Tracking Moisture in Buildings with Water Activity

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Abstract

Reports from building materials, building health and remediation industries highlight the connection between building dampness, mold growth, and health concerns. However, there is no clear definition of what “damp” means. The assumption is that damp means wet, and hence is detected by measuring moisture content. But, research over the past 60 years has consistently shown mold growth to be controlled by water activity, not moisture content. Water activity is a measure of the energy status of water. Microorganisms cannot utilize low energy water for their growth, regardless of how much water is present. The practical lower limit for molds growth is a water activity around 0.70, and toxin and spore production stops at even higher water activities. Therefore, a water activity measurement is the most appropriate test to determine if a building is damp enough to support the growth of mold. Water activity is easily measured on laboratory samples using advanced bench top instruments, but in situ measurements can be more difficult. Vapor equilibrium between the gas and liquid phases is necessary to determine water activity. A prototype probe was used to take in situ water activity measurements on a sheetrock wall. The probe uses a temperature/humidity element and is connected to a battery powered data recorder. Preliminary results indicate that this testing system is effective in distinguishing areas in buildings where water activity is high enough to support mold growth. This water activity testing system will provide a more direct indication of when building dampness will lead to mold problems than moisture content measurements can.

Introduction

While numerous reports emphasize the critical role of water in building health and mold prevention, these reports often suggest that dampness of building materials be monitored by measuring water content (NY State Dept of Health 2010). However, Scott (1957), and many subsequent studies, have shown that the growth and proliferation of microorganisms is controlled by water activity, not moisture content. Mold growth stops at water activities below about 0.70. Mycologists rely on water activity, not water content, to determine whether moisture is available for colonization of a substrate by mold (UCF, 2007). This would indicate that dampness in a building should be assessed by measuring water activity, not water content. Several reports on mold growth in buildings and building materials further confirm that it is the availability of water, as indicated by water activity, that determines if mold growth will occur (Menetrez et al. 2004, Pasanen et al. 2000).

Water activity is a measure of the energy state of liquid water in a material (Fontana, 2007). Values range from 0 to 1.0, and are unitless. Water activity is typically measured by equilibrating the liquid water in the sample under test with the surrounding air and measuring the relative humidity of the air. At equilibrium the air humidity is equal to the water activity of the sample (humidity being expressed as a fraction rather than percent). Water activity is easily and accurately measured using benchtop instrumentation, but in situ measurements are more difficult (Fontana, 2007).

Because moisture infiltration into buildings leads to so many problems, it is recommended that building owners try to prevent moisture infiltration and if moisture does become a problem, to make every effort to remove the moisture or the moist materials (NY State Dept of Health 2010). Moisture can infiltrate buildings either through exposure to high humidity or to liquid water. Water does not have to come into contact with a wall directly to be a problem because standing water on the ground can wick up into the drywall and create conditions that will allow mold growth (Greenwell and Menetrez, 2004). Consequently, effective monitoring of buildings for moisture problems requires a system that can detect the infiltration of water, determine if the water activity of the wallboard is high enough to support mold growth, be able to log data over time, and be accessed remotely. That being established, the issue at hand is finding the most effective manner of tracking moisture in buildings. Methods today include sonar, infra-red cameras, electrical resistance measurement, and even subjective human assessment. The most widely used methods measure water content and consequently don't meet the requirement of providing the water activity (MBEH, 2007).

Greenwell and Menetrez (2004) were able to track movement of moisture up wallboard using a moisture meter. The moisture meter did not have the capability to log data or be accessed remotely. The moisture measurements did show movement of water up the wallboard; however, they were not a good indicator of viability for mold colonization, since moisture content is not an indicator of mold growth. An arbitrary, habitable medium might have a high water content, but it still might not be colonized by mold or microbes until it had sufficiently high levels of water activity. The water activity of building material determines not only whether mold will grow but also the types that colonize the material (MBL, 2011).

The objective of this study was to test a method that could be used to track water activity in building materials using a sensor and logging system. This instrumentation could then be adapted for use as a water alarm system in buildings or as a tool to track the progress of remediation efforts after water damage.

Methods/Materials

Gypsum wallboard was obtained from a local supply store and used to assemble a 61 x 51 cm wall. The wall frame was composed of fir two-by-four studs and the wallboard was unaltered -5/8 inch gypsum with no covering. The wall was placed in a plastic-lined trough containing 7.6 cm depth of tap-water (Figure 1). After all sensors had reached their peak water activity value, the wall was taken back out of the water and allowed to dry.

Figure 1. Test setup showing water activity sensors placed at different heights on wallboard suspended in water.

Water activity sensors (RH/temperature sensors, Decagon Devices, Inc. Pullman, WA) were placed at 5, 15.2, and 45.7 cm from the waterline on the wallboard. These sensors were pre-calibrated with a reported accuracy of +/- 0.02 aw. Sensors were covered and sealed to the wallboard using black Gorilla tape. Each sensor was connected to a data logger, which collected water activity and temperature readings each half hour for the duration of each test run during both wetup and drydown. Data were averaged over 2 repeated test runs. The sensors were nonintrusive and had little to no impact on the condition or state of

Probe Height (cm)	Initial a_w Reading	Sensor a_w Reading (at time of sample)	Time to Peak	Instrument a_w (at time of sample)
5	0.30	1.00	11 hrs	Not taken
15.2	0.30	1.00	15 hrs	0.999
45.7	0.30	0.33	26 hrs	0.378

Table 1. Average initial and peak water activity readings by the sensors at 5, 15.2, and 45.7 cm during wall wetup. The time to reach the peak reading is also recorded. The water activity of a sample of wallboard as measured in a benchtop water activity instrument is also shown.

the wallboard. The wallboard was maintained at room temperature and did not significantly change during testing. In order to verify the readings of the sensors, the water activity of samples taken from the wall at 15.2 and 45.7 were analyzed for water activity using a benchtop dewpoint water activity meter (AquaLab Series 4, Decagon Devices, Inc. Pullman, WA).

The wall was suspended in the trough in order to maximize the area of open-ended wallboard exposed. Water was then poured into the trough until it just covered the top of the lowermost two-by-four. Water lost by evaporation was replenished as needed on a daily basis.

Results and Discussion

Water moved quickly up the wallboard once it was placed in the water trough in agreement with the results of Greenwell and Menetrez (2004) (Table 1). All sensors initially read a water activity of 0.30, which is typical for ambient room conditions. After 11 hours, the first sensor at 5 cm increased from 0.30 aw to 1.0 aw. The second sensor at 15.2 cm also increased to 1.0 aw, and the sensor at 45.7 cm remained unchanged (Figure 2). This indicated that water had saturated the wallboard at 5 cm, reached the second sensor and raised the water activity to high enough levels to support mold growth, but had not yet reached the highest sensor. After 15 hours, both of the lower sensors were giving peak aw readings, but the highest sensor remained unchanged (Figure 1). Finally, at 27 hours, the highest sensor read 0.70 aw (Table 1). The wall board at 45.7 cm never reached a water activity of 1.0, but its water activity was high enough to support mold growth. Table 1 shows a comparison of sensor water activities and water activity of samples taken from the wallboard and run in the AquaLab Series 4. The Aqualab measurements agreed well with those reported by the sensors, indicating that the sensors correctly represented the water activity of the wallboard.

Greenwell and Menetrez (2004) reported that after 2 days, the moisture content at 30 cm had risen from 0.3 % to approximately 15%. This indicated that water was moving, but did not provide information about the possibility of mold growth. By utilizing water activity sensors instead of a moisture content meter, the results from this study not only make it possible to track moisture movement, but also directly provide information about the susceptibility of the wallboard to molding as the water moves.

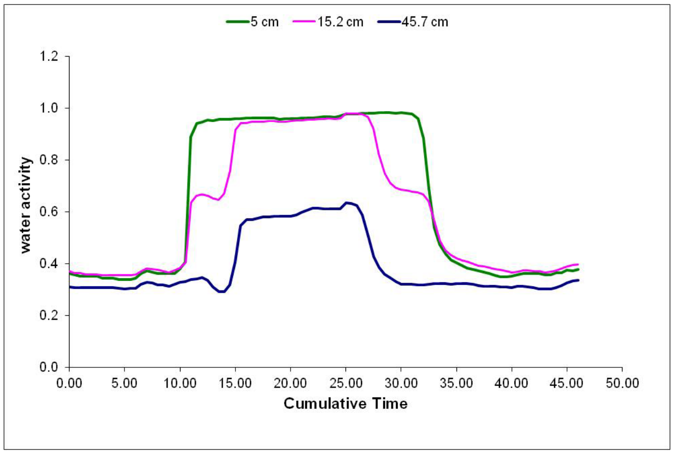

Figure 2. Water activity plotted as a function of time for the sensors at 5, 15.2, and 45.7 cm showing and increase in water activity as water moved up the wall and then a decrease in water activity as the wall dried out.

When the wall was removed from the water trough after 27 hours, water immediately began moving out of the wallboard through evaporation from the surface and from the edges of the wallboard (Figure 2). At 29 hours, the 45.7 cm water activity sensor was already back to reading 0.30 aw, indicating that the section it was measuring was no longer suitable for microbial growth. By 35 hours, the water activity readings of both the 5 and 15.2 cm sensors had dropped back to 0.40 aw, indicating that the entire wall had dried out and was no longer suitable for microbial growth. As with wetup, samples of wallboard were taken at 15.2 and 45.7 cm and measured for water activity using the AquaLab Series 4 water activity meter. The results again agreed well with those reported by the sensors, indicating that the sensors were still representing the water activity of the wallboard (Table 2).

Conclusions

The ability of the system proposed in this study to track both wetting and drying processes indicates that these sensors will follow water infiltration into building materials as well as the dry down progress during remediation. In addition, because the system is tracking water activity, it will not only be able to show water movement, but it will also indicate whether mold growth is possible when water infiltration has occurred. The system utilizes easy to install water activity sensors and a data logging system that can be set up anywhere. The data loggers are battery powered and have the capability to be accessed locally or, using a cellular link, over the internet. The software program that comes with the sensors can be setup to provide alarms if the water activity increases above unsafe levels, alerting a building owner that a water problem has occurred. The water activity system proposed in this study can effectively and correctly monitor dampness in buildings, meeting the directives outlined by many state health agencies that moisture in buildings needs to be monitored and controlled to ensure building health.

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Probe Height (cm)	Initial a_w Reading	Sensor a_w Reading (at time of sample)	Time to Peak	Instrument a_w (at time of sample)
5	1.00	0.40	35 hrs	Not taken
15.2	1.00	0.36	35 hrs	0.407
45.7	0.70	0.35	29 hrs	0.402

Table 2. Average initial and final water activity readings by the sensors at 5, 15.2, and 45.7 cm during wall drydown. The time to reach the low reading is also shown. The water activity of a sample of wallboard, as measured in a benchtop water activity instrument, is also shown.

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