Assessment and Remediation of Corrosive Drywall

Guidance Document

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Project Team

Ed Light, CIH Project Team Lead

Lila C. Albin, PhD (deceased)

Ronald B. Bailey,

Christopher P. D'Andrea

Matt Divine, CIH, CIAQM

Tracey Dodd

Howard E. Ehrsham, PE

Alyson Fortune

Benjamin L. Kollmeyer, CIH

John R. Kominsky, CIH, CSP, CHMM, ROH

Shawn Macomber

Roger G. Morse

Michael Tuday

For background information on corrosive drywall, see AIHA's "White Paper on Corrosive Drywall," available on the AIHA website.

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1.0 Introduction

Corrosive drywall (CDW) contains gypsum contaminated with sulfur and can emit gaseous pollutants associated with blackening of metal surfaces, and a burnt-match-like odor. This document focuses on assessing structures for CDW and overseeing corrective measures. It includes procedures and supporting information for field practitioners and is intended to help answer basic questions such as, "Does my home or building have CDW?" and "How can I restore normal air quality?" In this document, the term "remediation" is limited to the decontamination process (i.e., removal/ treatment) and will not address restoration of corrosion damage. Consideration of corrosion damage is outside the expertise of most industrial hygienists and is discussed only in general terms. In addition, assessment of health risks is not included.

Collection of evidence for legal purposes and documentation for real estate transactions are also beyond the scope of this document.

CDW is a relatively new source of indoor environmental contamination and there are significant gaps in our understanding of this complex issue. This guidance is based on available data, field experience, and professional judgment, and will be updated as the subject evolves. While the assessment procedures included in this document are generally supported by scientific research and verified by field experience, remediation procedures are based on field experience only and have not been scientifically validated.

Photo 1: Most corrosive drywall was imported from China between 2005 and 2007.

2.0 Background

The earliest reports of CDW installation date back to 2001, and the importation of CDW from China ceased in 2007. Peak years of CDW use appear to have been between 2005 and 2007, and more recent use is relatively rare. It is estimated that tens of thousands of U.S. homes and buildings contain CDW. CDW appears to have originated from China, where naturally occurring high-sulfur gypsum was processed into drywall. Drywall containing elemental sulfur is consistently associated with corrosive emissions. These emissions are a complex, variable mixture of contaminants at the parts per billion (ppb) level, which includes corrosive and odorous sulfide gases. The sulfides appear to be produced by a chemical/ physical mechanism, with emissions increasing along with temperature and moisture.

Sulfide gases produced by CDW react with metal surfaces to form black corrosion (i.e., copper sulfide, silver sulfide). This corrosion has been associated with the failure of air-conditioning coils as well as damage to electrical and mechanical systems and contents of the building belonging to the occupant.

3.0 Performance Objectives

3.1 Assessment

The primary goal of an initial screening is to determine whether CDW is likely to be present in a structure. The initial screening can be followed by a more detailed investigation to conclusively establish whether a structure has CDW and to locate CDW within the structure. The results of a detailed investigation can be used to compile information needed to develop a mitigation plan.

3.2 Remediation

Where CDW is found to be present, the overall remediation goal is to restore air quality to non- CDW conditions. This is generally achieved by replacing all drywall ("full removal") or replacing only corrosive panels ("selective removal").

During drywall removal, be sure to:

- protect workers and occupants during demolition and cleanup
- replace insulation behind drywall panels
- eliminate dust to the extent feasible
- resolve residual odor

Additional requirements for CDW remediation may include:

- documenting drywall products for legal proceedings
- including procedures consistent with court decisions and federal guidelines where needed to resolve liability concerns
- adding more detailed testing and documentation to support real estate transactions or a warrantee

Photo 2: Blackening of copper surfaces indicates sulfur corrosion.

Budgetary limitations and time constraints may preclude full achievement of these objectives. In such cases, CDW emissions should be minimized to the extent feasible.

CDW remediation also includes corrective measures to address corroded electrical and mechanical systems. These issues are generally addressed either by full replacement (i.e., replacing all systems) or repair to a functional condition (i.e., replace or clean components as needed).

4.0 Assessment Procedures

Guidance for CDW identification has previously been issued by the U.S. Consumer Product Safety Commission (CPSC). This AIHA document provides a more comprehensive approach to the assessment of structures with respect to CDW. Federal CDW guidance is summarized in Section 4.6.

4.1 Decision-making Process

The basic goal of assessment is to determine whether CDW is present. CDW is generally ruled out where drywall was installed before 2001. A simple screening may be considered sufficient to classify the structure, with negative findings suggesting that CDW is unlikely to be present. However, more information is needed for a conclusive negative finding. If an initial screening establishes that CDW is widespread (i.e., present in most rooms), further investigation may not be needed. However, if CDW appears to be localized, further investigation is needed to consider selective removal.

After initial screening, additional evaluation may be needed to:

- confirm a negative finding
- confirm and map the location of corrosive panels
- delineate areas free of CDW
- determine source(s) of surface blackening where sewer gas or water containing hydrogen sulfide is suspected
- confirm that blackening is sulfide corrosion
- assess occupant exposure
- collect information needed to develop a mitigation plan

Please note that information needed to support litigation (i.e., identify CDW manufacturers) is beyond the scope of this document.

4.2 Initial Screening

An initial screening for CDW should generally include five basic steps:

- **Step One:** Site Documentation. Record dates of drywall installation and product information, where available. Construction history can help localize areas where CDW was used.
- **Step Two:** Interviews. Ask occupants and other knowledgeable parties about conditions they have observed, including detection of "burnt-match" odors, failures of electrical or mechanical systems, or blackening of personal contents, such as jewelry. Appendix C lists some example interview questions.
- **Step Three:** General Observations. Note site conditions that are potentially related to the presence of CDW or other sources of indoor contaminants. References 3 and 4, listed on page 14, discuss how to evaluate and classify odors.
- **Step Four:** Product Identification. Document accessible drywall labels and check against lists that suggest which drywall types are corrosive. One such list can be found at www.chinesedrywall.com.
- **Step Five:** Corrosion Inspection. Inspect metal surfaces for blackening. An initial screening typically includes opening one electric receptacle per room

and viewing accessible piping and contents. Testing of the drywall may be needed to confirm the presence of CDW where other sulfide sources are suspected.

Corrosion of metal surfaces caused by CDW emissions has a unique appearance: a black, soot- like coating, some of which rubs off when touched (often called "blackening"). This type of corrosion can be visually differentiated from corrosion related to oxidation, which is green or white in color, and from tarnishing caused by moisture, which is gray. Photographs are useful in documenting corrosive conditions.

The examination of the condition of the electrical system focuses on exposed copper and silver components, such as uninsulated ground wires and wire tips at connections. These can be observed by opening electric outlet covers. An outlet or switch usually has to be pulled out from the wall to allow for appropriate inspection. Investigators should be cognizant of electric shock hazards. This process should be performed with the electrical system shut off at the breaker controlling the circuit with lockout, tag, and try out (LOTTO) procedures. Note that "try out" is important to ensure the correct breaker is turned off. The receptacles can then be removed, and the bare ground wire or screw connections where the insulated coating has been removed can be inspected for corrosion.

Mechanical inspection for corrosion focuses on accessible metal plumbing fixtures and uninsulated copper piping, such as a cold-water pipe to a water heater or a refrigerant line to an air conditioner. Blackening is often most severe on the evaporator coils inside air conditioning units. Investigators should open A/C units and look for discoloration of coils and wiring.

The inspection should also note discoloration of other susceptible metal contents, such as mirrors and silverware.

Appendix A includes an example procedure for initially screening a structure for CDW.

4.3 Detailed Investigation

Detailed CDW investigations should include one or more of the following procedures:

- Perform a comprehensive corrosion inspection of all accessible locations.
- Scan drywall using a hand-held X-ray fluorescence instrument (XRF) to determine strontium content.
- Identify non-CDW sources of sulfide emissions.
- Locate drywall labels.
- Perform contact tests (i.e., in-place identification of CDW by attaching silver strips).
- Perform XRF scanning of discolored metal surfaces to confirm the presence of sulfur.
- Perform laboratory analysis (i.e., analyze bulk drywall samples for elemental sulfur content, perform chamber testing for sulfide emissions, or observe for copper corrosion in a jar test).

Air quality monitoring is normally not needed to determine whether CDW is present or to locate CDW panels. Measurement of air corrosivity can provide an indication of relative exposure for risk assessment and is important to the verification of remedial work (see Section 5.10).

Corrosion Inspection: All accessible sites, including light fixtures and breaker boxes, are evaluated following the procedure described in Initial Screening Step Five in Section 4.2.

Strontium Measurement (XRF): To measure metal content, scan materials with XRF. CDW is generally associated with elevated concentrations of strontium, although that element does not contribute to CDW emissions. Hand-held XRF monitors are available for field use and can be used to scan accessible drywall, although paint and wall coverings may

reduce or increase the drywall strontium reading. The use of XRF is a regulated practice with limitations specific to each state. XRF use must be performed by individuals who are familiar with the limitations of the method and specific instruments.

Potential classification errors stemming from the use of XRF can be avoided as follows:

- While strontium levels exceeding 1,200 to 1,800 ppm generally correlate with CDW, a few non-CDW drywall products also have elevated strontium content. False positive conclusions can be avoided by laboratory analysis of high-strontium drywall in areas without blackening, or by observation of drywall labels.
- Very rarely, some CDW may have low strontium content. This may be suspected where blackening is observed near low- strontium drywall and can also be resolved by bulk analysis or label observation.
- Where drywall is inaccessible (i.e., covered by attached cabinetry), similar strontium readings to those around the perimeter can be assumed unless corrosion inspection of the area suggests the presence of a different drywall product.
- Readings should not be considered representative where drywall mud/joint compound is likely to be present (i.e., around panel edges). This source of error can be avoided by taking multiple readings of a drywall panel and discounting the lowest values.
- In some areas, CDW may have only been used in small strips or patches. The XRF testing pattern areas must be of sufficient detail to find such exceptions in low strontium areas.
- To minimize classification errors, confirmatory laboratory analysis of drywall suspected of being CDW should be considered (see Section 4.4).

A series of detailed XRF readings throughout the structure can produce an accurate map of CDW locations, as long as potential errors are recognized and corrected. References 3 through 6 discuss how to adjust XRF readings to account for interferences from surface coatings.

Other Sulfide Sources: Blackening of metal surfaces may also be caused by a release of sewer gas or the presence of water containing hydrogen sulfide. Such sources may be readily apparent during initial odor evaluation (i.e., "rotten-egg" odor is detected). Intermittent sources may also be identified by compiling site history and conducting a detailed inspection. Outside the structure, note the presence of "rotten-egg" odor by irrigation water, standing water, or treatment facilities. The indoor screening should check for "rotten-egg" odor from the initial discharge of water taps, dry traps (commonly found in unused sinks or vacant homes), or unintended venting of sewer gas.

Photo 3: On-site XRF analysis can be helpful for locating corrosive drywall panels, but several factors must be considered in data interpretation.

Product Labels: Where accessible, product labels, drywall end tape, or other markings on installed drywall may indicate whether or not it is corrosive. Labels can be observed on unfinished drywall (i.e., in return air plenums, drywall ceilings open to the attic, unfinished areas where drywall remains open at the back, and through cut access holes). Identifying the bar code on an end tape allows the inspector to identify the drywall manufacturer, or, at a minimum, its country of origin. End tapes can often be identified behind removed baseboards with no boring necessary, though inspection holes can also be cut. Font, size, and color of lettering may be important for label classification. Lists of markings and labels that establish whether drywall is corrosive are available from sources such as www.chinesedrywall.com.

Contact Tests: If a drywall panel is corrosive, copper or silver placed in contact with the gypsum core will turn black in several days. This reaction can be utilized as a test procedure by inserting a pin, nail, or wire into the drywall. A commercially available test system provides silver strips to be placed over a small slit cut through the drywall face.

Corrosion Confirmation: While visual observation of metal blackening is generally accepted as a sign of sulfide corrosion, these confirmatory methods are available:

- An XRF analyzer with a silicon drift detector can be used to determine if sulfur has been deposited on a metal surface.
- Laboratory analysis by electron microscopy can also be used to confirm sulfide corrosion.
- Cleanroom coupons (copper and silver) can be placed in the suspect environment and then analyzed for sulfides.

4.4 Laboratory Analysis of Bulk Drywall Samples

CDW emissions are consistently associated with the presence of an a l lotrope of elemental sulfur in drywall: orthorhombic cyclooctasulfur. Bulk drywall samples can be analyzed for cyclooctasulfur by gas chromatography/electron capture detection. Sulfide emissions from CDW can be detected in a static chamber test. Another test, the jar test, exposes copper to a piece of CDW in a closed container, with visible blackening suggestive of CDW emissions. False positive readings may result from emission testing of non-corrosive drywall that has become a sink for nearby CDW emissions. Where this is suspected, drywall classification should be based on elemental sulfur analysis. Although CDW can be confirmed by laboratory testing, each finding is directly applicable

Photo 4: Most CDW remediation projects replace all drywall, but selective removal can be considered in some cases. Note that the workers are improperly wearing their respirator straps and the workers' street clothes are exposed to contaminated dust. This can be avoided by properly wearing a respirator mask and protective coveralls.

only to the site sampled. The result may be applied to a wider area that has been demonstrated to have the same type of drywall (i.e., by XRF scanning).

Appendix A includes an example of a detailed CDW investigation.

4.5 Information Needed to Design Corrective Measures

Where CDW is found in a structure, an assessment can document other information needed to facilitate the mitigation process, such as:

- extent of corrosion damage
- materials that must be removed to access CDW
- relocation requirements for occupants and contents
- coordination with adjoining units
- layout to plan containment locations and work procedures
- scope of electrical and mechanical repair and/or replacement

4.6 Federal Guidance

CDW assessment recommendations by the Consumer Product Safety Commission (CPSC) are limited to a "threshold inspection" (i.e., is metal blackening present where drywall was installed between 2001 and 2009?) and "corroborating evidence" (i.e., data confirming that an individual drywall panel is corrosive). CPSC classifies a drywall panel as corrosive if at least two of the following conditions are found:

- a laboratory test is positive for elemental sulfur
- Chinese markings are present
- elevated sulfide emissions are measured in a chamber test
- copper corrosion is observed in a jar test
- corrosion tests positive for sulfide

AIHA discusses evaluation procedures for these factors in Sections 4.3 and 4.4. AIHA's assessment guidance is more comprehensive than CPSC's.

5.0 Remediation Procedures

CPSC's remediation guidance provides broad guidelines regarding the cleanup of dust. The only mandatory requirements governing remediation of structures with CDW are found in the Virginia Building Code in Section 112.5. In rooms where CDW is present, Virginia requires the removal of the following for remediation:

- drywall
- insulation
- carpet
- vinyl flooring
- dust

AIHA addresses gaps in previously issued decontamination guidance. It also clarifies and updates available protocols.

5.1 Interim Controls

Because CDW emissions may persist for years and remediation is expensive, lower-cost measures to temporarily reduce emissions would be beneficial where source removal cannot be accomplished quickly. Various methods have been suggested, such as operating portable dehumidifiers, fogging, and air cleaning, but insufficient data are available at this time regarding the efficacy of these methods.

5.2 Scope of Removal

Most remediation efforts include removal of CDW. Where CDW is widespread throughout the home, removal of all drywall may be considered the most cost-effective remedial strategy. However, this alone may not eliminate sulfide emissions, which may continue to be released from remaining demolition dust

or sulfide compounds sorbed on remaining surfaces (this situation is addressed in Sections 5.7 and 5.8).

Drywall replacement includes the removal of adjacent trim and millwork for access to and removal of insulation for control of residual emissions. Where damage to cabinets and countertops can be avoided, they may be removed and reset following the installation of non-CDW.

Other building materials and furnishings are sometimes left in place, if they can be protected against damage during remediation. Items considered acceptable for re-use may include doors, cabinets, vanities, sinks, bathtubs, toilets, items made of marble, granite, etc., as well as metal items without visible blackening, such as light fixtures and appliances. The need for carpet replacement should be determined on a case-by-case basis.

Home construction often includes installation of more than one type of drywall. CPSC's CDW guidelines discuss removal of only those drywall panels that are actually producing corrosive emissions. However, selective drywall removal may not be feasible unless a detailed inspection establishes that large areas are free of CDW. Construction history can be useful in delineating areas free of CDW, such as areas where new drywall was only used for restoration of a flooded lower floor, or for renovation or an addition. In areas with multiple drywall products, non-CDW panels may still need to be removed if they block access necessary to control residual dust or to repair corrosion damage. Successful selective removal requires detailed mapping of drywall types and a conservative scope of work (i.e., removing material when in doubt). After initial removal, accessed cavities should be checked to identify any remaining CDW. Observations of hidden ½" drywall or additional blackening may indicate that more drywall must be removed.

Some CDW remediation projects treat drywall without removal (see Section 6.2). Efficacy of these methods has not been established.

5.3 Project Management

After the remediation and repair objectives are determined, the project manager or environmental consultant should develop a site-specific plan. Elements of this plan may include the following:

- proposed specifications, including the location of drywall to be removed, materials that must be removed for access (trim, cabinetry, furnishings, stairways, piping, etc.), and adjacent insulation that must be removed to control demolition dust
- identification of materials and furnishings to be reused versus replaced
- location for storage of items to be reused
- proposed sequence of work and procedures for preparation, cleanup, and odor control
- coordination of remediation with electrical and mechanical repair and reconstruction

The project manager or environmental consultant should also ensure that the contractor understands the scope of work and procedures to be followed and has the necessary equipment and personnel. Successful decontamination is facilitated by on-site inspection during startup and periodically during the work process. Early identification and correction of improper practices is necessary to achieve project objectives in a timely manner.

CDW remediation involves a variety of trades accomplishing a sequence of tasks. The project manager must coordinate these activities, establish a clear chain of command, and encourage regular communication between parties.

Work should stop at critical points in the process pending approval by the project manager and/or environmental consultant. Stopping points should include:

- pre-demolition, to verify that contents have been removed or covered, surfaces are protected, and dust controls are in place;
- post-demolition, to verify that all specified materials have been removed and demolition dust eliminated; and
- final assessment, during which additional evaluation (i.e., air corrosivity testing) should be considered where residual emissions are of concern (i.e., CDW odor is still detected).

If project objectives are not achieved, additional remediation may be needed.

5.4 Worker Protection

The contractor is responsible for the protection of workers at the job site. Basic protection during demolition work includes an N-95 respirator (a high-quality dust mask), goggles, and work gloves. If workers are required to wear a respirator, then the contractor must have a respiratory protection program. Specific worker sensitivities should also be considered. During removal of CDW, workers are also exposed to nuisance sulfide odors and potentially irritating particles. These exposures have not been measured and additional protective measures are not required at this time; however, they may be incorporated as an additional margin of safety for workers. Care should be taken to not track CDW dust or wear contaminated clothing out of the work area.

5.5 Site Preparation

To prepare work areas for drywall demolition, contents and furnishings must be relocated or protected. Use of air scrubbers can also be considered to limit the distribution of airborne dust and to facilitate cleanup.

Where drywall is to be selectively removed, non-CDW areas should be fully isolated using sealed dust barriers or cleaning of demolition dusts will have to be performed in non-protected areas post-demolition.

Multifamily residences or commercial buildings with CDW require comprehensive planning to protect adjacent units from work activities and to protect cleared areas from recontamination. Each work area should be isolated from adjoining units and common spaces.

An example of site preparation procedures is included in Appendix B.

5.6 Demolition

When removing drywall, be sure to:

- minimize dust generation
- remove waste without contaminating surfaces outside the work area

Photo 5: During demolition, workers should wear a minimum of goggles, gloves, and an N-95 respirator for protective gear. The worker above lacks eye protection and is improperly wearing his respirator straps.

- isolate remediated areas from subsequent work sites

CDW debris can be disposed of as general construction waste (local requirements may vary) but should never be recycled.

5.7 Dust Cleanup

Elimination of demolition dust requires a systematic cleaning pattern and attention to detail. After removal of debris and larger particles, all surfaces should be cleaned until no demolition dust is present. Frequently, this is done by HEPA vacuuming followed by damp wiping. When site personnel believe that cleanup is complete, the project manager or third-party consultant should verify the cleanup results. First, the inspector should determine whether all remnants associated with drywall specified for removal have been eliminated. Air-moving devices in use should be shut off prior to the inspection to allow for suspended dust to settle. Dust inspection should be performed with a bright flashlight and is facilitated by wiping surfaces with a dark cloth. To the extent feasible, the inspector should access hidden surfaces for inspection. Further guidance on conducting dust inspections can be found in ASTM E1368-05, Standard Practice for Visual Inspection of Asbestos Abatement Projects. The contractor should be encouraged to perform additional spot cleaning during the inspection but should not be permitted to continue with other work until all surfaces in the work area are considered dust-free.

5.8 Control of Residual Odor

Volatile air contaminants often adsorb to porous surfaces, releasing odors after the removal of the primary source. This "sink effect" is resolved after surface residues off-gas. In some cases, CDW odor has been reported to persist for months after drywall removal and cleanup. Elimination of this odor is facilitated by airing out the structure by opening windows and using portable fans. The length of time required to control CDW odor by air- out alone ranges from several days to several months. Air-out can be concurrent

Photo 6: CDW can be disposed of as general demolition waste but must never be recycled.

Photo 7: Inspector identifies visible dust after attempted cleanup. The presence of dust indicates that additional work is required.

with other work but should be completed before installation of new structural materials. Opinions vary as to whether air-out is necessary.

A variety of odor treatments are in use to supplement or replace the air-out process. These include surface application of or fogging with solutions that oxidize or scavenge sulfides. Products used in this manner must not be strongly corrosive (some have been known to cause additional corrosion damage). Control of CDW emissions may be only short-term if the product does not achieve sufficient contact with the gypsum core, other affected surfaces, and remaining dust. Odors and further corrosion have been reported after some treatments produced initial improvement. Some vendors claim that these products provide ongoing control against future odors. Vendors do not address potential risks associated with exposures to residues remaining after treatment. While anecdotal information suggests that some treatments may be effective, supporting data is not conclusive.

Other methods currently in use as CDW odor controls include:

- **Bake-out.** Elevated temperature increases emissions but may damage materials.
- **Air cleaning.** Hydroxyl generators and ozonators create irritating by-products; treated filters have not been demonstrated to consistently control CDW odor.
- **Washing remaining surfaces.** Damp wiping with a bleach solution may oxidize surface residues. Pressure-washing surfaces with water creates moisture problems and may spread dust into inaccessible areas.
- **Surface steaming.**

It should be noted that efficacy has not been established for any of these methods.

5.9 HVAC System

The most severe corrosion in CDW homes is generally found on air conditioning coils, and these are generally replaced. Other components of the mechanical system specific to each property should be considered on a site-specific basis. Treatment, cleaning, or replacement may be considered necessary to control dust and/or residual odor.

5.10 Contents

Contents and furnishings in homes with CDW may retain odors that eventually dissipate over time. Contents' odor is often resolved by removing contents from CDW areas, cleaning (i.e., vacuuming surfaces or laundering), and then airing out.

5.11 Clearance

To date, research has not established the effectiveness of any CDW remediation procedure, so verification of each project should be determined on a site-specific basis. This clearance process should first confirm that all drywall and insulation has been removed as specified and that dust has been eliminated to the extent feasible.

Odor evaluation and/or air testing should not commence until after the work area has been closed up for a sufficient period of time for air quality to stabilize, and for temperature/relative humidity in the contained area to exceed that needed to generate CDW emissions.

The Virginia Building Code requires air quality testing before and after reconstruction of structures with CDW. References 3, 4, 8, 9, and 10 include procedures for clearing CDW remediation projects.

5.12 Air Monitoring

Chemical testing for airborne sulfide mixtures lacks the sensitivity and selectivity to document ambient concentrations of CDW emissions. Composite parameters such as air corrosivity and sulfur deposi-

tion can be used to evaluate indoor air quality (IAQ) in homes with CDW emissions. Reference 7 presents a three-day test employing a passive dosimeter, which has been peer-reviewed and validated for air corrosivity evaluation of indoor air. This test system is commercially available.

Air corrosivity is a parameter used by cleanroom industries to monitor the cumulative impact of airborne contaminants. The protocol used for IAQ evaluation is a modification of the industrial method. Metal loss is measured on probes, which can be read in the field using an electro- conductivity meter or shipped to a laboratory for analysis. Since air corrosivity measures all types of corrosion, false positive conclusions are possible where sources of oxidative corrosive emissions are present. Such interferences can be minimized by identifying and controlling non-CDW sources during the test period (i.e., prevent the use of bleach ammonia-based cleaners).

During the interpretation of air quality data in relation to CDW, consider the following:

- False negative findings are possible under dry and/or cold conditions when CDW emissions temporarily decrease or stop. Such a condition may be suspected where blackening is present and relative humidity (RH) is below 40 percent.
- Sulfide emissions from sources other than CDW sources, such as sewer gas or water containing hydrogen sulfide, are also detected by the air corrosivity test. Such sources can generally be identified during the inspection and should either be eliminated or accounted for when interpreting air corrosivity data.
- CDW emissions consist of a complex mixture of sulfide compounds with varying thresholds for odor and corrosivity. "Burnt-match" odor may be detected where measured air corrosivity appears to be within normal background. Therefore, monitoring of air quality should be supplemented by odor evaluation and detectable "burnt-match" odor should not be considered acceptable, even where air corrosivity is normal.

Another method being used to monitor air in CDW homes is measurement of sulfur deposition by XRF on copper or silver dosimeters (see Section 6.1).

The Virginia Building Code requires air monitoring for clearance using either the air corrosivity probes cited previously or air reactivity coupons. The latter method is used in industry but has not been validated for IAQ evaluation.

5.13 Documentation

The investigator should prepare a report including basic findings used for assessment and summarizing the remediation process. Some situations require additional documentation, such as the type of drywall removed. More detailed reports may also be necessary to support real estate transactions, property rental, etc.

6.0 Emerging Technologies

6.1 Monitoring Air Quality by Sulfur Deposition

This method analyzes deposited sulfur on copper or silver coupons utilizing XRF. Sulfur is a by-product of the metal's corrosion from sulfide gases. CDW emits sulfide gases that react with copper and silver to form copper sulfide and silver sulfide, respectively, on the surface of passive dosimeters ("coupons"). This process can be accelerated utilizing forced air over a set period of time. XRF is utilized to quantify the sulfur deposits on the coupons in micrograms per square centimeter. A non-detect reading suggests that sulfide gases were not present during the exposure period. Positive readings for sulfur are compared to a database of readings made under known environmental conditions to classify air quality.

6.2 Hybrid Remediation (Removal/Treatment)

Although various oxidizing solutions to treat CDW are in commercial use, controleffectiveness is dependent on sufficient contact with the contaminants associated with CDW emissions. For treatment of CDW panels in-place, the solution should spread throughout the drywall core. For residual odor treatment, all remaining surfaces and dust particles should be coated. One treatment process attempts to achieve full contact with sulfides associated with CDW emissions by foaming the solution into each drywall panel and fogging all remaining surfaces and particles with an electrostatic paint sprayer.

During a pilot project in which reconstruction would be more expensive, CDW panels were left in the kitchen and bathrooms of a home. The backs of these panels were treated with solution applied through the wall opened in the adjacent room. For residual emission control, all surfaces and remaining dust were fogged with an electrostatic paint sprayer, allowing charged aerosol droplets of the treating solution to adhere to all surfaces.

Treated CDW and dust from this process were tested for emissions in a static chamber, with sulfides below the detection limit. Air corrosivity measurements in the pilot home after this treatment were within normal background and no CDW odor was detected. While this method appeared to be effective in the pilot study, it requires expertise, planning, and quality control to execute effectively.

7.0 Electrical and Mechanical Considerations

Although electrical and mechanical issues are outside the expertise of many industrial hygienists, the resolution of corrosion damage is included in most CDW remediation projects and must be coordinated with decontamination. The scope of electrical and mechanical work depends on the property owner's objectives, which may include:

- restoring all potentially damaged components to pre-existing condition (i.e., replace all systems)
- repairing components to a functional condition (i.e., replacing coils, cutting blackened wires, cleaning blackened pipes, ensuring that low-voltage electronics are operable)
- addressing only immediate safety concerns (i.e., replacing smoke and carbon monoxide detectors)

A detailed assessment of electrical and mechanical systems is generally not needed for either full restoration or minimal safety repairs. However, the repair strategy should be based on a detailed assessment by a qualified electrician and mechanic and may be subject to approval by Code officials.

8.0 References

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Appendix A: Example CDW Assessment Procedure

The following is provided as a generic example of procedures and criteria that may be useful in assessing structures for CDW. This assessment model contains three phases: initial classification, screening inspection, and detailed evaluation. Alternative strategies that meet the performance objectives can be considered (see Section 3.0).

Initial Classification:

- Determine if any drywall may have been installed after the year 2000. If not, CDW is assumed to be "not present."

Screening Inspection:

- **Interview occupants and other persons with information about the property.**
  - Where is CDW suspected of being installed? *Location of CDW must be confirmed by further investigation.*
  - Where has CDW odor, which resembles "burnt-match" odor, or hydrogen sulfide odor from sewer gas or water, which resembles "rotten-egg" odor, been detected? *Further investigation is needed to identify sources.*
  - Is there a history of air conditioning or electronics failure? *If failure was corrosion-related, it may suggest presence of CDW.*

See Appendix C for additional interview questions.

- **Evaluate odor.**
  - Walk around the outside of the home or building.
  - Note first impression when entering the structure.
  - Note locations where odor appears to be stronger.
  - Note the character of the odor.
    - "Burnt-match" odor suggests that CDW may be present.
    - Lack of "burnt-match" odor does not rule out CDW, which can be intermittent or masked by other odors.
    - "Rotten-egg" odor is generally associated with sewer gas or water, not CDW.
    - Further investigation is needed to confirm any of these findings.
- **Inspect air-conditioning coils.**
  - Open all A/C units to access coils. *This may require a special tool.*
  - Check for discoloration on copper coils, coolant line, and uninsulated wiring.
    - Blackening, a black coating, or staining on metal that rubs off when touched suggests sulfur corrosion. Recently changed or corrosion-resistant coils may not show blackening.
    - Other discoloration (i.e., green, white, brown, or gray) suggests stains unrelated to CDW.
    - Further investigation is needed to confirm source of blackening.
- **Inspect electrical wiring.**
  - Access at least one outlet in each room.
  - Evaluate opened receptacle and behind cover plate.
    - Blackening of uninsulated wires suggests a source of sulfide emission in the immediate area.
    - Detection of "burnt-match" odor from electric outlet suggests CDW in wall cavity.
- **Inspect susceptible materials.**
  - Check accessible metal piping, fittings, fixtures, mirrors, and contents.
  - Blackening suggests a source of sulfide emissions in the immediate area.

- **Locate other potential sulfide sources.**
  - "Rotten-egg" odors from sewer gas or sulfide-containing water may cause localized blackening.
  - No presence of "rotten-egg" odor, sewer gas, or sulfide- containing water suggests that the drywall located near metal blackening is corrosive. *Further investigation may be needed for confirmation.*
- **Examine accessible drywall labels.** These labels may be observed on unfinished walls, from the attic (top of ceiling), or in air return plenums. Inspection should note the date, manufacturer name, or country of origin.
  - Font, size, and color of lettering may be important for label classification.
  - Compare to lists of labels and other markings with known emission characteristics. A helpful website to check is www.chinesedrywall.com.
- **Classify findings as one of the following:**
  - No suspect blackening, odor, or labels. *Structure appears to be free of CDW.*
  - Blackening is present in most areas and non-drywall sulfide sources are not suspected. *This may be considered sufficient basis to support removing all drywall.*
  - Blackening is localized, and owner-selective removal is being considered. *Drywall mapping by type is needed to determine feasibility.*
  - Blackening from non-drywall sources may be observed.
  - Initial findings are unclear or conflicting. Detailed investigation is needed to confirm findings.

Detailed Investigation:

Select from the following procedures to clarify preliminary findings from a screening inspection:

- **Check all accessible wiring and breaker boxes per procedure in Section 4.2.**
- **Check refrigerator.**
  - Open up the panel on the back of the refrigerator.
  - Check cooling system for blackening.
- **Check low-voltage electronics**, such as thermostats, speakers, security system panels, garage door openers, door bells, and appliances with circuit boards.
  - Check for blackening on exposed silver or copper components.
  - Determine if electronics are functional.
- **Scan all drywall for strontium content.**
  - Use a portable XRF instrument.
  - Note that different XRF instruments have different use characteristics.
  - The use of XRF is a state-regulated practice with limitations specific to each state.
  - Individuals performing inspections must be knowledgeable of XRF benefits and limitations of use.
  - See Section 4.3 and References 3–6 for suggested procedures.
- **Document sources of hydrogen sulfide other than drywall.**
  - Sources may contribute to metal blackening in nearby areas.
  - Inspect outside structure for potential odor sources, such as irrigation water, standing water, sewage, nearby industrial facilities, or sewage treatment plants.
  - Reports of past sulfide odors may be from intermittent sources.
  - Detection of "rotten-egg" odor suggests sulfide emissions.

  - Sniff initial discharge of water from tap.
  - Search for dry traps or drain line opening.
  - Surface tarnishing may be caused by excess moisture.
- **Collect bulk samples.**
  - Cut a small piece of drywall.
  - Analyze for elemental sulfur (orthorhombic cyclooctasulfur by gas chromatography/electron capture detection).
  - Detectable S8 verifies that drywall is potentially corrosive.
  - Test for sulfide emissions in a static chamber.
  - Expose copper to a piece of CDW in a closed container and observe for blackening.
  - Consider the possibility of false positive results from emission testing of non-corrosive drywall that has become a sink for nearby CDW emissions.
  - Note that each result is directly applicable only to the sample.
  - Similar properties may be assumed for other panels of the same type of drywall as determined by XRF mapping.
- **Confirm the presence of sulfide corrosion on metal surfaces.**
  - Scan surface with XRF attachment or coupon analysis.
- **Expand the search for product labels.**
  - Access may require damage of drywall to locate markings behind wall.
  - Drill or cut holes for observation. The use of a boroscope, where feasible, allows for smaller holes.
  - Note the date, manufacturer name, and country of origin.
  - Font, size, and color of lettering may be important for label classification.
  - Compare findings to lists of known CDW manufacturers' labels and markings.
- **Findings are classified as one of the following:**
  - Confirms the presence of CDW (and may establish locations).
  - Confirms no evidence of CDW.
  - Inconclusive, with a more detailed investigation needed.

Appendix B: Example CDW Remediation Protocol

The following is provided as example of procedures and criteria that may be useful for the remediation of structures with CDW. These specifications generally assume complete removal of drywall throughout a single-family home. Options for selective removal and work in multifamily or commercial buildings are also described. Procedures are generic and can be modified to meet site-specific objectives and conditions. Other procedures can also be used to achieve the overall performance objectives discussed in Section 3.0.

1. Move furnishings and contents to a storage area.

- Items should be isolated from CDW remediation activities.
- Store items allowing air circulation to help eliminate residual odors.
- Carpets may be replaced, protected in place, or stored.

2. Protect items left in place.

- Cover surfaces not to be removed with plastic sheeting.
- Floors inside the work area and also along the egress route must be covered to protect flooring (i.e., with plywood or cardboard).
- Seal HVAC vents and HVAC components not to be replaced.

3. Isolate areas for selective removal or phased remediation (for multifamily or commercial buildings).

- Erect sealed barriers around work areas.
- Seal all penetrations and allow for access.
- Maintain work area under negative pressure relative to adjacent areas where feasible.

4. Place HEPA-filtered fan units in the work area.

- Can be operated as air scrubbers or negative-air machines.

5. Exclude occupants and visitors from work areas.

- Vacate the home for full removal.
- Partial occupancy may be considered for selective removal if complete isolation of the work area can be ensured.
- Occupancy may be allowed in adjoining units in multifamily or commercial buildings contingent on inspections during demolition and cleanup.

6. Approve site preparation before starting removal.

- Approved by an independent inspector when possible.

7. Remove materials to access drywall.

- May include baseboards, trim, cabinetry, doors, fixtures, and countertops.
- For items to be reused, protect or store in area isolated from removal activities.

8. Don personal protection (for demolition and cleanup workers).

- Minimum good practice for demolition: use N-95 disposable face masks, goggles, and work gloves.
- Avoid tracking dust out of work area.
- Change out of dusty clothing when leaving the job site.

9. Remove all drywall specified in remediation plan.

- Minimize dust generation.
- Locate and remove all drywall remnants, nails, etc.

10. Remove all batt insulation behind corrosive drywall.

11. Remove debris and heavy dust.

- Haul to waste storage without contaminating

surfaces outside the work area.

- Do not recycle waste drywall.

12. Perform detailed cleaning.

- Use a HEPA vacuum on all surfaces, from top to bottom, if available.
- Clean all surfaces with damp wiping.
- Repeat as necessary to eliminate visible demolition dust.

13. Verify removal and cleanup.

- Inspector should confirm that all specified drywall and insulation has been removed and no demolition dust is visible.
- For multifamily or commercial buildings, also inspect surfaces in adjoining areas.
- Contractor is to re-clean until area is cleared by inspector.

14. Mitigate residual emissions.

- Address residual emission concerns (i.e., consider air-out and/or surface treatment) where needed to eliminate CDW odor and restore air quality to normal background.
- Restore contents:
  - Clean contents, furnishings, and fixtures (i.e., HEPA-vacuum, launder, and dry-clean, as needed) before returning to site.
  - Evaluate for odor.
  - Consider additional treatment if CDW odor is detected.

15. Establish site conditions for clearance evaluation.

- Close all windows and doors.
- Shut down exhausts.
- Cease all work activity.
- Maintain RH of 40–80%; T>70 F˚.
- If HVAC is operable, set to continuous fan; if not, circulate air with small portable fans.
- Prevent smoking or use of corrosive products.
- Seal sources of sewer gas and H2S-containing water.
- For selective removal, establish the above conditions in adjacent areas for evaluation.

16. Evaluate odor.

- Close up inspection area for at least 24 hours before evaluating.
- Evaluation includes initial impression of two or more persons able to detect environmental odors (i.e., not congested).
- Area fails to clear if any CDW-type odor is detected, such as “burnt-match” odor.

17. Conduct air quality test.

- Complete the test after CDW odor is no longer detected.
- Maintain site conditions established in Step 16.
- Do not base air quality on chemical tests due to insufficient sensitivity.
- Measure air corrosivity with probes (passive dosimeters).
- Place probes in representative areas and analyze per specified method.
- For selective removal, also test representative non-CDW areas.
- Sulfur deposition tests can be used as an alternative.
- The site is clear if all readings are within normal background range per method protocol.
- If any reading is elevated and non-CDW sulfide sources are suspected in the area, further investigation is needed.

18. Address clearance test failures.

- Re-evaluate remediated areas.
- Perform additional cleanup and/or odor control.

19. Protect remediated areas in phased/selective removal.

- Maintain barriers separating remaining CDW and future decontamination activity from remediated areas.
- Keep penetrations sealed to adjacent space(s).
- Establish positive pressure in the remediated area, if feasible.

20. Evaluate drywall to be reinstalled.

- Drywall suspected of being corrosive should test negative or not be used.

21. Re-evaluate site after the next cooling system.

- Confirm that no CDW odor is detected.
- Verify that no new CDW-related blackening has occurred. *When inspecting new A/C coils, note that corrosion-resistant coils do not blacken at the same rate as non-corrosion-resistant coils.*
- Consider repeating the air quality test. *Results should remain within normal background.*

Appendix C: Interview Form

The following set of questions is useful in assessing and investigating suspected CDW sites. Data gathered can refine further investigation efforts and determine available courses of action.

- Why are you having your home inspected for CDW? What are your objectives?
- Have you previously had an inspection for the purpose of identifying CDW?
- When was the home built? When was drywall installed? Who did it? Where did the drywall come from?
- Describe any additions and renovations.
- Do you notice an odor that smells like matchbooks?
- If you are in a development, do any of your neighbors have a problem?
- How old is your current HVAC system? Have you had to replace the coils on your air conditioning system? How many times?
- Have you noticed any unusual tarnishing or pitting on your faucets, mirrors, or silver jewelry and housewares?
- Are you having problems with any of your electronics, such as your computers, microwave control panel, TVs, or other items?
- Describe any past water or smoke damage.
- How do you operate your thermostat? When are windows open?
- What is the square footage of the building and how tall are the ceilings?
- Do you have any photos from the construction/renovation of your home that may show the drywall before it was hung or painted?