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Effects of Flooding on Preexisting Mold Spores with in Drywall Sold by Distributors - Results of a Two-Year Study

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Abstract

Protocols for studying the effects of flooding on building materials need development. Validation is needed for common rules which form the basis of disposition of materials post flood. So called rules of thumb for removal of finishes including drywall after sustained flooding by industry and governmental organizations after wetting for 72 hours and lack of ventilation of the wetted surfaces were adopted into the experimental design of this study. The objective of this experiment was to examine whether preexisting mold spores within a drywall board, in addition to those already present in the air and flood water, contribute to mold damage after flooding. The study's protocol and experimental methods can be used as a reference for future related studies.

Keywords: Heavy Metals; Mangrove; Sediments; Red Sea; Yemen

Implications

The objective of these experiments was to examine whether preexisting mold spores within drywall board, in addition to those already present in the air and flood water, contribute to mold damage in houses after flooding. The results indicate it is highly likely that the growth of molds on the drywall construction germinated from spores within the drywall, although the presence of the mold spores from the air cannot be exclusively excluded from the tank chamber. This paper reports on bench experiments over a two-year period that mirror work conducted by ORNL's Buildings Technology Center and Tuskegee University's College of Engineering, Architecture and Physical Sciences.

Introduction

In the United States, floods bring more damage to houses and buildings than any other forms of natural disasters. Since 1990, property damage related to flooding in the United States is estimated to be more than US $30 billion [1]. In addition, millions of homeowners have been left homeless as the houses could not be remediated and restored after flood damage. Therefore, it is imperative to engineer houses that can resist flood damage. This can be achieved through the usage of building materials that resist physical damage from flood water and microbiological damage from mold and mildew, in which the high moisture and humidity during and after the flood provides desirable conditions for growth. Furthermore, interior structures of houses in flood-prone areas are being redesigned to provide easy and efficient remediation and renovation after a flood [2]. The Residential Group of Oak Ridge National Laboratory (ORNL)'s Buildings Technology Center, along with Tuskegee University's College of Engineering, Architecture, and Physical Sciences have been conducting extensive research on developing flood damage-resistant housing and have developed protocols for studying the effects of floods on building materials which were adopted into the experimental design of this study [3].

Flood damage can occur both during and after a flood. The presence of water wets building materials and physically alters the appearance and properties. Even after the water level recedes, houses retain high moisture level that promote mold growth. Past experiments have shown that there is a timeline for mold growth and different species of molds appear at different stages. *Aspergillus* and *Penicillin* for example, are one of the first molds to appear, while the infamous *Stachybotrys* appears later [4]. Because molds are stationary and natural decomposers, obtaining nutrients is accomplished by externally secreting enzymes that digest large organic molecules into nutrients for absorption. When molds grow on buildings materials, gradual degradation of the building structures occur. In addition, the mere presence of molds in living habitats can be dangerous. Some molds, such as *Stachybotrys chartarum,* or black mold, produce deadly toxins suspected to cause pulmonary hemorrhage [5]. Even with molds that do not produce toxins, reproductive spores can be unhealthy and can illicit allergic response or cause inflammation of the respiratory airway.

Drywall is commonly used for interior building material in the United States. A panel of drywall is made of gypsum plaster pressed between two sheets of paper liners. Gypsum plaster or plaster of Paris is created by the heating of soft mineral gypsum [6]. Most gypsum boards or drywall panels used in the United States are manufactured within the country for local supply with some imports from Canada and Mexico [7]. From 2004 to 2007, high demand for gypsum boards in the United States due to the housing boom and rebuilding after several hurricane incidents in the South led to imports of drywall from China [8]. In a previous study, mold spores were found within drywall sold directly by distributors [9]. While it is common knowledge that mold spores are present in the air and are the primary source for molds found growing on wall surfaces, it has yet been confirmed whether mold spores preexisting within the drywall play a role in flood damage.

Methods

The Tuskegee University flood research facility built a prototypical test structure resembling a small house of dimension 8’ length x 8’ width x 10’ height in an outdoor basin in Tuskegee, Alabama [1,3]. Water was pumped into the basin flooding the test structure for a controlled period of time and observations made of the flood damage. While such a setup was ideal for this study, it was not realistic for bench scale testing. To study the effects of flooding on drywall in the laboratory, the setup for the experiment was scaled down proportionally. Using a room with an air volume of 800 cubic feet with a typical two-foot flood, the wet surface area would approximate 180 square ft. This would yield a ratio of room air volume to wetted area of 800 cubic ft./180 square ft. or a 4.4 ratio. The simulation of opening windows for drying required 5-10% of the enclosure surface area to be opened. In addition, the temperature and humidity of the chamber were regulated using a Zoo Med HygroTherm™ hygrometer and readings were recorded during the experiment. A coupon of drywall was mounted on a wooden frame and placed within a sealed polyethylene chamber and flooded by submerging in water for 72 hours. The flood water was then drained and the drywall coupon remained in the enclosure with little to no air movement for another 120 hours (5 days). During the submersion period, the environment inside the chamber simulated the impact of a very wet enclosed space with little to no air movement. The drywall construction design had an enclosed air volume to wet surface ratio approximate to finishes in a flooded house. For fungal identification, bulk samples were prepared from the surface of selected areas of drywall coupon. Samples were then examined under a light microscope and identified based upon the agreement between the observed morphology with the dichotomous key compiled by Dr. David Malloch, a mycologist of the New Brunswick Museum [10,11].

Results

The temperature and humidity readings from the digital sensor of the Zoo Med HygroTherm™ were recorded during the entire period of flood simulation. These data are plotted into graphs as shown in Figure 1 to display and analyze the trend of temperature and humidity change inside the chamber.

The temperature inside the chamber was set to 80^{o}F. Prior to ventilation, the temperature inside the chamber remained slightly lower in comparison to the exterior temperature after opening the windows, most likely due to the presence of high relative humidity. According to Figure 1, the relative humidity inside the chamber was initially recorded at 59% then rapidly increased to 95% (<24 hours). After the water level receded (post 72 hours), the humidity level remained approximately 95%. It was not until the chamber was opened to ventilate (after 192 hours) that humidity began to gradually decline. This prolonged period of high humidity provided optimal conditions for mold growth as molds prefer humidity levels 65% and above. Figure 2 shows large amount of growth on the coupon upon removal from the chamber. Table 1 shows the distribution and identification of fungal species on the drywall coupons. Upon examination, five genera of fungi were identified *Aspergillus*, *Cladosporium*, *Penicillium*, *Ophistoma* and *Rhizopus*.

Conclusions

This paper reports on bench scale studies using sealed and then ventilated tanks containing drywall coupons to mirror events during flooding incidents to examine the effects of flooding with respect to mold growth on drywall. While likely the growth of molds on the drywall coupons germinated from spores within the drywall, the presence of mold spores from the air cannot be exclusively excluded from the tank design although every precaution was taken to limit this event. A more advanced chamber system is needed to prevent possible points for contamination within the chamber to rule out the presence of spores from the air to reach an absolute conclusion. This study was designed as bench scale attempt to begin to examine flooding damage and mold growth on building materials and can be considered a stepping stone for investigating the presence of mold spores within drywall material and the impact on drywall performance at bench scale parameters. Future studies include determining how spores within drywall contribute to flood damage compared to spores present in the atmosphere. Another area for future study is comparing mold resistant and non-mold resistant drywall compared to regular drywall. Lastly, a comparative study between U.S. manufactured drywall and imported drywall from Canada, Mexico or China may produce different results.

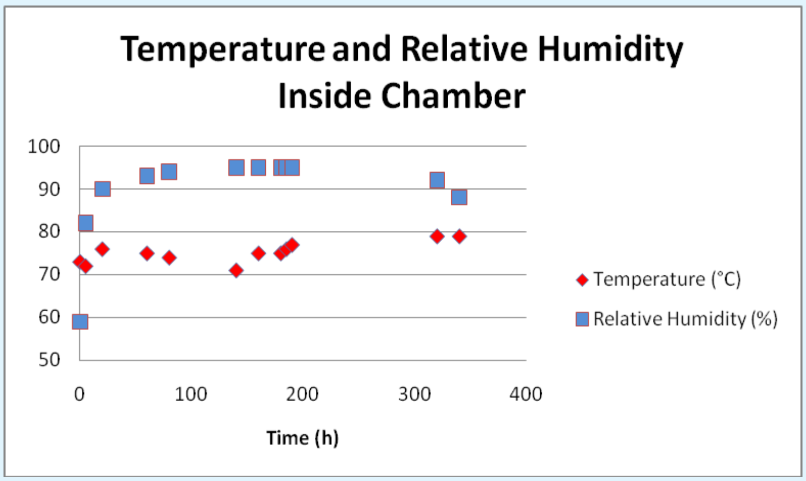

Figure 1: Plotted data of the recorded (a) temperature and (b) relative humidity inside the chamber.

Figure 2: Distribution of mold on the drywall coupon.

Appearance	Location	Identified Genus
Greyish-green, dense and moss-like	Sides of the drywall near the top	*Aspergillus*
Black, dense at the center, flat	Edges of the top of the drywall specifically on the gypsum plaster	*Cladosporium*
Olive green to brown, dense and moss-like	Sides of the drywall near the top	*Penicillium*
Black, tall and fibrous	Top of the drywall, on wood surface	*Ophistoma*
White, cotton like with ring formation	On the side of the drywall starting from the top to the middle	*Rhizopus*

Table 1: Molds found growing on the test drywall construction.

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