

# Health Concerns Associated with Mold in Water-Damaged Homes After Hurricanes Katrina and Rita --- New Orleans Area, Louisiana, October 2005

by

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## ABSTRACT

Breaches in the levees after Hurricanes Katrina and Rita in August and September, 2005 led to flooding in the New Orleans area making the likelihood of mold contamination a certainty. The Louisiana Department of Health and CDC assessed mold exposure in homes and mold remediation knowledge and behaviors of residents and workers. A convenience sample of residents and remediation workers with potential exposure to mold were asked questions about their knowledge, attitudes, and practices regarding mold. One consenting adult from a random selection of 112 of the 440,269 households in the New Orleans area responded to questions on demographics, home occupancy, and participation in remediation activities a visually assessment of water damage and mold growth was done. Samples were collected from a subset of homes and tested for culturable fungi, endotoxins, glucans and fungal spores. A total of 235 (70.1%) of the 332 workers and residents approached were for interviewed. Most workers and residents were aware that exposure to mold could affect health, but neither workers nor residents consistently wore personal protective equipment (PPE). An estimated 46% or about 110,000 homes had some mold growth. Although typical molds were found, environmental markers of mold and other micro-organisms were above levels

typically reported with an inversion of the outdoor/indoor ratio. Novel approaches are needed to increase the availability of PPE and to communicate health prevention strategies to reduce exposure to mold in post disaster situations that involve floods.

KEYWORDS: mold, hurricane, flooding,

## 1.0 INTRODUCTION

On August 29 and September 24, 2005, Hurricanes Katrina and Rita respectively made landfall along the Gulf Coast. After both instances, levees were breached leading to massive flooding in New Orleans and surrounding parishes. The duration and extent of flooding, and the number of structures flooded in New Orleans, made the likelihood of massive mold contamination a certainty.

Recent parallels to the degree of flooding seen in New Orleans as a result of Hurricanes Katrina and Rita occurred in 1997 in Grand Forks, North Dakota, and in 1999 in North Carolina after Hurricane Floyd (CDC 2004). In North Carolina there was a reported increase in persons presenting with asthma symptoms and this was postulated to be due to exposure to mold (CDC 2004). In 2001, flooding and subsequent mold growth on the Turtle Mountain reservation in Belcourt, North

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Dakota was associated with self-reports of rhinitis, rash, headaches, and asthma exacerbation (Stock 2005). The Institute of Medicine report on Damp Indoor Spaces and Health (IOM 2004) determined that exposures to mold are associated with respiratory illnesses, and that immunocompromised persons are at risk for fungal colonization and opportunistic infections. Although there have never been reports of increased fungal infections related to floods in the United States, anecdotal case-reports of fungal infection after floods include *Apophysomyces elegans* wound infection in a man who sustained traumatic injuries after the southeast Asian tsunami in December 2004 (Andresen 2005). In addition, there is an endemic area of Blastomycosis in Washington Parish, Louisiana, about 70 miles from New Orleans (Lowry 1989).

CDC, state public health officials and the general public were therefore concerned about possible health effects for returning residents due to the anticipated mold contamination of homes and other structures along the U.S. Gulf Coast associated with massive flooding after these hurricanes (CDC 2005). Because of these concerns, CDC was invited by the Louisiana Department of Health and Hospitals (LA-DHH) to assist in an investigation of the respiratory health effects of mold exposure. The epidemiologic investigation was planned to determine if there were increased respiratory symptoms, assess mold exposure, and determine mold remediation knowledge and behaviors of residents and workers. This report summarizes partial results and findings from the investigation.

## 2.0 METHODS

During October 2005, a team composed of CDC personnel assisted LA-DHH to conduct a variety of public health surveillance activities in and around hospitals, worksites, and communities in the Greater New Orleans area.

### 2.1 Knowledge, Attitudes, and Practices Survey of Residents and Workers

During October 18--23, the assessment team conducted interviews in English and Spanish with residents and remediation workers in recently flooded communities at the FEMA Disaster Recovery Center in St. Bernard, a home improvement store in West Jefferson, and a grocery store in East Jefferson and at worker gathering sites. A convenience sample of residents and remediation workers with potential exposure to mold were asked questions about their knowledge, attitudes, and practices regarding mold; non-identifying demographic information was also collected. A display of respirators was used for reference during the interviews. Statistical analyses were done using SAS (version 9.12) software packages (SAS Institute, Cary, NC, USA) to generate means, medians and frequency distributions for questionnaire items. Comparative analyses were done using Chi-squared and Fisher's exact tests.

### 2.2 Survey of New Orleans Residences to Assess Level of Flooding and Mold Growth

#### 2.2.1 Selection of Residences

During October 22--28, the team assessed a sample of a cross-section of the 440,269 households in the four-parish area (on the basis of the 2000 U.S. Census). Sampling was restricted to blocks with more than 20 housing units yielding 239,949 potential households. Blocks were classified into three strata (mild, moderate, and severe) on the basis of Federal Emergency Management Agency (FEMA) flood and damage maps. Geographic information system (GIS) mapping software was used to select a random number of waypoints (latitude and longitude) proportionate for each stratum. A sample size of 88 homes was required to obtain estimates within 10% accuracy. Global positioning system (GPS) units were used to locate each waypoint as the random starting point to locate the nearest home at or north of the waypoint.

### 2.2.2 Investigation of Residences

A questionnaire on demographics, home occupancy, and participation in remediation activities was administered to one consenting adult from the homes in which someone was in the home. A standard instrument designed for this study was used to visually assess water damage and mold growth. Statistical analyses were done using SAS (version 9.12) software packages (SAS Institute, Cary, NC, USA) to generate means and frequency distributions for questionnaire and visual assessment items.

### 2.2.3 Environmental Sampling and Laboratory Analysis

Between October 22—27, 2005, samples were collected indoors and outdoors at a subset of participating homes. Indoors, samples were collected in the “moldiest” room of the residence, as visually assessed by an industrial hygienist, using 0.4 µm pore size, 37 mm closed-faced filters, sampling at a rate of 3 liters per minute. Sampling time ranged from 36 to 144 minutes.

The filters were analyzed for culturable fungi, (1→3, 1→6)-β-D-glucan (a cell-wall component of many fungi) (Blanc 2005), endotoxin (a cell-wall component of gram-negative bacteria) (Thorne 2000) and fungal spores. For statistical analyses, post priori, residences were grouped into mild and moderate/heavy-damaged categories. Statistical analyses were done using SAS (version 9.12) software packages (SAS Institute, Cary, NC, USA). Concentrations were expressed as geometric means (GM) and geometric standard deviations (GSD).

## 3.0 RESULTS

### 3.1 Survey of Residents and Workers

A total of 332 persons (workers and residents combined) were approached for interviews; 235 (70.1%) participated. Of 159

residents interviewed, 82 (51.6%) were male; the overall mean age was 51 years (range: 18--81 years). Nearly all (96.2%) residents responded affirmatively to the question, "Do you think mold can make people sick?" One hundred eight (67.9%) correctly identified particulate-filter respirators as appropriate respiratory protection for cleaning of mold. Sixty-seven (42.1%) had cleaned up mold; of these, 46 (68.7%) did not always use appropriate respirators. Reasons for not using respirators included discomfort (10 [21.7%] respondents) and lack of availability (10 [21.7%]). For public communications about potential risks from exposure to mold and the use of personal protective equipment, 139 (87.4%) respondents recommended the use of television or radio.

Seventy-six persons who self-identified as remediation workers were interviewed. Of these, 14 (18.4%) were self-employed, and 62 (81.6%) worked for a company doing remediation. Of the 76 workers, 70 (92.1%) were male; the mean age of respondents was 33 years (range: 18--57 years); 41 (54%) spoke only Spanish. Seventy-two (94.7%) thought mold causes illness. Sixty-five (85.5%) correctly identified particulate-filter respirators as appropriate protection for cleaning of mold. Sixty-nine (90.7%) had already participated in mold remediation activities at the time of the interview. Of these, 34 (49.3%) had not been fit tested for respirator use and 24 (34.8%) did not always use appropriate respirators; 13 (54.2%) cited discomfort as the reason for not using respirators. For worker communications about potential risks from exposure to mold and the use of personal protective equipment, 36 (47.4%) recommended use of television or radio and 17 (22.4%) recommended communication through employers.

### 3.2 Environmental Survey of New Orleans Residences to Assess Level of Flooding and Mold Growth

In the sampled areas, 141 homes were found to be occupied. The questionnaire was administered to an adult from 113 of the 141 homes in which someone was in the home. One assessment was abandoned resulting in a final sample of 112.

Of 112 homes inspected (Table), flood levels were assessed from the outside for 105 homes as been high (>6 feet) in 21 (20%) homes, medium (3--6 feet) in 18 (17.0%), and low (<3 feet) in 66 (63%) (including 38 [36%] homes with no flooding). Flood levels were assessed as been high indoors for 16 (15%) of 109 homes. Seventy-six (67.9%) homes had roof damage with water leakage. Visible mold growth occurred in 51 (45.5%) homes, and 19 (17.0%) had heavy mold coverage (>50% coverage on interior wall of most-affected room). The distribution of homes with heavy mold coverage was 10 (52.6%), seven (36.8%), and two (10.5%) in high, medium, and low flood areas, respectively.

Participants reported being indoors doing heavy cleaning an average of 13 hours since the hurricanes (range: 0--84 hours) and 15 hours doing light cleaning (range: 0--90 hours). Sixty-eight (60.7%) participants reported inhabiting their homes overnight for an average of 25 (standard deviation: +13.7) nights since the hurricanes.

### 3.2.1 Environmental Samples

Samples were collected indoors from 20 of the 112 residences that participated in the survey, and also outdoors from 11 of these 20 residences. Of the 20 residences sampled, 5 were in mild-damaged areas and 15 were in heavy-damaged areas. Moderately to heavily-damaged residences had higher measures of microorganisms compared to mild-damaged residences. However, only for culturable fungi were they significantly different (Table 1). Indoors, for culturable fungi, *Penicillium* and *Aspergillus* were the most commonly identified fungal species. In outdoor

samples, *Penicillium*, *Aspergillus* and *Cladosporium* were most commonly identified.

### 3.2.2 Household Factors and level of Mold and Micro-organisms

As noted, level of flooding was associated with observed and culturable mold growth. Though not statistically significant, for the 20 homes where samples were taken, there were differences in the levels of endotoxin, glucan and mold growth by the type of material used for wall, ceiling or flooring (Table 2). The amount of endotoxin, glucan and mold growth was greater for drywall or wood compared to plaster or tile. However, no similar relation was seen for observed mold growth and type of wall or floor material in analyses including all surveyed homes (table 3). In a logistic regression model of the full sample controlling for remediation, observed indoor flood level was associated with mold wall coverage whether the wall material was drywall or not. When indoor flooding was greater than 3 feet, both drywall/wood paneling (odds ratio, OR=26; CI 6.0-114.3, p<0.05) and plaster/tile (OR=36; CI 2.5- 527.0, p<0.05) were associated with mold wall coverage of >50%.

## 4.0 DISCUSSION

The typical molds found indoors and outdoors in all regions and all climates in the United States are *Aspergillus*, *Cladosporium* and *Penicillium* (Shelton 2002). Indoor concentrations are generally lower than outdoor levels and for culturable fungi, median indoor levels are approximately 80 CFU/m<sup>3</sup> ranging from the lower limit of detection to 10,000 CFU/m<sup>3</sup> (Shelton 2002). Indoor concentrations were found to be lowest in the Northeast and highest in the Southwest, Far west and Southeast (Shelton 2002).

We estimate that in New Orleans there were at least 110,000 homes with elevated mold

and bacteria levels and at least 40,000 homes that were heavily contaminated with mold and bacteria. Based on samples taken from a limited number of homes, typical fungi were found indoors and outdoors. However, the levels indoors and outdoors were much higher than typically found and indoor levels were higher than outdoors.

Similarly, levels of glucan and endotoxin were higher than typically reported. In this assessment, a newer assay for (1→3, 1→6)-β-D-glucan (Douwes 2005) which has a higher specificity for fungi, yielded higher indoor than outdoor levels in New Orleans homes, confirming the findings from visual assessment of homes and measurements of culturable fungi and spore counts. Levels of airborne endotoxin inside homes in post-hurricane New Orleans averaged more than 20 times higher than the usual 1.0 EU/m<sup>3</sup> average (Park 2000), with an inversion of the expected indoor-outdoor relationship. Thus in addition to mold, these environments most likely had other microorganisms and possibly their toxic metabolites.

As expected the main factor associated with mold growth was the extent of flooding. However, though not statistically significant, drywall and wood were more likely to be found with higher levels of mold growth, glucan and endotoxin. However, observed mold growth in all homes surveyed was not associated with type of building material. These results could imply that elevation of homes and type of building materials may be important when building in flood prone areas such as New Orleans, but more data is needed to resolve this question.

Although a variety of clinical syndromes and symptoms are reportedly associated with mold and microorganisms in damp environments, the Institute of Medicine report on Damp Indoor spaces (IOM 2004) found sufficient evidence of an association for a limited number of conditions. Exposures, especially to mold were often determined by self-report. Associated

conditions included: upper respiratory tract symptoms (such as nasal congestion, sneezing, runny or itchy nose, and throat irritation); lower respiratory tract symptoms of cough and wheeze; asthma symptoms in sensitized people with asthma; hypersensitivity pneumonitis in a small proportion of susceptible people; invasive respiratory and other fungal infections in severely immunocompromised people; and fungal colonization of the respiratory tract or infection in individuals with chronic pulmonary disorders.

In some homes, the measured indoor endotoxin levels were comparable to those of certain industrial settings in which declines in pulmonary function have been demonstrated (Douwes 2002). The levels of mold found were well above levels reported as being associated with symptoms of respiratory tract illnesses in children (Stark 2003). However, based on the currently available evidence, we cannot determine a level of mold that is either safe or likely to be associated with adverse health effects (IOM 2004) and there are no standards that relate health effects to specific levels of molds in the air (Rao 1996).

In October 2005, the CDC Mold Work Group published guidelines for remediation workers and the public on preventing mold-associated illness (CDC 2005, CDC 2006). Recommendations included avoiding exposure when possible and using a particulate-filter respirator during activities that create mold-contaminated dust. Despite the apparent risk of exposure to mold and other microorganisms in New Orleans homes post Katrina and a seeming awareness by workers and residents about the potential for adverse health outcomes from exposures, PPE was not consistently used. This was despite the fact that residents reported spending a lot of time inside homes doing clean-up work. Disruption of normal communication channels made the dissemination of public health messages difficult immediately post Katrina. Novel measures to increase awareness of

appropriate respiratory protection among the public are warranted in the immediate post disaster settings. As conditions return to near normal, communication could be carried out via traditional media announcements and educational sessions for employees of home improvement stores and other commercial entities that sell respirators. Public availability of particulate-filter respirators might be increased through partnerships with respirator manufacturers. For remediation workers, the importance of appropriate respiratory protection should be emphasized via traditional media announcements and/or employers, with messages in both English and Spanish. Fit testing should occur according to the OSHA Standard (OSHA 2004); making such services available to small or individual operators might increase compliance with requirements.

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Table 1: Geometric means (GM) and geometric standard deviations (GSD) of indoor microbiological measurements by FEMA classification of water damage and outdoor microbiological measurements,

	Indoors					Outdoors		Indoor vs Outdoor P-value
	Mild GM (GSD)	Moderate/ Heavy GM (GSD)	Mild vs mod/heavy P-value	Overall GM (GSD)	Min-Max	GM (GSD)	Min-Max	
<b>Endotoxins (EU*/m3)</b>	9.7 (2.0)	31.3 (6.5)	0.08	23.3 (5.6)	1.2 – 1,200	10.5 (2.5)	2.2-83.0	0.1
<b>Glucans (ng/m3)</b>	1.1 (5.3)	1.8 (4.3)	0.28	1.6 (4,4)	0.33 – 45.5	0.91 (2.0)	0.40-3.3	0.3
<b>Culturable fungi at 25°C (CFU**/m3)</b>	3700 (9.1)	67,000 (10.1)	0.02		270 – >LOD***	4,700 (2.8)	1,300- 34,000	
<b>Culturable fungi at 37°C (CFU**/m3)</b>	630 (3.1)	16,000 (10.5)	0.002		<LOD – 1,200,000	980 (3.7)	149-16,000	
<b>Total spore counts (spores/m3)</b>	60,000 (5.8)	460,000 (14.9)	0.10		8,200 – 67,000,000	43,000 (5.0)	8,400- 2,500,000	



**Table 2a: Observed surface mold coverage for different types of material in the 20 homes where samples were taken**

	Material	N	Surface mold coverage* Mean $\pm$ SD	P-value
<b>Wall</b>	Drywall/wood	16	2.20 $\pm$ 1.7	0.07
	Plaster/Tile	4	0.50 $\pm$ 0.6	
<b>Ceiling</b>	Drywall/wood	16	0.90 $\pm$ 1.2	0.5
	Plaster/Tile	4	0.03 $\pm$ 0.6	

\*Mold coverage values are based on the mean of the rank after arranging the mold coverage categories in rank order such that:  
0= none; 1= <25%; 2=25-50%; 3=50-75%; & 4>75%.

**Table 2b: Endotoxin and glucan levels by type of interior wall material in the 20 homes where samples were taken**

	Material	N	GM (GSD)	P-value
<b>Endotoxin</b>	Drywall/wood	16	28.5 (6.4)	0.3
	Plaster/Tile	4	10.4 (1.8)	
<b>Glucan</b>	Drywall/wood	16	2.0 (4.6)	0.2
	Plaster/Tile	4	0.7 (3.7)	

**Table 2c: Endotoxin and glucan levels by type of floor material in the 20 homes where samples were taken**

	Material	N	GM (GSD)	P-value
<b>Endotoxin</b>	Hard Surface	8	23.3 (5.7)	0.3
	Carpet/wood	12	16.8 (5.4)	
<b>Glucan</b>	Hard Surface	8	2.3 (5.6)	0.4
	Carpet/wood	12	1.2 (3.7)	

**Table 3: Observed surface mold coverage for different types of material for all surveyed homes**

	Estimated Percent of Surface covered with mold			P-value
	None	Less than 50%	At least 50%	
<b>Wall material</b>				
Drywall/wood	42	23	14	
Plaster/Tile	18	8	4	0.5
<b>Floor Material</b>				
Tile/linoleum	21	9	9	
Carpet/wood	39	22	9	0.3