

# Measuring the Corrosivity of Indoor Air

Ed Light<sup>1,\*</sup>, Brian Little<sup>2</sup>, Michael Barclay<sup>3</sup>, Barbara Manis<sup>4</sup>, Roger Gay<sup>1</sup>, James Bailey<sup>1</sup>

<sup>1</sup>Building Dynamics, LLC, Ashton MD, USA

<sup>2</sup>NanoScale, Corp., Manhattan KS, USA

<sup>3</sup>Barclay Assessment Services, Mandeville LA, USA

<sup>4</sup>Building Health Sciences, Inc., Rockville MD, USA

*Corresponding email: [ELight@building-dynamics.com](mailto:ELight@building-dynamics.com)*

Accepted for publication in [Proceedings of Indoor Air 2011](#)

## SUMMARY

The corrosivity of air is determined by the pollutants present and is influenced by moisture. This parameter integrates the net effect of all reactive airborne pollutants, similar in principle to the monitoring of combustible gas. The authors adapted a commercially-available industrial (clean room) monitoring system to general IAQ assessment by modifying sampling and analytical procedures. The system selected for evaluation utilizes a dosimeter which records copper loss. Pre- and post-measurements are made with a portable meter and net metal loss is reported in Angstroms per thirty days. Measurements can be made onsite or the probes can be stabilized for shipping and off-site analysis. A database of air quality in homes with and without corrosive drywall was established as the basis for developing relative air corrosivity criteria. Air corrosivity in homes with corrosive drywall were generally an order of magnitude above normal background.

## IMPLICATIONS

Air corrosivity is identified as a new IAQ parameter. It directly measures the synergistic potential of airborne contaminants to corrode metal surfaces and, in some cases, may provide a surrogate measurement to help track odorants and irritants. A simple method for measuring air corrosivity by passive dosimetry is validated.

## KEYWORDS

corrosive drywall, sampling and analytical, odor, irritants, residential

## INTRODUCTION

The corrosivity of air is determined by the concentration of a wide variety of different compounds and is influenced by moisture. This property has been a concern with respect to protection of susceptible surfaces in industrial environments, but has not been a parameter of interest in other buildings. Air corrosivity integrates the net effect of all reactive airborne pollutants, similar in principle to the monitoring of combustible gas (Leygraf, 2000). Because industrial corrosion monitoring differs in many respects from general IAQ assessment, a commercially available monitoring system was used with modified sampling and analytical procedures. Air corrosivity was then measured in a wide range of homes with and without potentially significant emission sources.

The corrosion control industry has developed air quality monitoring systems for protecting Clean Rooms (i.e., areas used to manufacture computer chips or archive historical documents) and electronic equipment in industrial environments (Leygraf, 2000). These

systems measure the synergistic effect of all reactive chemicals present in terms of “air corrosivity,” similar in principle to industrial hygiene assessment of combustible gasses.

Corrosion of metal surfaces is a result of environmental exposure. For example, moisture, salt, bleach, and ammonia cause oxidation while sewer gas and water containing hydrogen sulfide cause sulfidation. Measurement of air corrosivity does not distinguish sulfidation from oxidation without more detailed analysis. Sulfidation is visually distinctive as a unique blackening of surfaces.

Interpretation of air corrosivity is based on atmospheric classification with respect to Clean Room protection (ISA, 1985). These standards are not applicable to general IAQ evaluation, where low-level air corrosivity is ubiquitous and considered acceptable.

Some drywall products from China can be a significant source of corrosive emissions in the residential environment (CPSC, 2009). Emissions from corrosive drywall (CDW) are composed of a variable mixture of sulfides in the parts per billion range (Burdack-Frietag, 2009), making direct measurement of the specific compounds infeasible. A validated air quality test is needed to assess relative exposure to CDW emissions and determine the effectiveness of remedial measures. Since airborne sulfides are irritants, air corrosivity may also provide a potential indicator of irritants.

Data reported in CPSC (2009) supports the feasibility of air corrosivity monitoring for IAQ. Air reactivity (a measure of corrosion gain in copper coupons) ranging from 20-100 A°/30d in homes without CDW, compared to 300-2000 A°/30d in homes with CDW. These data were collected to confirm the source of electrical damage in the homes and was not considered with respect to air quality assessment. Accuracy, precision, and sample stability for IAQ evaluation using copper coupons was not established, and there was no protocol specifying test conditions or data interpretation.

Objectives of this study were to establish a procedure for measuring air corrosivity in residential air and compare readings in typical homes without strong emission sources (normal background) and compare this to levels measured in homes with CDW.

## **METHODOLOGY**

Air was sampled by passive dosimetry, exposing a microscope slide with attached copper strips which are measured for metal loss. Probes were placed on a horizontal surface in the breathing zone for varying amounts of time with the windows closed and relative humidity between 40 and 80%. Air corrosivity measurement was based on the electrical resistance of the copper sensor. As the element corrodes, the corrosion products are non-conductive, while the underlying metal is conductive. Resistance of the measurement element increases as it corrodes due to the thinning of the element. Temperature effects are controlled by measuring the exposed copper element against a reference element with a protective coating. A direct-reading meter was used to measure this resistance ratio and to compute the metal film thickness that had corroded, displaying the change in metal loss over time in Angstroms. Cumulative metal loss is calculated to produce a corrosion rate in terms of Angstroms per month. Measurement resolution is 0.1 divisions. The meter readout is in “divisions,” each division is 0.1% of the probe span, and the repeatability of readings is  $\pm 1.0$  division (Rohrback Cosasco, 2009). Where a meter is not available onsite, probes can be tested off-site before and after sampling, shipping them in a sealed vial with desiccant bags (to stop further corrosion). A field blank is represented by a probe in a sealed vial which is briefly

opened onsite.

Before and after sampling, the probes are inserted into the meter, with metal loss determined by an average of three readings. Air corrosivity is reported in  $A^\circ/30$  days, calculated by the formula:

$$[.0304 \times \text{span} \times \text{change in meter reading}] \text{ divided by the number of days}$$

\* Value reported as “divisions” (assigned by the manufacturer to each probe)

\*\* Subtract the pre-test reading (in “divisions”) from the reading after sampling

IAQ is rated based on the highest probe reading in a home. Relative criteria for data interpretation can be based on a database representing a wide variety of homes, e.g., “normal background,” “elevated,” or “highly corrosive.”

Thirty-eight (38) homes were tested, comparing air corrosivity at sites with and without CDW. Homes were classified as non-CDW if an inspection failed to identify a strong source of corrosive emissions. Measurements from these latter homes were considered to represent normal background. Homes included in the study did not have other strong sources of corrosion as determined by an inspection. The homes including a variety of construction types and occupant activities and were located in Louisiana, Florida, Virginia, and Maryland. Daily probe measurements were also made in the laboratory utilizing a static chamber containing CDW.

## RESULTS

Air corrosivity in the twenty homes without CDW ranged from none detected to  $123 A^\circ/30d$ . Ninety-four percent (94%) of peak readings (highest room in each home) were less than  $80 A^\circ/30d$  and eighty-four percent (84%) were less than the lower detection limit of  $25 A^\circ/30d$ . Peak air corrosivity measurements in the eighteen homes with CDW ranged from 55 to  $3115 A^\circ/90d$ . Ninety-four percent (94%) of these homes exceeded  $80 A^\circ/30$  days, and twenty-two percent (22%) exceeded  $1000 A^\circ/30d$  (Figure 1). In non-CDW homes with chlorine odor from bleach or hydrogen sulfide odor from water, air corrosivity was generally under  $80 A^\circ/30d$ . Classification of air corrosivity (normal background vs. corrosive vs. elevated) remained the same where follow up sampling was conducted during a second time period.

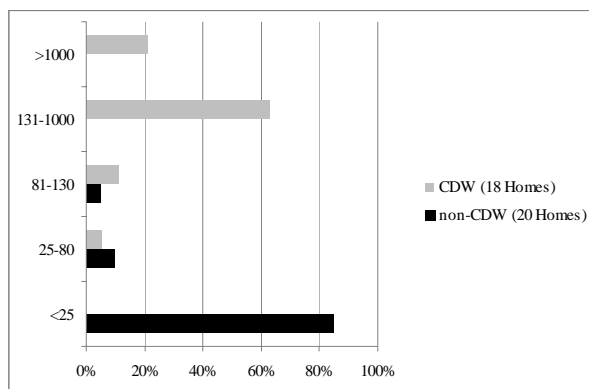


Figure 1. Distribution of Peak Air Corrosivity Readings in Homes With and without Corrosive Drywall in Angstroms per 30 days

Probe response over time was evaluated by a series of air corrosivity measurements made under stable conditions in order to determine the minimum sampling time needed to establish a representative air corrosivity rate. Home classification remained the same when air corrosivity rates calculated from three day tests were compared to rates determined over a one week period. Air corrosivity classification varied between sites within a home because of local differences in sources, ventilation, and temperature/relative humidity.

Probe response after one day was also evaluated in homes with known CDW status. A short-term test may be useful as a progress indicator during the remediation of CDW homes. Metal loss measured after one day was less than 1.0 meter divisions in sixty percent (60%) at non-CDW sites and greater than 2.0 meter divisions at ninety percent (90%) of CDW sites (Figure 2).

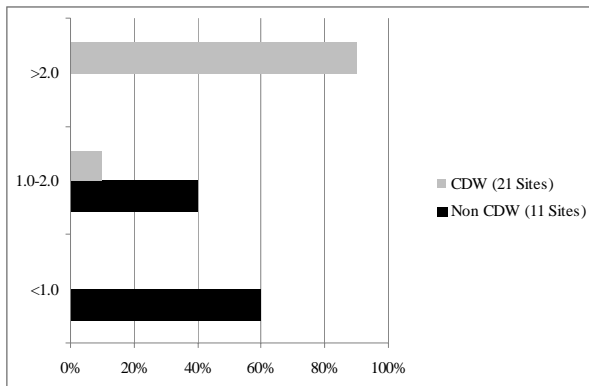


Figure 2. Distribution of homes by Air Corrosivity (one day measurement in meter divisions)

## DISCUSSION

Ambient sulfide concentrations produced by CDW emissions vary based on the characteristics and loading of corrosive panels present, ventilation, humidity, and temperature. Other sources of airborne sulfides include water and sewer gas. Typical materials and routine activities in the indoor environment produce a low level of air corrosivity which is considered acceptable (normal background). In addition to detecting sulfides, air corrosivity testing can also be affected by dust, moisture, cleaning agents with bleach or ammonia, salt water spray, and other indoor pollutants with corrosive properties. The only other common source of airborne sulfides in the residential environment are water and sewer gas. Worst-case conditions could cause higher levels of air corrosivity in the presence of water containing sulfides or bleach cleaners than the low readings measured in this study.

Sampling conditions simulating near worst-case concentrations provide for standardized interpretation of test data. Because air quality sampling by dosimetry requires a minimum face velocity (Brown, 1995), air circulation should be induced in test areas where there is no activity. Identifying any strong sources of corrosive emissions by inspection prior to testing is necessary to enable the elimination or control of interferences when the IAQ impact of a specific source (i.e., CDW) is being evaluated. In this regard, the authors suggest the following site conditions and controls when evaluating homes for CDW emissions:

- Close windows 24 hours prior to and during sampling.
- Limit temperature to the comfort range and relative humidity to 40 - 80%.

- Provide for air circulation in the test area (i.e., set thermostat to “on” or operate small portable fan).
- Refrain from the use of corrosive agents such as bleach and ammonia during the test period.
- Minimize any other corrosive agents and account for their presence in data interpretation.
- Locate samples at representative sites.
- Keep probes away from excessive dust or moisture.
- Place probes on a covered surface with the copper strips facing down to prevent dust and moisture droplet deposition.
- Where non-CDW sulfide sources are suspected inside the home or building, eliminate these emissions to the extent feasible (i.e., wet the drain traps, shut off water, seal toilets) and then air out the home or building prior to initiating the air corrosivity test.
- Where outside sulfide sources are suspected, compare interior air corrosivity to measurements made in a nearby structure without CDW.

The authors are developing relative criteria for residential air corrosivity from their home testing database. Homes will be classified as either normal background, elevated, or highly-corrosive based on probe measurements made under a wide range of environmental conditions in homes known to have or not have CDW.

Minor variability in meter readings is addressed by recording an average of three readings. Side-by-side readings in older probes were variable but sufficiently accurate to classify air corrosivity as normal, elevated, or highly-corrosive. Use of new probes is preferable. Because new probes are not always responsive during the first two days of exposure, they should be exposed to indoor air for at least three days prior to first use.

Series of daily probe readings suggest that a representative air corrosivity rate is established within three days under stable conditions. Probe readings after one day are generally consistent with home classification established over a longer sampling period.

Measured metal loss in newer probes shipped in a vial with desiccant bags was stable for one week. This allows for the shipping of pre-calibrated probes to a site and post-testing of probes off-site. Additional metal loss was measured in some older probes, making these less reliable for off-site measurement.

Air corrosivity varies by location within a home or building. Classification based on the highest reading from multiple sites is therefore recommended (i.e., at least two different rooms including one where CDW is most likely to be present).

Interpretation of air corrosivity data should consider construction history and past conditions, along with observations of surface blackening, drywall markings, and other sources of indoor pollutants. Because CDW emissions represent a variable mixture of sulfides, some of which are highly corrosive and some of which are highly odorous, CDW odor may still be detectable where air corrosivity has been restored to normal background. Therefore, systematic odor evaluation is suggested to supplement air corrosivity measurement when assessing homes for CDW.

## CONCLUSIONS

1. An industrial corrosion monitoring system adapted for IAQ consistently classified homes as either normal background, corrosive, or elevated with respect to the presence of CDW emissions.
2. Background air corrosivity in homes without strong sources of corrosive emissions is generally below 20 A°/30d.
3. Most peak air corrosivity readings in homes with corrosive drywall exceeded 200 A°/30d.
4. A three day measurement of air corrosivity can be used to classify IAQ with respect to the investigation of CDW contamination and remediation.
5. For tracking the progress of CDW remediation, a one day probe test provides a good indicator of remediation efficacy, however, a three day test is needed for verification.
6. Use of new probes for each test provides for the most reliable accuracy and shipping stability.

## RECOMMENDATIONS

1. Additional data should be collected to statistically evaluate the protocol described in this study for accuracy and precision.
2. The contribution of individual sources of corrosive emissions in the residential environment should be quantified.

## ACKNOWLEDGEMENT

Rohrback-Cosasco Inc., NanoScale Corp., Sun City Corrosive Drywall Coordinating Group, Ainsle Builders, Healthy Home Solutions, and MZA Consultants contributed time and materials to this study.

## REFERENCES

- Brown R. and Monteith L., 1995, *Air Sampling Instruments*, ACGIH, Cincinnati OH.
- Burdack-Freitag A., Mayer F., and Breuer K.: Identification of odor-active organic sulfur compounds in gypsum products. *Clean* 37:459–465 (2009).
- Instrument Society of America, 1985, *Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants*, ISA Standard-71.04-1985.
- Leygraf C. & Graedel T., 2000, *Atmospheric Corrosion*, Wiley & Sons.
- Rohrback Cosasco Systems, Inc.: *Model Checkmate Corrosometer Portable Instrument*. Bulletin #526-D. Santa Fe Springs, Calif.: Rohrback, 2009.
- U.S. Consumer Product Safety Commission (CPSC): *Draft Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*. Report 16512 prepared by Environmental Health and Engineering, Inc., Needham, Mass., Nov. 18, 2009.