INDOOR ENVIRONMENTAL TECHNOLOGIES
Building Health • Testing & Consulting

Evolution of Chinese Drywall Inspections and Findings Based on Laboratory Data, FDOH Guidelines and the Need to Incorporate New and Productive Inspection Techniques

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Abstract

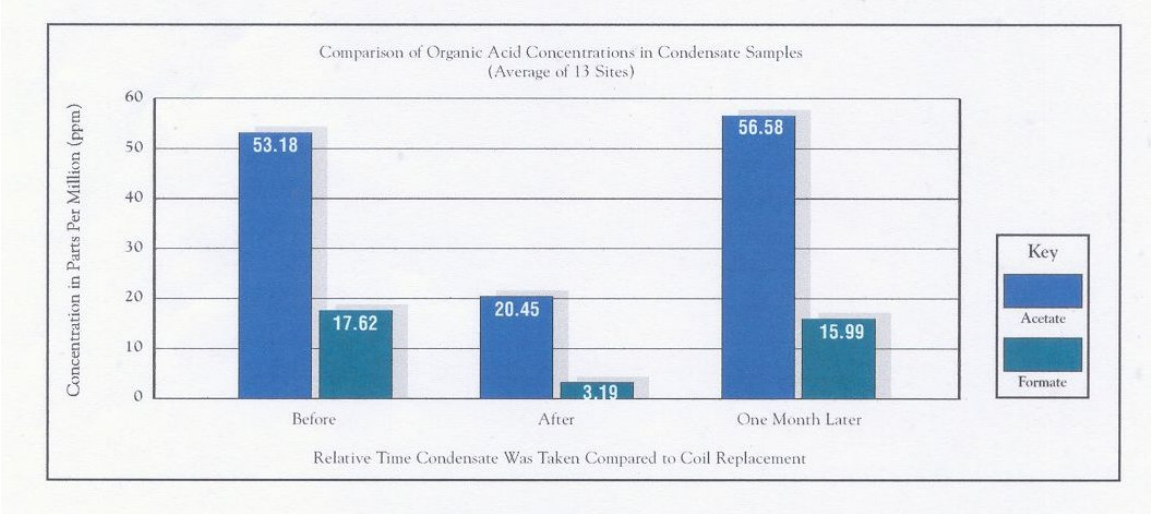
The authors believe a valid inspection protocol is evolving. Based on our experience, a thorough inspection technique incorporating rigorous visual inspection, site location data, and material sampling; then applying this data to the **Florida Case Definition (FCD)**, can determine the likelihood of presence or absence of **Chinese Drywall Syndrome (CDS)** with a high degree of scientific probability. The rush to press with laboratory tests, remediation methods and inspection techniques has resulted in information overload and the use of questionable if not unethical or damaging, testing, remediation and inspection methods. In our experience, the presence of drywall labeled as made in China does not necessarily implicate a building as affected by CDS. Best practices for CDS inspections have progressed rapidly in recent months, and a variety of testing techniques have demonstrated their usefulness and effectiveness. Conversely, some testing techniques have failed to demonstrate copper corrosion or the presence of sulfur compounds in air testing under laboratory conditions, despite the inspected and sampled buildings demonstrating the presence of strong odors, copper corrosion and HVAC repair history consistent with the FCD. It is our intention to share

what has proven useful and consistent in testing techniques and methodologies when compared with the observed physical symptoms. While acknowledging this information is largely anecdotal, we believe it is none the less useful. Inspection techniques and sampling methods will continue to improve as we learn more about CDS and this credible information is reported in articles and blogs on reputable sites.

Introduction

Indoor Environmental Technologies, Inc. (IET) has been performing inspections of conditions associated with CDS since the fall of 2007 in response to multiple Heating, Ventilating and Air Conditioning (HVAC) air handling unit (AHU) coil failures. These failures were common to a recently constructed condominium complex (2006) in west central Florida. Our attempts to ascertain the cause of the copper coil failure started IET down a winding path of questions without conclusive answers. Testing of condensate water in the HVAC systems at that time was focusing on formicary corrosion and was the approved path as HVAC companies such as *Carrier* had done extensive studies and published papers on this subject. At that time,

implication of Chinese drywall had not surfaced. Our test results were consistent with the Carrier Paper "*Indoor Coil Corrosion*" printed in 2004 implicating fin pack leaks from formicary corrosion. HVAC coil failure did exist prior to the introduction of Chinese drywall to the U S housing market. Carrier's conclusion stated that the reduction in air exchange (tight buildings) and the use of building materials that off-gas corrosive vapors were implicated.



Carrier Article Graph, 2004

Working with a laboratory specializing in material analysis, IET performed condensate water testing and material analysis of failed copper coils. These tests came back with elevated levels of Acetate and Formate in the results and interestingly, elevated sulfur.

Indoor Environmental Technologies

TEI Number: 75737 Sample: Sample 091907 WS-1

TEST	RESULTS		DATE PERFORMED
Acetate (D4327-03)	45.9	mg/l	11/6/2007
Formate	14.9	mg/l	11/6/2007

TEI Number: 75738 Sample: Control

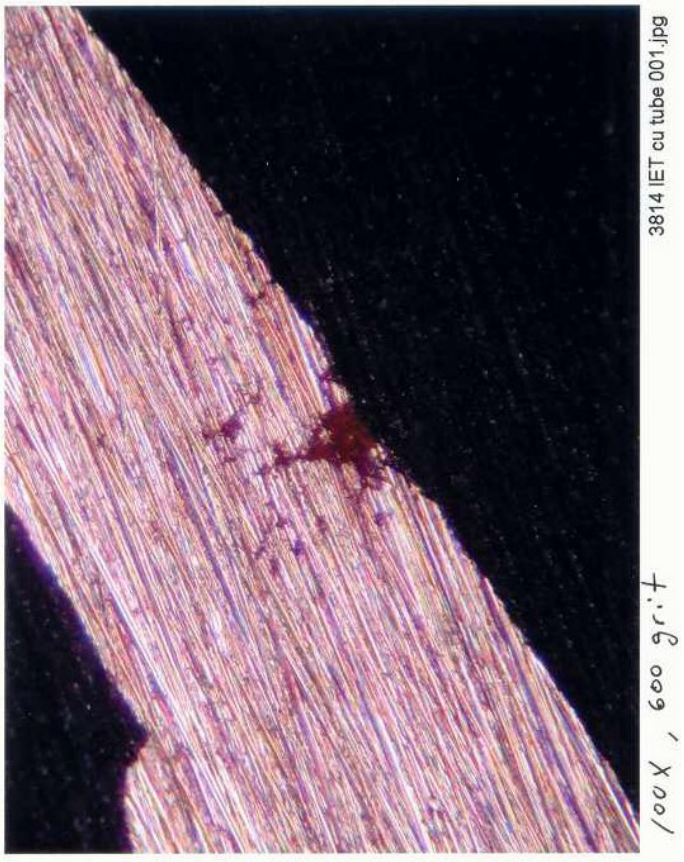
TEST	RESULTS		DATE PERFORMED
Acetate (D4327-03)	<0.5	mg/l	11/6/2007
Formate	<0.2	mg/l	11/6/2007

TEI Number: 75921 Sample: 101107 WS-1

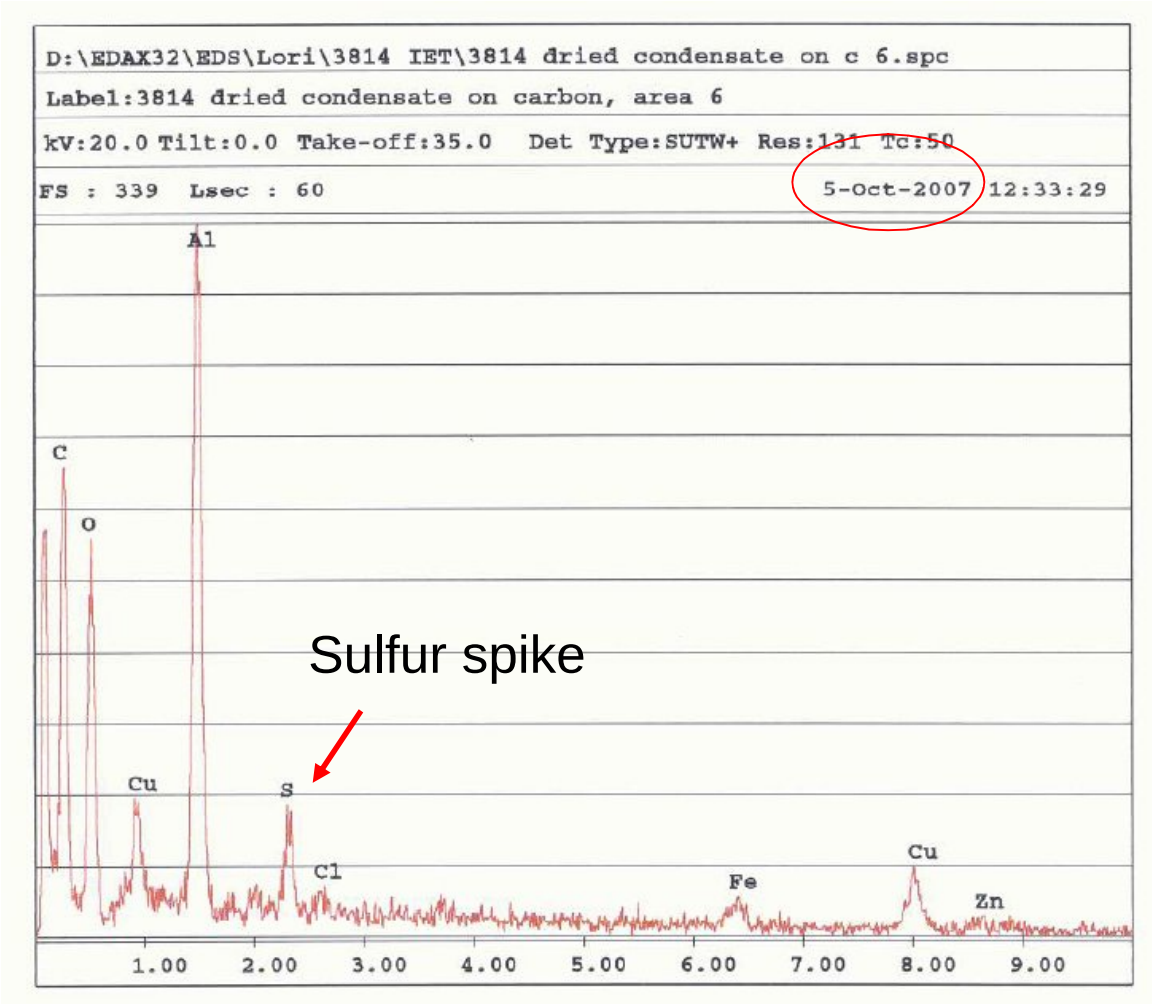
TEST	RESULTS		DATE PERFORMED
Acetate (D4327-03)	<10*	mg/l	11/6/2007
Formate	32.9	mg/l	11/6/2007

*High detection limit due to large amount of Formate present.

Photomicrograph of AHU copper coil corrosion from the sample data represented above.

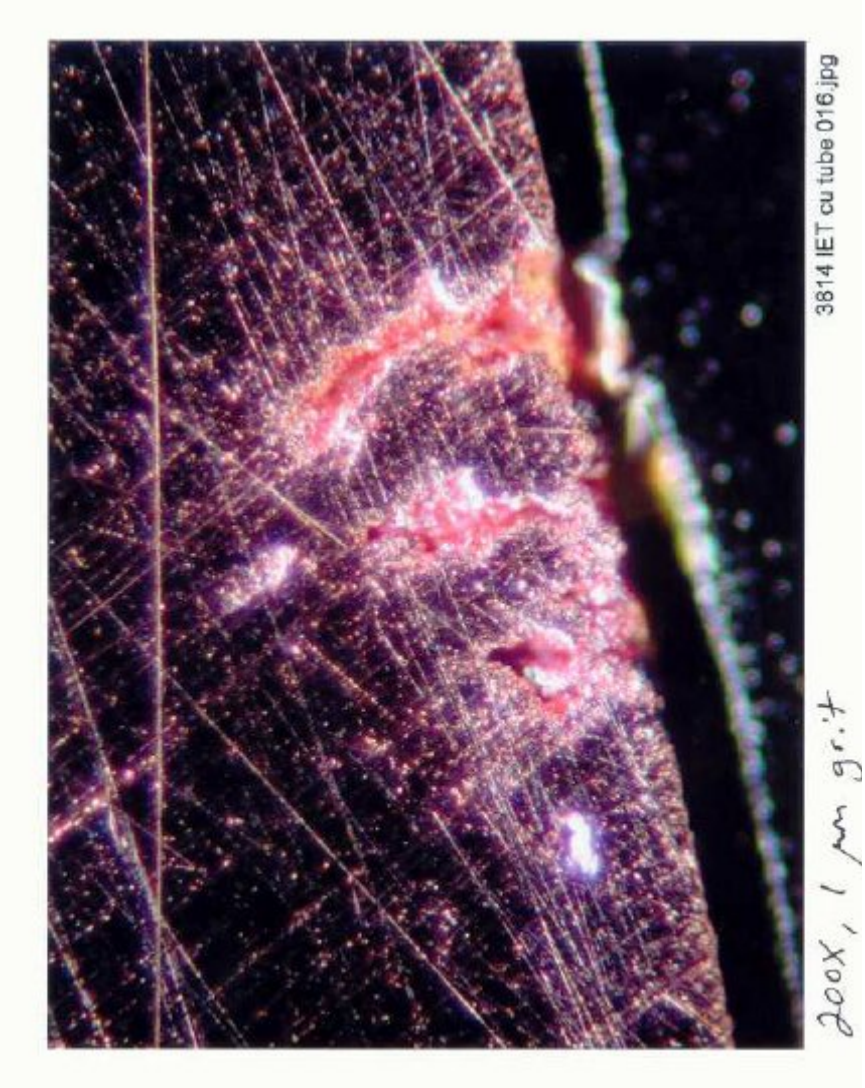


These same samples were analyzed using SEM/EDS microscopy of dried condensate water indicating elevated sulfur compounds.



The condo development where these samples were taken has been determined to have contained Chinese Drywall and suffer from CDS. While coil failures were not unheard of in 2007, a specific building material such as Chinese drywall had not been implicated.

Further early investigation using photo documentation of microscopic analysis of AHU coils indicated a corrosion pattern that had occurred within six months of coil replacement.



Again, in 2007, IET was not aware of CDS and was following the published research on indoor fin coil failure and the hypothesis put forth by manufacturer's research. Today, our investigative technique has changed considerably. In conjunction with the Florida Case Definition (FCD) and other testing techniques, IET is encouraged by the recent

developments in the laboratory analysis of materials. Combined with a building and site history and visual inspection, conclusions can be drawn as to the presence or absence of CDS. We used to cut one foot square pieces of drywall out of walls to look for labels and secure samples for analysis. The theory was that a large enough sample of drywall material placed in a chamber under hot humid conditions could lead to copper corrosion. Well, they didn't, even with drywall labeled Knauf and sampled for over 20 days at 80 degrees and 95% RH. Today we are taking a two inch square piece of drywall, placing it in a zip lock bag and sending it to a lab for Strontium analysis. In the past we used TO15 grab samples and Tedlar bag grab samples for sulfur compounds before we realized that the detection limits for the results were so low as to sometimes be below outside ambient levels. We have stopped performing air samples until we are introduced to a method that is cost effective and productive.

Old Way: 6 sq feet. Note different color paper

New Way 4" hole saw

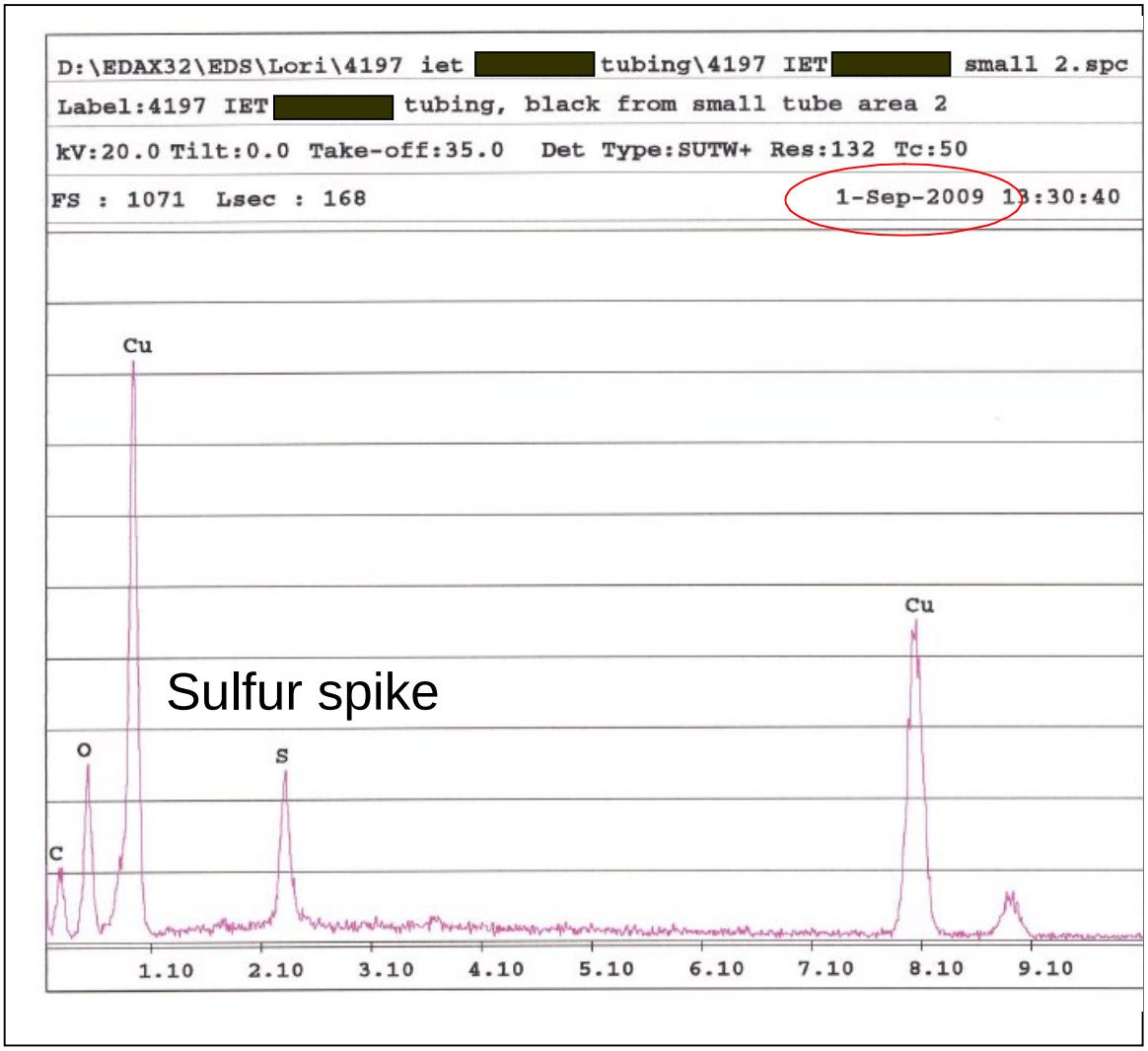
Sampling Methods

IET's current material sampling methods consist of the analysis of Chinese drywall and corroded copper for the presence of sulfur or strontium.

Corroded Copper

Corroded copper (black copper) is analyzed by SEM/EDS from a prepared sample of the copper sample. The spectrum analysis of compounds will indicate a sulfur spike when sulfur compounds are present on the sample. Collecting a sample can be difficult from a working HVAC system; however IET has been successful in securing samples from failed systems related to the inspection location which have proven productive. This requires working with an HVAC contractor. There are other sources for corroded copper such as the electrical house wiring. A sample can be secured from a duplex outlet or the electrical panel for analysis, taking the proper precautions and within compliance of local code requirements for securing the sample. Some states may require an electrician to secure the sample.

This chart indicates a sulfur spike from a piece of copper tubing that was collected by an HVAC technician from an AHU coil during our inspection.



This sampling method assists in further confirming the presence of sulfur compounds associated with CDS.

Strontium Sampling

Strontium is a compound found in both domestic and imported drywall. Domestic levels range from 400 to 800 milligrams per kilograms (mg/kg) of Strontium. There appears to be a relationship with elevated Strontium levels, sulfur odors and corrosion of metals. Chinese drywall has been measured in our samples as high as 2,850 mg/kg and has been reported to reach levels of 5000 mg/kg.

This is an easy sampling method requiring the collection of about ten grams drywall dust (a few teaspoons). IET's Standard Operating Procedure (SOP) for this collection method consists of the removal of about a two inch square piece of drywall using a utility knife taken from a likely productive area. Sample concentrations recovered by IET have varied from 400 to >2800 mg/kg.

Analytical Report

Client:	UNIFIED ENGINEERING, INC.	**Date Collected:**	10/08/09
Project ID:	IET ([redacted]	**Time Collected:**	
Sample ID:	091007TR-2-5	**Date Received:**	10/08/09
Sample No:	9-4229-005	**Date Reported:**	10/12/09

Results are reported on an "as received" basis.

Analyte	Result	R.L.	Units	Flags
Total Metals **Method: 6020A**		**Preparation Method 3050B**		
Analysis Date: 10/09/09		Preparation Date: 10/09/09		
Strontium	2,850	2.0	mg/kg	N

These two samples taken from the same sub-division indicate one home with elevated Strontium levels in % per bulk sample. Interestingly, the lower sample showed no pipe corrosion but had elevated levels of Strontium.

Analyte	*Sample 5607-131-WS(A)*	*Sample 5607-131-WS(B)*	*LOD (ppm)*
Gypsum	99.0	96.9	N/A
Aluminum	0.177	0.450	65
Copper	<LOD	0.0137	45
Iron	0.110	0.223	32
Magnesium	0.0646	0.693	49
Manganese	<LOD	0.0325	65
Phosphorous	<LOD	<LOD	74
Potassium	0.0950	0.146	150
Silicon	0.516	0.516	78
Strontium	0.0731	0.0731	15
Titanium	<LOD	<LOD	69
Hydrogen sulfide	<LOD	<LOD	0.2
Sulfur dioxide	<LOD	<LOD	0.4
Formaldehyde	<LOD	<LOD	0.2
Mercaptan	<LOD	<LOD	0.25
Pipe Corrosion	None Observed	None Observed	N/A

Analyte	*Sample 5631-137-WS(A)*	*Sample 5631-137-WS(B)*	*LOD (ppm)*
Gypsum	98.3	98.3	N/A
Aluminum	0.221	0.228	65
Copper			45
Iron	0.155	0.152	32
Magnesium	0.311	0.316	49
Manganese	<LOD	<LOD	65
Phosphorous	0.0290	<LOD	74
Potassium	0.0562	0.0552	150
Silicon	0.675	0.717	78
Strontium	0.215	0.193	15
Titanium	<LOD	<LOD	69
Zinc	<LOD	<LOD	48
Hydrogen sulfide	<LOD	<LOD	0.2
Sulfur dioxide	<LOD	<LOD	0.4
Formaldehyde	<LOD	<LOD	0.2
Mercaptan	<LOD	<LOD	0.25
Pipe Corrosion	None Observed	None Observed	N/A

The table below indicates the seven sets of samples taken from seven individual units for this project. The town homes were constructed in 2006 and completed in 2007 and were all part of the same building. They were 2.5 years old at the time of testing.

Unit	Strontium Sample 1	Strontium Sample 2
1 (5607)	0.0731	0.0731
2	0.0711	NA
3	0.0713	0.160
4	0.0358	0.0726
5	0.0625	0.0676
6	0.0716	0.0746
7 (5631)	0.215	0.193

Highlighted areas are over twice the background levels for the domestic drywall identified in the other samples.

What was interesting about this case was that there was evidence of copper corrosion in 5631 and no evidence in the other units. These tests were performed in January 2009 prior to IET's understanding of the significance of the differences in Strontium levels and the relationship with domestic and imported drywall and prior to the release of the FCD. Drywall in

5631 was identified as labeled Knauf / China, had strong odors and black copper, though no history of AHU coil failure. IET's lab analysis was turning up negative results because we did not know what we were looking for, nor did many of the lab technicians we were working with. We were all just trying our best with the unfolding of this challenging situation. Fortunately, the discoveries of productive testing methods were becoming available later in 2009.

Florida Case Definition

The **State of Florida** has developed a **Case Definition** to assist in determining whether a building has Chinese Drywall installed. To meet the current definition (03-30-09), homes constructed after 2003 (2004 to present) must meet two or more conditions listed below:

1. There is presence of sulfur-like or other unusual odors
2. Confirmed presence of Chinese-manufactured drywall in the home
3. Observed copper corrosion, indicated by black, sooty coating of un-insulated copper tubing leading to the air handling unit present in the garage or mechanical closet of the home

4. Documented failure of air conditioner evaporator coil (located inside the air handling unit)
5. Confirmation by an outside expert or professional for the presence of premature copper corrosion on un-insulated copper wires and/or air conditioner evaporator coils (inside the air handling unit)

IET uses a combination of these three sampling and inspection methods and is looking at other possibilities.

As of this date, Monday, November 02, 2009, the State of Florida has published that no state or federal agency has validated a specific test for drywall to determine if it will emit corrosive gases in a building under normal conditions. The following was also reported by the State of Florida: “Private laboratories, consultants and government agencies have been testing drywall in order to understand the differences between American and imported drywall. We know of no one who has validated a test capable of detecting drywall that emits reduced sulfur gases under the same conditions that occur in the homes that are currently exhibiting copper corrosion.”

Visual Inspection Protocol

IET's SOP consists of a thorough visual inspection of the structure and site and building history.

1. Outside temperature, humidity and weather conditions
2. Estimated age of building
3. Building construction
4. Water source: Well ___ City___
5. Sewage disposal: Septic ___Sewer___
6. HVAC status
7. Building occupied?
8. Building location: Conservation area ___ Swamp ___
9. Underground utilities ___
10. Odors present___ Strongest area___
11. Health concerns
12. AHU coil failure ___ Black copper ___
13. Electrical and wire corrosion:
    - Main panel ___ Receptacles ___
    - Light switches ___ Speaker wires ___
14. Other metal corrosion ___
15. Drywall identification, China ___ Domestic ___

Material testing consists of Strontium testing of gypsum and sulfur analysis of copper corrosion.

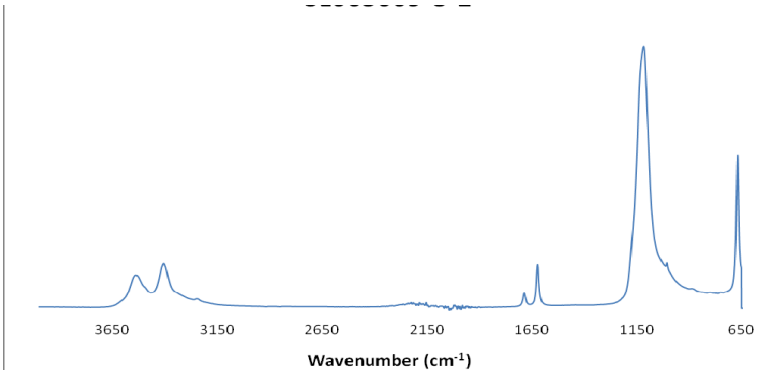
Examples above indicate the different paper backing on Knauf drywall (light gray) and domestic drywall (brown). Different manufacturers have different paper backings and a library of pictures for inspectors is helpful, but not conclusive by any means. Knowing the difference in paper backing when inspecting a home is important.

Observing copper corrosion in a home is also nothing new. Black copper has been reported by home inspection companies for years during real estate transaction inspections. There are theories that black copper MAY occur in homes with underground utility feeds that are located in old wetland or swamp areas and where the soil composition is muck based rather than sand or loam based. We have seen corrosion on the first floor and not on the second floor. Using the FCD,

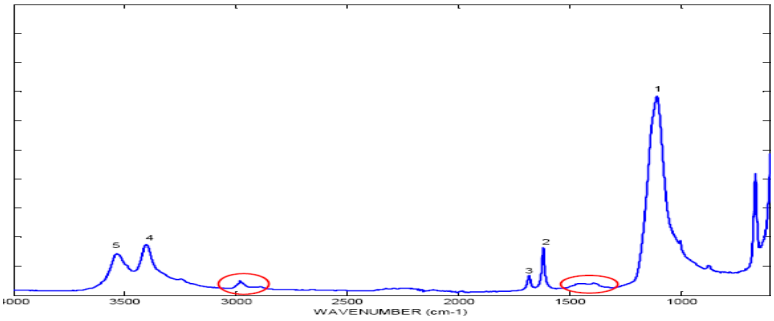
where do you draw the line with black copper wiring? You need to be able to interpret all the symptoms and make informed decisions. There are some situations that are not clearly black or white.

Other Testing Techniques

Fourier Transform Infrared Spectroscopy (Mid-Infrared) deals with the infrared region of the electromagnetic spectrum. In this application a drywall sample is collected and analyzed with an infrared spectrophotometer. The analysis results look similar to this report based on which lab you use.



The above sample is from domestic drywall



The above drywall is representative of Chinese drywall

Air Sampling

IET has not ventured into the realm of air sampling past our initial experience due to the costs involved that prevent most clients from using these varied methods. We tried it once in a building with strong odors and other FCD indicators and we did not receive any conclusive results. Granted, this inspection was done early on in our experience with CDS and prior to the establishment of the FCD. We would know better now than to request these types of tests when other more productive methods are available. The results for air samples below are in parts per million. We now know that the detection limits for this type of test were not capable of detecting levels low enough to be productive. LOD represents the minimum level of detection for the Drager CMS gas analyzer.

Analytes	Sample 1	Sample 2	Odor Threshold	Minimum LOD
Hydrogen Sulfide	<LOD	<LOD	0.5 ppb	0.2 ppm
Sulfur Dioxide	<LOD	<LOD	?	0.4 ppm
Formaldehyde	<LOD	<LOD	?	0.2 ppm
Mercaptan	<LOD	<LOD	8.5 ppb	0.25 ppm

Another challenge is that the odor thresholds for the human nose are often many times more sensitive than the sampling methods. Even with the best equipment, the potential to detect odors with a meaningful significance is challenging for even research scientists in this application. Bulk sampling has been more productive in our opinion.

Not Considered Sampling Options

The Internet offers for sampling methods at ridiculously low costs are an invitation for what we would consider disappointment. A test kit for only $34.95 offers:

Chinese Drywall Tester Kit

Protecting your home and family from toxic Chinese drywall

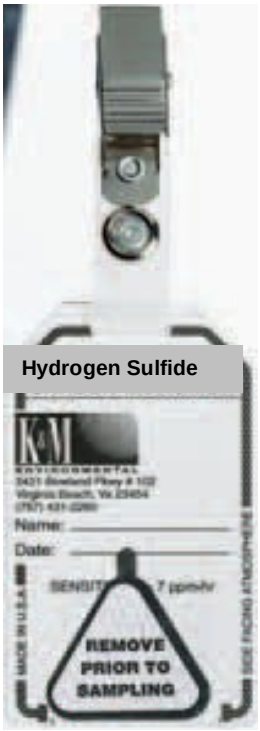
Included in the test kit:

- 20 reusable analysis probes
- Probe cleaning tool
- Awl tool
- Carrying pouch
- Probe labels
- Probe assignment cards
- Color Instructional manual

Do you think this can really work?

An attempt to use traditional industrial monitoring badges to detect sulfur odors has been marketed openly as a means to detect the presence of sulfur odors in your home. To date, the sulfur levels detected in homes are:

1. **Carbon Disulfide** detected at 0.02 to 0.1 ppm.
    a. OSHA PEL is 20 ppm (200 X detected levels)
2. **Carbonyl Sulfide**: Odor threshold 0.05 ppm
3. **Hydrogen Sulfide**: Odor threshold **<5 ppb**
    a. OSHA PEL 10 ppm (10,000 ppb)
    b. Badge monitors sold on the web measure to 2 ppm in one hour



In reality, without grants to support their efforts, the opportunity for an inspection firm to have access to the resources necessary to take air samples and get usable results are beyond all but the most ambitious research firms, government agencies and university research scientists.

Microbial Sampling for Chinese Drywall

It is well known that drywall in landfills produces sulfur gasses. There have been conferences on how to dispose of drywall without producing the noxious odors. Anaerobic bacteria are to blame for the landfill condition. "Gypsum is blended with other ingredients, which may include starch, sugar, and cellulose as binding agents. When gypsum decomposes in a landfill under anaerobic conditions, proper pH, and moisture, it forms hydrogen sulfide (H_2S), which has a "rotten egg" odor.

"The disposal of gypsum drywall in landfills has been linked to the formation of hydrogen sulfide H_2S gas. When gypsum drywall (~90% $CaSO_4$ x 2 H_20 and 10% paper) becomes wet in a reducing environment, such as a landfill, sulfate-reducing bacteria (SRB) use sulfate as an electron acceptor to produce H_2S. Characterized by an offensive odor at relatively low detectable concentrations (reported as low as 0.5 ppbv), H_2S is

a nuisance odor around landfills and in homes with CDS. Concentrations as high as 12,000 ppmv were measured from gas produced in various Construction & Debris landfills in Florida. Although concentrations in the ambient air surrounding landfills do not approach dangerous levels because of dilution, concentrations are large enough to create odor problems."[1]

So how does the climate in a wall cavity with a suspect material such as Chinese drywall react to produce odors? Is the humidity in Florida's hot and humid climates the culprit? Are the contaminants in Chinese drywall reacting with the wall cavity and attic humidity which often exceeds 75% in the summer time? We don't know. And what is the best way to test for microbial contaminants in drywall? We are not aware of any reliable test that demonstrates the same repeatable results as Strontium or Sulfur testing of bulk materials in conjunction with a thorough visual inspection. Where is the evidence that shows that this is an actual condition and that SRB are present in Chinese drywall?

Conclusion

Performing a careful inspection and using productive testing techniques has proven effective for IET in the evaluation of

suspect homes containing Chinese drywall. IET is not aware of any published data that suggests that CDS is the result of any specific agent, whether Strontium, source of Carbonyl sulfide, mold or bacteria. There is an X factor out there as the causative agent waiting to be discovered and announced. Therefore we are obliged to continue with what appears to be an effective inspection technique.

There are several questions that need to be answered to better understand this condition.

- What role does building pressure play in this situation?
- Does highly elevated humidity and differential humidity resulting in vapor pressure differentials have an effect on the release of odors and corrosive agents?
- Does microbial growth from mold and SRB play a role in this situation?
- Why are we unable to detect sulfur compounds in air samples from affected homes in concentrations that would be capable of the corrosive conditions observed?
- Is there a valid wall cavity air sampling method available?

These questions require more research.

Reference:

1 Kenton Yang, Qiyong Xu, Timothy G. Townsend, Paul Chadik, Gabriel Bitton, and Matthew Booth. Journal of Air and Waste Management Association, August 2006