological presence of asbestos chrysotile cloths at the Batujaya site (1st century BCE – 4th century CE), in the West Java province, Indonesia (Cameron et al., 2015).

The earliest evidence of asbestos in China is dated to the 1st-3rd centuries CE and is linked to textile production associated with the Da Qin (the Roman Empire), likely introduced through trade with the Roman Orient via the Central Asian overland routes. Chinese sources referred to asbestos textile as 'fire-cleansing cloths' in recognition of its fire-resistant property (Cameron et al., 2015).

Unprocessed non-weaved asbestos has been found in the archaeological site of Kamrej in northwest India, historically identified as the port of Kammoni mentioned in the Periplus Maris Erythraei (Gupta et al., 2004).

In the Mediterranean area, chrysotile was first discovered and utilised in Cyprus, possibly as early as 5•000 years ago (Dilek and Newcomb, 2003; Ross and Nolan, 2003). The ancient Greeks and Romans employed asbestos for weaving textiles, including cremation shrouds, candlewicks, and garments, as documented by both archaeological findings and historical accounts. Notably, Naturalis Historia by Pliny the Elder mentioned the use of asbestos in various textile forms, such as cremation robes or sacks, sheets, napkins (vivum), clothing, royal shrouds, and other fabrics (Di Gennaro et al., 2008; Gupta et al., 2004; Steinby, 2003). The diversity of terms used in antiquity, including asbestos, asbestus, asbestinon, asbeston, amiantos, amiantus, amianthus, and amiante, can be traced to the writings of ancient Greek philosophers (Ross and Nolan, 2003; Skinner et al., 1988).

In nearly all of these cases, asbestos was intentionally used or added in the weaving of textiles and the production of pottery and ceramics, respectively.

3.2. Middle Ages (5th - 15th century CE): painting support

During the Middle Ages (5th - 15th century CE), the only known evidence of asbestos use comes from areas that had already been exploited in earlier centuries, such as Scandinavia, Corsica, Greece and Cyprus (Hillerdal, 2004).

Kakoulli et al. (2014) reported that asbestos composites were already in use during the Byzantine period (12th century CE) in Cyprus (Kakoulli et al., 2014). Chrysotile fibres were identified within calcium carbonate-rich upper plaster layers situated directly beneath the paint surface in the wall paintings of the Enkleistra of Saint Neophytos. This unique finding represents the earliest known use of asbestos in wall-painting finish coatings (Kakoulli et al., 2014).

Early Medieval times are notorious for the attribution of "salamander or wool of Abraham land" to asbestos materials (Fiumi, 2025).

3.3. Early Modern and Modern Age (16th century CE to present): products of the secondary industrial sector

The Early Modern period (16th – 18th century CE) was marked by extensive archaeological campaigns across the Mediterranean area. During this time, mainly asbestos textiles have been recovered from burial sites (e.g., Roman tombs in Italy) and subsequently housed and preserved in museums and cultural heritage institutions, such as the Vatican Museums in Rome and the National Archaeological Museum of Naples (Di Gennaro et al., 2008; Steinby, 2003). Based on current knowledge and findings, asbestos was not intentionally used in art creations of the Early Modern period, which primarily focused on traditional techniques such as frescoes, marble and wood sculptures, and oil paintings. Most of these objects are not accessible to the public, primarily due to the lack of guidelines and adequate training for managing the associated risks.

Beginning in the late 18th century, the advent of the industrial age spurred the extraction and use of asbestos, notably through the exploitation of chrysotile deposits in north-western Italy (e.g., the Balangero mine, Province of Turin) and Canada (e.g., the Asbestos mine). The large-scale commercial application of asbestos intensified during the modern era, particularly around and following the Second World War (Alleman and Mossman, 1997). Industrial expansion peaked between the 1960s and 1980s, driven by rapid economic development. During this period, asbestos cement products - such as roofing sheets and panels manufactured by companies like Eternit®, Fibronit®, and Uralita® - became ubiquitous worldwide (Cortesi, 2026).

Owing to the remarkable technological properties of asbestos, combined with its low cost, it has been widely used in the industrial production of a broad range of objects, including furnishings and vehicles, many of which have now become part of cultural heritage. In parallel, asbestos and ACMs were intentionally employed by architects, artists and designers to enhance specific functional or aesthetic qualities. Furthermore, given the low cost of asbestos cement sheets and their excellent performance as a support for oil painting, many artists have used them to paint their works.

As a result, nowadays, a diverse array of artefacts with historical and artistic value contain asbestos. Beyond well-known art forms such as religious and civil buildings, frescoes, murals, wall paintings, sculptures, art plasters and stuccos, mineral and natural collections, and contemporary installations, modern ACCHIs also include musical instruments, vehicles, historic World War gas masks and helmets, radio and film equipment, decorative ceiling panels, theatre curtains, furniture, decorative garden vases, lamps and safety lamps, interior bookcases, and even pinball machines.

A comprehensive review of objects containing asbestos and currently considered part of cultural heritage is beyond the scope of this manuscript and is the subject of ongoing work.

4. Decision-support workflow for asbestos hazard assessment and management

The heritage of asbestos-containing artefacts (ACCHI) is far more extensive than commonly recognised, ranging from everyday objects to industrial complexes and means of transport, and encompassing architectural heritage, archaeology and industrial archaeology, and works of art that are often undocumented or insufficiently recorded. In this complex scenario, cultural heritage institutions and their staff face the dual challenge of preserving cultural and historical assets while simultaneously ensuring the health and safety of art professionals and visitors.

To accomplish this goal, the authors propose a structured approach to detecting asbestos in ACCHI, assessing handling risks, defining management procedures for intervention and conservation purposes, and establishing a periodically updated ACCHI registry. By linking screening outcomes, analytical evidence, risk assessment, monitoring actions, and institutional documentation, this workflow is intended to support adaptive management of asbestos hazards over time.

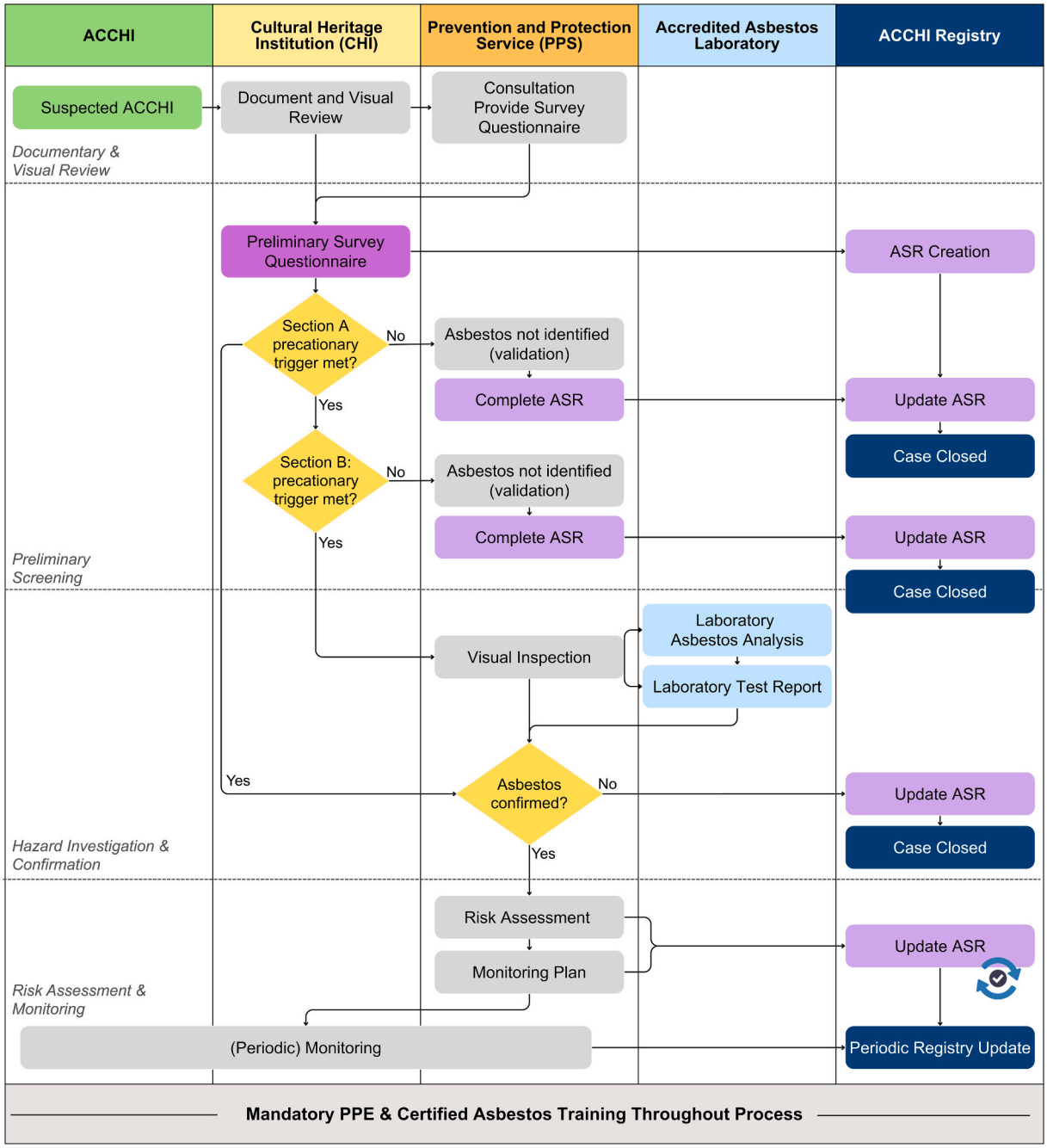


Fig. 1. Swimlane diagram illustrating the workflow for asbestos assessment and risk management in cultural heritage institutions and sites (CHI). The process involves five main actors, identified by distinct colours: asbestos-containing cultural heritage items (ACCHI, green), cultural heritage institutions (CHI, yellow), the Prevention and Protection Service (PPS, orange), accredited asbestos laboratories (light blue), and the ACCHI Registry (blue). The workflow is read from top to bottom and from left to right and is organised into four sequential stages: Documentary and Visual Review; Preliminary Screening; Hazard Investigation and Confirmation; and Risk Assessment and Monitoring. Operational activities are represented by rounded grey rectangles, decision points by yellow diamond shapes, and document-related actions by purple boxes. Throughout all phases of the procedure, professionals handling ACCHI must use asbestos-specific personal protective equipment (PPE). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Within this framework, hazard assessment refers to the identification and characterization of asbestos-containing materials, whereas risk assessment considers the likelihood of fibre release and potential human exposure under specific use, handling, or conservation scenarios. Accordingly, asbestos presence alone does not imply exposure, which depends on the potential for fibre release under specific material conditions and disturbance scenarios.

The decision-making flowchart shown in Fig. 1 illustrates the process for assessing and managing the hazard of asbestos in cultural heritage suspected of containing asbestos and the risk when its presence is confirmed. It outlines the interactions among five main actors, as listed and described below.

i. Asbestos-Containing Cultural Heritage Items (ACCHI; first row, green swimlane in Fig. 1), namely any artefacts, monuments, buildings and sites having an outstanding historical, artistic, archaeological, architectural, scientific, or technological value and that are suspected or known to contain asbestos.
ii. Cultural Heritage Institution (CHI; first row, yellow swimlane in Fig. 1) refers to any organization whose primary mission involves the conservation, preservation, and promotion of cultural heritage. This encompasses entities such as museums, libraries, archives, churches, art galleries, and theatres. CHI are typically characterised by the presence of designated management and/or specialised conservation teams tasked with executing and upholding this mission. CHI are responsible for the proper care, storage, conservation, handling operations, and documentation of cultural heritage, as well as for conducting preliminary screening to identify suspected or known ACCHI requiring further asbestos assessment.
iii. Prevention and Protection Service (PPS; first row, orange swimlane in Fig. 1) indicates the specialised technical unit responsible for coordinating activities related to hazard assessment and occupational risk prevention and protection, with the aim of improving workplace health and safety conditions (in accordance, for example, with the European Recommendation 2025/2609 of 18 December 2025 on the management of occupational risks, including asbestos-related risks, in working activities and associated sites). Within this framework, PPS is used as a generic term to indicate the entity responsible for occupational health and safety management, which may vary according to national regulations and institutional structures.
iv. Accredited asbestos laboratories (first row, light blue swimlane in Fig. 1), refer to laboratories that have been assessed and certified to meet stringent standards for asbestos analysis on different materials and matrices (air, bulk materials, soil/rocks, water). As an example, in Italy, the laboratory accreditation is coordinated by the Ministry of Health (https://www.salute.gov.it/new/it/tema/rischio-chimico/laboratori-che-effettuano-analisi-sullamianto).
v. ACCHI Registry (first row, dark blue swimlane in Fig. 1), consisting of a proposed dynamic and continuously updated documentation system intended to track the occurrence, conservation condition, monitoring activities, and interventions associated with suspected or confirmed ACCHI over time. The Registry is conceived as an asbestos-specific documentation system that can be integrated with existing museum, collection, or institutional record-management systems rather than as a stand-alone database. Interoperability may be supported through shared object identifiers and cross-referencing with existing institutional catalogue records. Each registry record may include, at minimum, a unique identification code, basic information on the cultural heritage item and its location, material and conservation condition, and the associated Asbestos Survey Reports (ASR). Such a registry could support institutions in the systematic documentation and adaptive management of suspected or confirmed asbestos within collections, buildings, and heritage sites.

The process begins with cultural heritage institutions (CHI) conducting a historical-documentation review and a visual survey of each artefact, monument, building, or site potentially associated with the presence of asbestos, either as a primary component or as a contaminant (see Fig. 1, Document and Visual Review, in the grey activity box). CHI management and/or conservation teams are required to verify the available historical information (i.e., archive documentation, previous Asbestos Survey Reports), taking into account factors such as material composition, dating, and provenance.

In cases where the presence of ACCHI is suspected, the CHI must contact the Prevention and Protection Service (PPS) and complete the preliminary survey questionnaire (see Fig. 1, Preliminary Survey Questionnaire, in the purple document-related box). The template of the proposed survey questionnaire is shown in Fig. 2, and the full edited version is provided in Supporting Information S1. Two case-study examples of completed Asbestos-Containing Cultural Heritage.

Survey Questionnaires are included in Supporting Information S2A and S2B. This stage of the survey can be conducted using various sources of information that are already available or readily obtainable, through a series of cascading questions.

The Asbestos-Containing Cultural Heritage Survey questionnaire consists of a brief open-ended description of the item, followed by two screening sections, Section A (subdivided into A1 and A2) and Section B, based on “Yes”, “Unknown”, “No” questions and answers. Section A addresses the assessment of the potential presence of commercially manufactured ACMs, as well as the geographical provenance, documentary evidence, dating of the artefact (Section A1; Fig. 2 and Supplementary Materials S1), and the evaluation of the mechanical condition of the material, focusing on indicators of friability (Section A2, Fig. 2 and Supplementary Materials S1). Section B addresses the main components and technological properties of the cultural heritage item. It evaluates the constituent components and their potential technological functions, particularly those related to insulation (thermal, acoustic, electrical, or mechanical), which may historically have involved the use of asbestos (Fig. 2 and Supplementary Materials S1). Questionnaire responses are assigned a weighted score of 1 for “Yes”, 0.5 for “Unknown”, and 0 for “No”. The intermediate 0.5 weight assigned to “Unknown” reflects unresolved information that does not constitute affirmative evidence but cannot be considered equivalent to a negative response. Section-specific operational thresholds reflect the different purpose of each questionnaire component. In Section A1, a score of 4.0/4 requires complete convergence of the four compositional, geographical, historical, and documentary indicators and meets the precautionary screening threshold. Section A2 uses a threshold of $\geq$1.0/2 because it addresses material friability and mechanical condition; reaching this score requires immediate precautionary action and PPS consultation. Scores below the Section A1 threshold, in the absence of an A2 trigger, require continuation of the assessment through Section B. In Section B, a cumulative score $\geq$ 4.0/11 meets the precautionary screening threshold and requires further professional assessment and consultation with the PPS, whereas intermediate scores (2.5–3.5/11) require continuation of the assessment. Scores $\leq$2.0/11 do not exclude asbestos presence. The proposed scoring configuration and operational thresholds were examined through an exploratory robustness assessment using literature-informed cultural heritage profiles representing different historical periods, geographical locations, material compositions, and technological functions. Alternative scenarios varied the weight assigned to “Unknown” responses and the Section B decision threshold, and the resulting screening outcomes were compared through an exploratory threshold sensitivity analysis. Full details of the scoring scenarios, literature-informed profiles, and sensitivity and robustness assessment are provided in Supplementary Materials S3 (Tables S3A-S3D).

Asbestos Containing Cultural Heritage Survey Questionnaire

This questionnaire provides a structured screening tool for the preliminary identification of cultural heritage (CH) items that may require further asbestos-specific assessment.

Complete this checklist before any handling activity involving the CH item, including packaging, transport, cleaning, restoration, or diagnostic analysis. Scoring: Yes = 1; Unknown = 0.5; No = 0.

Brief description of the cultural heritage item under investigation

.....
.....
.....

Section A1	Material composition, geographical provenance, and historical period	Yes	Unknown	No
A1.1	Does the CH consist partially or entirely of commercially manufactured asbestos materials? (*e.g.*, products branded as *Eternit®, Uralite®, Fibronit®, Rovana™*)	☐	☐	☐
A1.2	Does the CH originate from a geographical area located near natural asbestos deposits or sites of asbestos industrial activity? (*e.g., the Western Alps, IT Broni, ES Cerdanyola del Vallès*)	☐	☐	☐
A1.3	Is the CH datable to the 20th century (*i.e., the period of commercial introduction and widespread use of asbestos*)	☐	☐	☐
A1.4	Is there any historical and/or archival documentation suggesting the presence of asbestos in the CH under investigation?	☐	☐	☐

A1 score: ____ / 4

Section A1: A score of 4.0/4 meets the precautionary screening threshold. Scores <4.0/4 require continuation of the questionnaire.

Section A2	Assessment of material friability/compactness	Yes	Unknown	No
A2.1	Does the CH visibly exhibit powdery parts and/or surface fibres?	☐	☐	☐
A2.2	Does the CH appear prone to fragmentation and/or pulverisation under gentle mechanical stress (i.e., manual handling)?	☐	☐	☐

A2 score: ____ / 2

Section A2: A score ≥1.0/2 requires immediate precautionary action. A score of 0.5/2 indicates an intermediate material-condition outcome requiring continued assessment. A score of 0/2 indicates that no material-condition trigger was identified.

Section B	Main components and technological properties	Yes	Unknown	No
B.1	Is the CH made of materials other than metal, glass, or wood? (*include any other materials, even if present in minor parts or components*)	☐	☐	☐
B.2	Does the CH contain organic or inorganic fibres of unknown or difficult-to-identify origin? (*e.g., cloths and threads, drywall joint tapes, book bindings, flame-retardant fabrics, theatre curtains*)	☐	☐	☐
B.3	Does the CH contain stone elements? (*e.g., sculptures or sculptural components, stone blocks used in construction*)	☐	☐	☐
B.4	Does the CH contain cement-based binders or manufactured building materials? (*e.g., mortars, plaster, slabs, panels, surface preparation layers for painting, pipes, bituminous products*)	☐	☐	☐
B.5	Does the CH contain putties, pastes, mastics or other modelled components? (*e.g., mouldable pastes, resins, wall or wood putty, glazing mastics*)	☐	☐	☐
B.6	Does the CH contain components made of Bakelite, Paxolin, or other synthetic resins? (*e.g., Knobs, composite synthetic materials, Formica®, furniture elements*)	☐	☐	☐
B.7	Does the CH contain heat-generating components that may require thermal insulation or fire protection? (*e.g., heating elements, light bulbs, projector lamps, thermionic valves*)	☐	☐	☐
B.8	Does the CH contain components that may require insulation for heat, sound, vibration, or friction? (*e.g., slabs, panels, felts, cardboard, paper, bearings, insulating shells, spray coatings, friction materials*)	☐	☐	☐
B.9	Does the CH contain components that may require electrical insulation? (*e.g., fuse holders, lamp holders, junction boxes, textile-covered wires, arc protection shields*)	☐	☐	☐
B.10	Does the CH contain components designed for hydraulic or pneumatic sealing? (*e.g., gaskets, textile braids, cords*)	☐	☐	☐
B.11	Are there any parts of the CH that are not accessible for visual inspection?	☐	☐	☐

B score: ____ / 11

Section B: A score ≥4.0/11 meets the precautionary screening threshold. Scores of 2.5-3.5/11 require continuation of the assessment. Scores ≤2.0/11 do not exclude asbestos presence.

Date of completion .....

Signature of Responsible Person .....

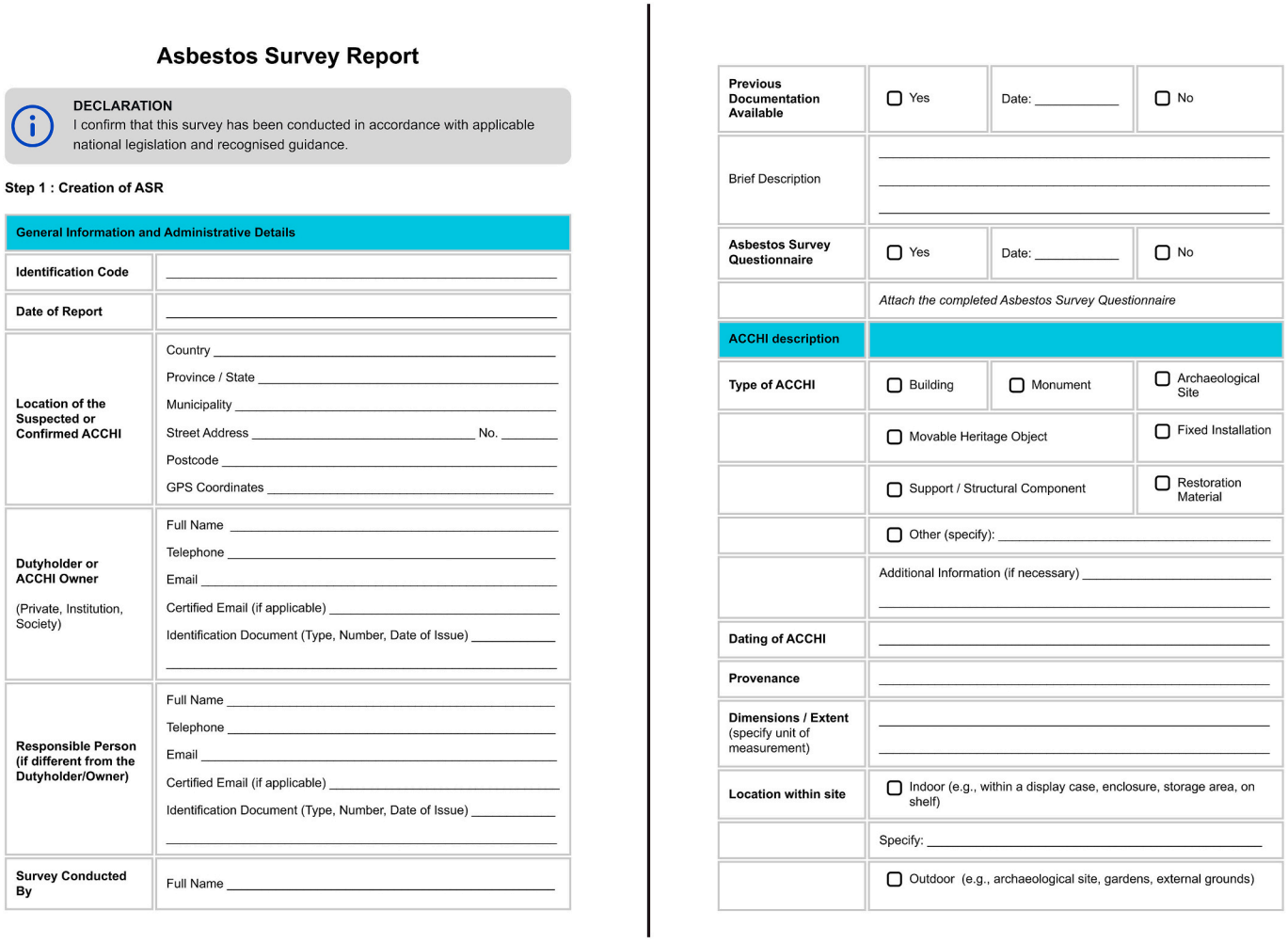
The resulting scores support decision-making but are not intended as direct quantitative estimates of asbestos. This preliminary screening questionnaire must be completed, retained, and accompany the CH item for future reference. It should form part of the documentation associated with suspected or confirmed ACCHI within the ACCHI Registry.

Fig. 2. Template of the Asbestos-Containing Cultural Heritage Survey questionnaire to be completed by cultural heritage institutions (CHI) management and/or conservation teams before any handling activity to support preliminary screening for potential asbestos presence. Two examples of completed ACCHI Survey Questionnaires are provided in Supporting Information S2A and S2B, respectively, addressing the Babcock & Wilcox boiler (Cortesi et al., 2025) and asbestos composites associated with the production of Byzantine wall paintings (Kakoulli et al., 2014).

This investigation should be carefully documented through an official ASR for each suspected or subsequently confirmed ACCHI (Fig. 3 and Supporting Information S4). The ASR provides the structured asbestos-specific record supporting the ACCHI Registry and progressively incorporates screening results, material-condition information, analytical evidence, and subsequent assessment outcomes. The ASR serves as the starting point for subsequent stages of the process. The investigation then proceeds according to the flowchart presented in Fig. 1 and discussed below.

The Prevention and Protection Service (PPS) provides professional advice. If the precautionary screening thresholds are not met (scores in Sections A and B), the PPS reviews the available information and determines whether further examination is considered necessary. Where no additional investigation is considered necessary, the PPS completes the ASR and submits it to the ACCHI Registry. The procedure is then concluded (Case Closed). If the screening thresholds are met, or if uncertainty remains following PPS review, the PPS coordinates additional examination measures. An inspection carried out by PPS or qualified asbestos experts includes a thorough visual examination of the cultural heritage item and its surrounding environment (e.g., exhibition area, storage area). Specialised procedures and equipment are adopted to prevent any asbestos exposure event, even when asbestos presence is only suspected at this stage. The inspection determines whether laboratory investigations are required. Where analytical evaluation is deemed necessary, the PPS liaises with an accredited asbestos laboratory to define the appropriate sampling and analytical strategy. Depending on the type, condition, and size of the object, this may involve in situ analyses by portable instruments, in situ sampling collection or transport of the entire item. The laboratory conducts the analytical investigations and issues the official Test Report in accordance with applicable accreditation and legislative requirements. The analytical outcome and the associated Test Report should subsequently be incorporated into the ASR and linked ACCHI Registry record, ensuring that the documentation reflects the current asbestos status of the cultural heritage item. This approach ensures procedural continuity and strengthens the coordinated roles of the CHI and the PPS in subsequent decision-making.

Sampling operations may be carried out by qualified laboratory personnel, trained conservation scientists, or specialised and trained operators. Micro-sampling is permitted when minor damage to the cultural heritage item is acceptable within the conservation framework, and may require supervision by the CHI conservator. When sampling is feasible, asbestos identification generally relies on electron microscopy techniques, such as scanning electron microscopy (SEM) or transmission electron microscopy (TEM), coupled with energy-dispersive X-ray spectroscopy (EDS) (Millette and Compton, 2024), or on other recognised analytical methods included in applicable standards, such as the ISO 22262 series. When sampling is not allowed, non-destructive or minimally invasive techniques, such as portable handheld Raman spectroscopy, may be employed (Bloise and Miriello, 2022; Petriglieri et al., 2020). Analyses should be performed using validated methods and appropriate quality-assurance procedures, in accordance with



Asbestos Survey Report

DECLARATION
I confirm that this survey has been conducted in accordance with applicable national legislation and recognised guidance.

Step 1 : Creation of ASR

General Information and Administrative Details	
Identification Code	_____
Date of Report	_____
Location of the Suspected or Confirmed ACCHI	Country _____ Province / State _____ Municipality _____ Street Address _____ No. _____ Postcode _____ GPS Coordinates _____
Dutyholder or ACCHI Owner (Private, Institution, Society)	Full Name _____ Telephone _____ Email _____ Certified Email (if applicable) _____ Identification Document (Type, Number, Date of Issue) _____ _____
Responsible Person (if different from the Dutyholder/Owner)	Full Name _____ Telephone _____ Email _____ Certified Email (if applicable) _____ Identification Document (Type, Number, Date of Issue) _____ _____
Survey Conducted By	Full Name _____

Previous Documentation Available	☐ Yes	Date: _____	☐ No
Brief Description	_____ _____ _____		
Asbestos Survey Questionnaire	☐ Yes	Date: _____	☐ No
	Attach the completed Asbestos Survey Questionnaire		
ACCHI description			
Type of ACCHI	☐ Building	☐ Monument	☐ Archaeological Site
	☐ Movable Heritage Object		☐ Fixed Installation
	☐ Support / Structural Component		☐ Restoration Material
	☐ Other (specify): _____		
	Additional Information (if necessary) _____ _____		
Dating of ACCHI	_____		
Provenance	_____		
Dimensions / Extent (specify unit of measurement)	_____ _____		
Location within site	☐ Indoor (e.g., within a display case, enclosure, storage area, on shelf)		
	Specify: _____		
	☐ Outdoor (e.g., archaeological site, gardens, external grounds)		

Fig. 3. First two pages of the Asbestos Survey Report (ASR) template developed for the identification, documentation, and long-term management of suspected or confirmed asbestos-containing cultural heritage items (ACCHI). The ASR provides the core asbestos-specific information to be incorporated into the ACCHI Registry, including administrative data, material condition, analytical results, risk assessment, management measures, and monitoring updates. The complete editable template is provided in Supplementary Materials S4.

internationally recognised standards and applicable national requirements.

If asbestos is confirmed, the PPS may develop a site-specific risk assessment and monitoring plan, and the relevant information may be incorporated into the ACCHI Registry. The site-specific risk assessment should consider the conservation condition and friability of the asbestos-containing material, its accessibility and potential for fibre release under normal or reasonably foreseeable activities, the type and frequency of handling or disturbance, occupancy and use patterns, and existing control measures. Risk assessment and subsequent management measures should, in all cases, be implemented in accordance with applicable national legislation and national occupational health and safety requirements. Future quantitative developments of the framework could incorporate these variables within established asbestos risk-assessment approaches, following adaptation and validation for heritage-specific settings. Based on the assessment outcomes, the CHI and PPS may define and implement a tailored ACCHI monitoring programme that reflects the specific characteristics of the cultural site or object.

The PPS determines the frequency of periodic monitoring inspections based on the type, location, conservation condition, and use of the ACCHI. For example, monitoring requirements will differ between an outdoor archaeological site exposed to atmospheric agents and an object permanently housed in a controlled display case. Where necessary, an air-monitoring programme may also be implemented to ensure the safety of on-site personnel and visitors. The ACCHI Registry records should be updated whenever monitoring identifies relevant changes in material condition, accessibility, location, or management measures, as well as following conservation interventions or new analytical investigations. Each update should be dated and attributed to the responsible operator or service to preserve the chronological history of the ACCHI. Based on the monitoring results, remedial actions may be defined and implemented. These may include containment, encapsulation, or, where appropriate, removal of asbestos-containing material, while safeguarding the physical integrity and historical significance of the heritage item. The programme also includes provisions for ongoing follow-up monitoring over time, in accordance with best practices and applicable regulations.

Conversely, if laboratory analyses confirm the absence of asbestos, the asbestos-related assessment process may be formally concluded and the outcome documented within the ACCHI Registry.

It is important to emphasise that the workflow proposed herein is designed as a generalised framework intended to cover a broad spectrum of artefacts, monuments, and architectural structures classified as cultural heritage. Category-specific protocols should be developed to address the distinct technical and conservation requirements associated with different ACCHI. Given the variability of materials and construction techniques, intervention protocols should be implemented on a case-by-case basis, while remaining consistent with the decision-making

flowchart described above.

Throughout all phases of the procedure, professionals who come into contact with ACCHI must use asbestos-specific personal protective equipment, including respiratory protective equipment (half mask FFP3), nitrile gloves, eye protection, disposable workwear (full-body coverall in high-density polyethylene synthetic material), and appropriate footwear (EU Directive 2009/148/EC). Additionally, all personnel directly involved in asbestos-related tasks must have completed the required training before starting the project. Asbestos specialists and workers must hold up-to-date advanced asbestos training certifications and be licensed to carry out asbestos operations (e.g., containment, restoration, removal, etc.).

Although the questionnaire scoring scheme and operational thresholds were examined through an exploratory robustness assessment, the proposed framework as a whole has not yet been systematically evaluated through prospective application in real institutional collections, heritage sites, or conservation projects. Such evaluation will require dedicated case-study-based research involving coordinated participation of conservation, occupational health and safety, analytical, and institutional stakeholders over an adequate implementation period. Future applications will provide the opportunity to assess its operational feasibility, further refine the screening and management procedures, and evaluate the effectiveness of the framework under realistic management conditions. The present work does not address operational procedures concerning the handling or disturbance of ACCHI. A dedicated manuscript describing a specific protocol for the safe ACCHI movement and manipulation is currently under preparation.

5. Conclusions

A large number of objects, textiles, machinery, and monuments produced worldwide from antiquity to modern times contain asbestos either intentionally incorporated or naturally present. Many of these items fall within the category of cultural heritage and are currently housed in museums, private collections, historical archives, archaeological sites and other heritage complexes. Despite the extensive regulatory framework governing asbestos in construction materials and industrial contexts, specific regulations or widely adopted guidelines addressing the identification, handling, and management of ACCHI remain largely absent. Consequently, the protection of both heritage professionals (e.g., conservators, curators) and users of cultural spaces (e.g., visitors) remains insufficiently addressed in this context.

Evidence from isolated studies suggests that some CHI have started to develop internal procedures to manage ACCHI. These initiatives remain fragmented and limited to individual experiences. This situation highlights the need for a shared scientific framework capable of guiding institutions in the identification, documentation, and risk management of ACCHI.

The framework proposed in this work provides a basis for structured decision-support in asbestos hazard governance and risk management for cultural heritage assets. A key step consists of a structured preliminary screening questionnaire designed to identify cultural heritage items that may require further asbestos assessment before any handling activity. When a section-specific precautionary screening trigger is met, the procedure requires the involvement of the Prevention and Protection Service, enabling the adoption of appropriate precautionary measures and continuation of the assessment workflow. The framework also attempts to classify the operational roles and interactions among the key actors involved in the process, including CHI personnel, PPS experts, and, where necessary, accredited asbestos laboratories.

The proposed protocol further supports the systematic documentation of ACCHI through the use of the Asbestos Survey Report (ASR) and recommends the adoption of a dedicated ACCHI Registry as a tool for long-term documentation and management. These tools enable the implementation of a tailored risk assessment plan and monitoring programmes aimed at ensuring the safe management of ACCHI over time. Periodic re-inspections and registry updates allow institutions to track changes in material condition, eventual repositioning and potential exposure risk while maintaining the long-term conservation and accessibility of heritage items.

Overall, the proposed framework provides a practical and adaptable model that cultural heritage institutions can integrate into their existing management system, offering a structured approach to address the complex challenge posed by asbestos within heritage collections and sites. Future institutional applications will provide further opportunities to evaluate the framework under real-world conditions and refine its operational decision criteria.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare the use of AI-assisted technologies - ChatGPT, powered by GPT-5.6 (OpenAI), through the ChatGPT Edu service provided under the University of Turin institutional subscription- to improve the English language and readability of the manuscript. The authors reviewed and edited the output as needed and take full responsibility for the content of the published article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eiar.2026.108734.

Data availability

No data was used for the research described in the article.

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