Cyclododecane as Temporary Consolidant for Asbestos-Containing Fill Material in Historic Osteology Specimens

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INTRODUCTION

Historically prepared and treated collection materials can pose an increased risk to specimen safety and human health, especially during conservation treatment. For example, several osteology specimens on exhibit at the National Museum of Natural History (NMNH) reflect early 20th century techniques that incorporated asbestos-containing plaster fill material. If disturbed during handling or treatment, these asbestiforms may pose an inhalation hazard to collection care personnel, other Museum staff, and the public. Our goal is to develop a mechanism for the stabilization and temporary encapsulation of asbestos-containing plaster in order to safely de-install specimens for conservation treatment. The authors explored the application of cyclododecane as a temporary consolidant of asbestiform plaster via three application methodologies on mock-up samples. The consolidation efficacy was assessed quantitatively via microvacuum sampling and transmission electron microscopy (TEM) analysis of asbestos fiber levels [ASTM D5755].

ASBESTOS

Asbestos, a naturally occurring silicate mineral in several fibrous polymorphs, was widely used throughout the 19th and 20th centuries as an insulator, fire-retardant, and filter material (fig. 1). Common asbestos-containing products include brake pads, shingles, building tiles, and plaster. Its role in causing a variety of diseases, including cancer, primarily through inhalation exposure led to bans in the 1970s on production and use of most forms in the U.S.

Fig. 1. Asbestos specimen of chrysotile (middle fibrous band) in lizardite matrix (NMNH 91261)
Photo: Rebecca Kaczkowski

Fig. 2. An exhibit preparator creating a plaster model of a python, ca. 1960
Image: MNH-36818A, Smithsonian Institution Archives

In the museum, asbestos can be found in a variety of places that are both surprising and potentially dangerous for an unwitting museum professional. In addition to laboratory sinks, fume hoods, and other building applications, asbestos has also been identified as a bulking agent for plasters used as fill materials on specimens (fig. 2). Specifically, the serpentine polymorph chrysotile was identified on several osteology mounts at NMNH, necessitating deinstallation and conservation treatment plans for the safety of the specimens, staff, and visitors.

CYCLODODECANE

Since the 1990s, conservators have adopted cyclododecane (CDD) as a temporary consolidant based on several unique properties (table 1).

Common Uses:
Consolidant: affords strength to an artifact during transit or treatment.

Barrier coating: masks water- or solvent-sensitive areas during treatment or protect surfaces from direct contact with casting & mold materials.

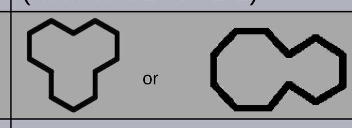
Application Methods:
Hotmelt: Heat over a double-boiler to apply by brush or melt directly with a modified heat spatula tip (fig. 3).

Solvent-borne: Create a saturated solution in an aromatic or non-polar solvent to brush on.

Fig 3. Modified heat spatula tips
Image: http://www.willard.co.uk

Some Challenges & Unknowns:
Using CDD as a hotmelt can be tricky due to rapid cooling; solvent- borne solutions can alter the resulting crystalline formation and affect efficacy (Brückle et al.; Rowe et al.; Stein et al.). Controlling the sublimation rate with consolidation efficacy is also challenging, and questions of potential residues remaining upon sublimation and subsequent aging of treated areas are not resolved (Cagna et al.; Pohl et al.).

Table 1. Cyclododecane Properties
(Kremer Pigmente MSDS & NIST Chemistry WebBook)

Chemical Characterization	Cyclododecane 100% (CAS No. 294-62-2)
Structure	
Formula	$C_{12}H_{24}$
Form	waxy solid
Solvent Compatibility	non-polar and aromatic
Melting Point	60.65°C (333.8K ± 0.3K)
Boiling point	247°C
Flash point	>93°C
Vapor Pressure	0.028 mm Hg (50°C)
Enthalpy of Sublimation	76.2 kJ/mol

HEALTH & SAFETY

Fig. 4. Fossil preparators preparing to deinstall the Museum's mastodon within an abatement enclosure, modeling their personal protective equipment.
Photo: Research Casting International

When maintained in good condition, asbestos-containing materials do not pose a health risk. Asbestos, however, becomes a hazard when, due to damage, disturbance, or deterioration, fibers are released into the air (table 2). Asbestos exposure can lead to asbestosis (a disease characterized by scarring of the lungs), mesothelioma (a disease characterized by cancer in the lining of the lung), and lung cancer. While a dose-effect relationship has been established between the inhalation of airborne asbestos fibers and these diseases, the levels of asbestos in settled dust does not directly correlate to airborne asbestos levels. The hazards posed from surface asbestos contamination can be mitigated through encapsulating or by enclosing the surface in an airtight barrier (fig. 4).

Very little is known about the hazards associated with cyclododecane (CDD) exposure (table 3). A literature review suggests that CDD is not acutely toxic when classified using criteria established by the OSHA Hazard Communication Standard. Occupational exposure limits have not been established for CDD. Because other cyclic alkanes are capable of causing headaches, dizziness, and disorientation, good hygiene practices are warranted when working with CDD. We suggest keeping containers capped when not in use, and ventilating the work area. Museum staff should avoid breathing CDD vapors and wear chemical protective gloves and lab coat. A safety specialist or industrial hygienist should be consulted for workplace-specific controls.

Table 2: Asbestos Quick Facts
(TOXNET NIH Online Database)

Hazard	Disturbed asbestos fibers rendered airborne
Adverse Health Effect	Asbestosis, mesothelioma, and lung cancer
Exposure method	Inhalation or ingestion
Mitigation & Protection	Encapsulation of fibers, enclosing surface in an airtight barrier

Table 3: Cyclododecane Quick Facts
(TOXNET NIH Online Database)

Hazard	Cyclododecane vapor
Adverse Health Effect	Unknown
Exposure method	Inhalation and dermal contact
Mitigation & Protection	Seal CDD containers, use ventilation and wear lab gloves & coats

MICROVACUUM SAMPLING & QUANTITATIVE ANALYSIS

Microvacuum samples were collected using ASTM Method D5755-09—a standard method used in the environmental industry for measuring surface asbestos structure loading.

Figs 5 & 6. Air sampling kit fully assembled to ASTM guidelines (above); detail of the sampling cassette (below).
Photos: Rebecca Kaczkowski

Materials:
An air sampling pump, calibrated at 2.0 liters per minute (LPM), connected via Tygon® tubing to a 25mm sampling cassette housing a 0.8µm mixed cellulose ester (MCE) filter (figs. 5 and 6). A plastic nozzle was placed over the inlet to the cassette and cut at a 45º angle to improve dust capture.

Procedure:
The surface area of each plaster section was measured and a microvacuum sample was collected via four passes of the nozzle immediately over the surface. After collection, sample cassettes were sealed and shipped to RJ Lee Group Inc., where the surface dust was washed from the MCE filter with a 50/50 mixture of ethanol and distilled water then brought to a volume of 100ml. Aliquots were pulled from the suspension, filtered onto a 25 mm polycarbonate filter and transferred to a TEM grid where asbestos structures were identified, measured, and counted.

APPLYING THE APPROACH

PREPARING MOCKUPS

Samples of asbestos-containing plaster were harvested from several modeled sections of the recently deinstalled mastodon (*Mammut americanum*, USNM 8204) (fig. 7). A sample of the bulk plaster was analyzed by polarized light microscopy and found to contain 10% chrysotile. The plaster was sectioned into nine pieces using a wet saw in the fume hood, and three CDD hotmelt application methods were explored (fig. 8).

Figs. 8 & 9. Mastodon (USNM8204) on exhibit (above); sectioned ribs in the fume hood (below).
Photos: Rebecca Kaczkowski

Cyclododecane Application Methods:
Samples 1, 6, 9: melted CDD brush applied approximately 2mm thick from double boiler (fig. 9).
Samples 2, 4, 8: Sheets of thin Reemay® impregnated with melted CDD; sheets tacked onto samples with a heat spatula and silicon brush (figs 10-13).
Samples 3, 5, 7: hybrid of the first two—brush-applied 2mm thick base coat with CDD-impregnated Reemay® tacked onto samples.

Figs. 11-13. Creating heat-reactivated CDD Reemay® sheets.
Photos: Boudicca Buteau-Duitschaever

Figs. 9 & 10. Brush applying molten CDD (above); adhering heat-reactivated Reemay® to a coated sample (below).
Photos: Boudicca Buteau-Duitschaever

EXPERIMENTAL

To ascertain the effectiveness of the CDD treatments for encapsulating asbestos structures, microvacuum samples were collected from the surface of the nine plaster sections before treatment (baseline), immediately after treatment, and on days 8 and 14 following treatment. Baseline samples were collected immediately after sectioning.

One week later, CDD was applied to the plaster using the three methods described above (figs. 14-16). Samples 1-3 were left in the fume hood for the duration of the experiment, while samples 4-6 were transferred to a 1744ft² collections workroom and samples 7-9 were transferred to a sealed collections cabinet within the workroom. Microvacuum samples were collected *in situ*.

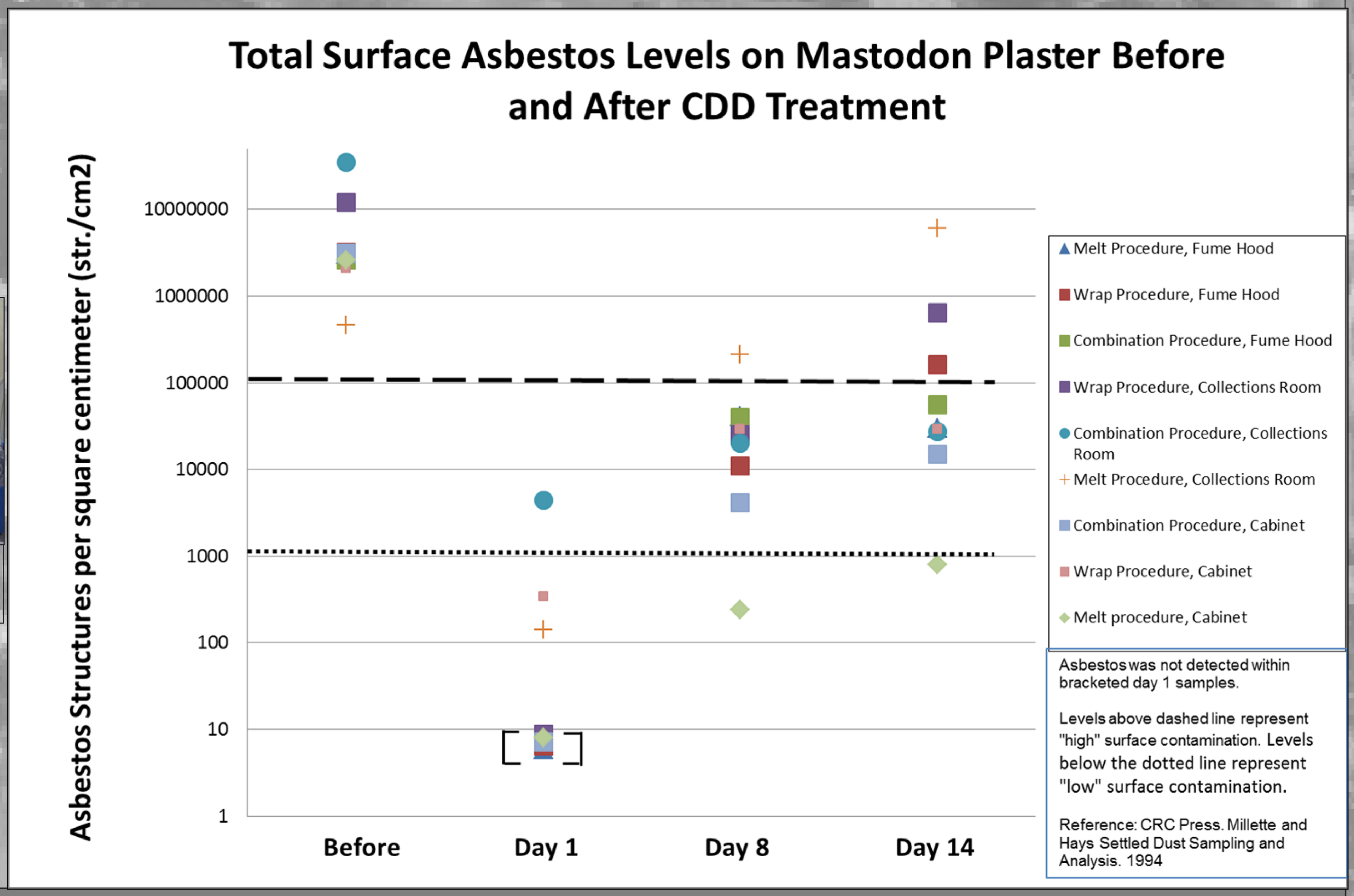
Figs. 14-16. Samples 1-3 in fume hood; samples 4-6 in workroom; samples 7-9 in collections cabinet.
Photo: Rebecca Kaczkowski

The post-treatment surface asbestos levels were compared to the before-treatment levels using a paired t-test (all procedures pooled), and the levels graphed. Evaluation guidelines employed within the environmental industry were used to assess the effectiveness of the treatment.

DATA & RESULTS

Before CDD treatment, asbestos structure levels ranged from 460,000 to 35,000,000 structures per square centimeter (str/cm²), indicating a high level of surface contamination on all of the plaster sections. Immediately after treatment, asbestos structure levels ranged from <5.9 to 4,400 str/cm²—levels representing low surface contamination. The effectiveness of the treatment diminished over time. Surface asbestos structure levels ranged between 240 and 210,000 str/cm² 8 days after the CDD treatment, and 800 and 6,000,000 str/cm² 14 days after treatment. The measured surface asbestos structure levels on the CDD treated sections were statistically different from the baseline surface levels (on both day 1 and day 8 – all treatments pooled, $p < 0.1$).

Fig. 17. Michael Hunt measuring to the sample site and collecting Sample 1 data on day 14.
Photo: Rebecca Kaczkowski



CONCLUSIONS

The results of this study indicate an effect of the CDD treatments on the measured asbestos structure levels on day 1 and day 8 versus the baseline asbestos structure levels (p<0.1). The strength of the measured CDD effect is fairly weak, which we attribute to the large variability in asbestos-laden dust on the plaster surfaces. Surface asbestos levels rapidly increased during the study, presumably due to the sublimation of the CDD. Prior to use of CDD in deinstallation and transport of NMNH osteology specimens, more work is needed to characterize its effectiveness at mitigating the airborne asbestos inhalation hazard or at preventing the contamination of adjacent surfaces. Its effectiveness needs to be reviewed versus established techniques (e.g., plastic) in a controlled environment. This study lacked a sufficient number of samples to determine which treatment method was the more effective encapsulant for asbestos contaminated osteology specimens. Our expectation is CDD would sublimate more quickly within a fume hood versus a closed collections cabinet due to the higher air speeds expected in a hood.

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Background image: backscatter image of chrysotile in a sample of asbestos newsprint (USNM 76126); FEI Nova NanoSEM 600, acc. voltage15keV.

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