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Case Report

Molds and mycotoxins indoors III: Three case reports

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Abstract

Molds are microscopic fungi which are one of the most diverse and abundant eukaryotes. Not all fungi produce molds, some produce mushrooms and others grow as single cells like yeasts. Molds are ubiquitous, both outdoors and indoors. Certain molds produce mycotoxins that can cause many adverse health effects, especially in immunocompromised and/or genetically predisposed individuals. Here we present three cases of adverse health effects from the exposure to molds and mycotoxins: one healthy individual, one individual with an autoimmune disease, and one individual with genetic predisposition in five HLA/DR/DQ gene alleles.

Keywords: Mold indoors, Mold toxicity, Immunogenecity and mold toxicity, Susceptibility of mold toxicity and human leukocyte antigen (HLA) genes, Case reports, Mold risk assessment

Case Number 1

General description

A healthy female in her mid-40s. The subject never felt a need to seek out a doctor for ailments or illnesses and did not have any allergies. Prior to the development of health conditions described below, the subject had only one physical exam, an annual checkup with unremarkable findings.

Mold exposure history

The subject lived in a water damaged/mold infested apartment for over five years and was exposed to many toxic molds and mycotoxins present inside her residence.

Presence of molds and allergens, pathogenic bacteria, and endotoxins at the exposure site

The apartment subject lived in was infested with many toxic molds; 25 toxic molds were detected in the air collected from inside her residence. That included six species of *Aspergillus*, four species of *Penicillium*, four species of *Caldosporium*, and one species of *Chaetomium*, *Stachybotrys*, and others. Molds and water damage was found in the ventilation systems, walls, ceilings, and floors of the whole section where her apartment was located. Very high levels of two pathogenic bacteria belonging to the genera *Brevundimonas* and *Microbacterium* along with high levels of endotoxins were also found inside the subject's residence.

Systemic exposure to pathogenic molds, bacteria, and yeast

Systemic exposure to toxic molds was confirmed from the presence of markers of toxic molds (*Stachybotrys*, *Fusarium*, *Aspergillus*, *Cladosporium*, *Alternaria*, *Penicillium*) in the subject's serum. The subject's urine also contained elevated levels of ochratoxin A (OTA) (produced by many *Aspergillus* species) and citrinin (CTN) (produced by species of many molds including *Penicillium, Aspergillus* and *Monascus*). Fecal samples contained four species of commensal bacteria along with high yeast counts.

The subject's blood and urine were tested for the markers of mold (mycotoxins) exposure ~60 and ~90 days after she moved out to a non-mold infested residence, respectively. Presence of OTA in urine was not a surprise given the presence of high levels of six species of *Aspergillus* which produce OTA and its long elimination half-life ($t_{½}$) of ~36 days in humans [1]. On the other hand, presence of detectable levels of CTN in urine ~90 days after and several mycotoxins in blood ~60 days after the cessation of exposure indicate extremely high levels of CTN and other mycotoxins in her system while she was living in the mold infested apartment. Presence of extremely high levels of CTN in the subject's system was assumed with certainty given the elimination $t_{½}$ of CTN is only ~9 h [2]. Presence of other mycotoxins in the subject's system during her apartment at the mold infested apartment was assumed with high confidence due to the presence of many toxic molds (i.e., *Aspergillus*, *Caldosporium*, *Chaetomium, Penicillium*, *Stachybotrys*, etc.) in her apartment and their short elimination $t_{½}$ in humans (e.g., aflatoxins produced by *Aspergillus* have a $t_{½}$ of ≤ 8 h, mycophenolic acid [MPA] produced by many *Penicillium* species has a $t_{½}$ of 18 h, and roridin E produced by *Stachybotrys,* a trichothecene, has a $t_{½}$ of less than 8 h) making their levels to go below the lowest limit of quantification (<LLQ) within few days after ending the exposure [3-6].

Health issues

While staying at the mold infested apartment, subject suffered from fatigue, weakness, loss of appetite, diarrhea, cramps, severe pains, headache, photosensitivity, blurred vision, postnasal drip, chocking cough, shortness of breath, abdominal pain, joint pain, back pain, numbness, tingling, vertigo, memory issues, anxiety, focus impairment, brain fog, confusion, disorientation, excessive sweating (hyperhidrosis), hair loss, and other issues. Her most severe and lingering symptoms even long after moving out to a non-mold infested residence are/were enlarged liver, early onset of infertility, abnormal uterine bleeding, sudden back paralysis, and fatigue.

Possible reasons

The apartment subject lived in for over five years was infested with at least 25 species of toxic molds and she was likely exposed to several mycotoxins produced by the molds found therein with OTA still present in her urine ~90 days after moving out from the mold-infested apartment due to its long elimination $t_{½}$ of ~36 days in humans [1]. Readers are directed to Saghir *et al.* [7] for the description of the toxic molds and mycotoxins found at the subject's residence and detected in her blood, urine, and feces. Based on the presence of toxic molds in the apartment and mycotoxins in blood and urine along with medical records showing the subject was healthy before moving into the mold-infested residence, the reasons for the subject's health issues are most likely from the exposure to molds and mycotoxins. This finding was further strengthened by the fact that the subject's roommate, who also lived there for a significant amount of time, exhibited the same symptoms.

Case Number 2

General description

A female in her early 40s with a chronic lymphocytic thyroiditis (Hashimoto's disease), an autoimmune disease, often triggered by genetic or environmental factors that result in hypothyroidism, fatigue, and weight gain; subject was obese (Body Mass Index [BMI] of 45.0-49.9). She was allergic to mold-based medicines (e.g., Amoxicillin derived from *Penicillium,* and Cephalexin derived from *Acremonium/Cephalosporium*), Non-steroidal anti-inflammatory drugs (NSAIDs), sulfonamide drugs (e.g., Sulfamethoxazole), and other commonly household items/foods (e.g., bleach, onion). Prior to the illness, the subject was highly energetic; worked and went to school fulltime, cooked/prepared every food from scratch using ingredients she was not allergic to, took part in children's activities, and even traveled cross-country.

Mold exposure history

The subject lived for six years in a mold infested house with frequent water leaks.

Presence of molds and allergens, pathogenic bacteria, and endotoxins at the exposure site

The air collected from the residence contained 32 toxic molds including ten species of *Aspergillus*, six species of *Penicillium*, four species of *Caldosporium*, and one species of *Acremonium*, *Stachybotrys*, and others. High levels of two pathogenic bacteria belonging to genus *Acinetobacter* accompanied with high levels of endotoxins were also found inside the residence.

Systemic exposure to pathogenic molds, bacteria, and yeast

Systemic exposure to toxic molds was confirmed by testing her urine, albeit, 67 days after she had moved out to a non-water-damaged house. Urine of the subject contained elevated levels of OTA, which was expected from the presence of high levels of 10 species of *Aspergillus* and long elimination $t_{½}$ of OTA of ~36 days in humans [1]. Presence of other mycotoxins in the subject's system cannot be ruled out due to the presence of many toxic molds (i.e., *Acremonium*, *Aspergillus*, *Caldosporium*, *Penicillium*, *Stachybotrys*, etc.) in her residence and their short elimination $t_{½}$ in humans reaching <LLQ quickly after the cessation of exposure (e.g., aflatoxins, ≤ 8 h; MPA, 18 h; roridin E, <8 h) [3-6]. Fecal samples contained four species of commensal and one species of dysbiotic bacteria; fecal samples also contained high yeast counts.

Health issues

After about five years of living in a water-damaged house, the subject started to feel ill, she started to slow down, felt exhausted, fatigued, irritated and angry, and suffered from hypersomnia. Close to the sixth year of her living in the water-damaged house, she started coughing blood, struggled to breathe and unable to speak properly. She was admitted to ER and remained hospitalized for almost two weeks. The subject was diagnosed with an acute respiratory failure with extensive bilateral infiltrates in lungs that developed within 24 h prior to her admittance to the hospital for which she needed extracorporeal membrane oxygenation. Numerous tests could not find any specific diagnosis, including any physical/physiological reason(s), for her conditions, other than chronic fatigue. The subject started to feel better after she moved out of the mold-infested residence, however, remained fatigued with memory difficulties.

Possible reasons

The subject was an immunocompromised individual with known allergies to antibiotics derived from molds such as Amoxicillin and Cephalexin, NSAIDs, sulfonamide drugs, and other common household items, like bleach and onion. Immunodeficiency has made her more susceptible to toxic molds and mycotoxins. The

residence subject lived in for six years was heavily infested with molds, the collected air samples contained 32 toxic molds. Readers are directed to Saghir *et al.* [7] for the description of the toxic molds and mycotoxins found at the subject's residence and detected in her urine and feces. She was likely exposed to several mycotoxins produced by the molds found therein with OTA still present in her urine ~67 days after moving out from the mold-infested residence due to its long elimination $t_{½}$ of ~36 days in humans [1]. The subject's health started improving after moving out of the mold-infested residence. Based on these facts, we can conclude with high confidence/certainty that the subject's pulmonary conditions and chronic fatigue were either directly linked to the exposure to toxic molds present at the residence she lived in or exacerbated as the subject was an immunocompromised individual. This assessment was also supported by the fact that mycotoxins produced by *Penicillium* are very potent immunosuppressant, mycotoxins produced by *Chaetomium* can cause invasive infections in the lung, and mycotoxins produced by *Stachybotrys* are attributed to cause debilitating respiratory symptoms including pathological changes in the lungs at even low concentrations in the indoor environment [8-15]. Additionally, allergic sensitization, inflammation, and cytotoxicity of the upper and lower respiratory tracts of animals have been associated with airway exposure to *Stachybotrys* and have been linked to infant pulmonary hemosiderosis [12,16,17].

Case Number 3

General description

A male in his early 50s with a normal health (e.g., unremarkable blood test results, not diabetic, normal blood pressure and liver and kidney functions), slightly (5-7%) higher in total and LDL cholesterol, 2.8-fold higher triglyceride levels, with Class I obesity (BMI = 31.4). During young age, subject developed drug dependency but quit later, after the birth of his children. The subject was prone to seasonal allergies. He possessed predisposition in his five human leukocyte antigen (HLA) gene alleles of the major histocompatibility complexes for the cell surface receptors DR and DQ (DRB1*01:01:01G, DRB1*03:01:01G, DRB3*02:02:01G, DQB1*02:01:01G, and DQB1*05:01:01G).

Mold exposure history

The subject worked at a food processing facility for six years and apparently had been exposed to low levels of molds and mycotoxins during his entire working years which was confirmed from the presence of black molds in his office; he was exposed to very high levels of molds and mycotoxins, approximately four years after he started working, during cleaning a closet where black molds were growing.

Presence of molds and allergens, pathogenic bacteria, and endotoxins at the exposure site

Visual inspection of the facility showed mold growth at many areas within the building. Air and dust samples collected from the facility were positive for 25 molds and allergens (*Alternaria, Arthrospores, Ascospores, Aspergillus, Aureobasidium, Basidiospores, Chaetomium, Cladosporium, Curvularia, Epicoccum, Eurotium*, Hyphal Fragments, Insect Fragment, *Mucor and Rhizopus, Paecilomyces*, Particulate Matters/Fibers, *Penicillium, Pithomyces,* Pollens, *Rust, Scopulariopsis, Smuts/Periconia, Trichoderma,* unidentifiable spores, *Wallemia*). These molds and their components (*i.e.,* hyphal fragments, spores, and mycotoxins) are known to cause allergies and other toxicities. In addition to molds and their components, elevated levels of pathogenic bacteria and endotoxins were also found inside the building.

Systemic exposure to pathogenic molds, bacteria, and yeast

Systemic exposure to pathogenic molds was confirmed from the presence of elevated levels of OTA, MPA, and CTN. Fecal samples contained five species of commensal bacteria along with one dysbiotic yeast species when cultured in appropriate media; fecal samples also contained high yeast counts.

Health issues

Following the exposure to high levels of molds and mycotoxins, subject developed diffuse maculopapular (both flat and raised) lesions on scalp and back and allergies (e.g., watery eyes, nasal congestion, runny nose, postnasal drip, sore throat, mild cough, swollen lymph nodes in the neck and armpits, and fatigue) without any fever. He subsequently developed a dry cough, runny nose, watery eyes without chest pain, fever, or chills. He also experienced dyspnea with intense tightening of the chest, difficulty breathing, breathlessness, and feeling of suffocation. He was diagnosed with exacerbated allergies, chronic rhinitis, hypertrophy of nasal turbinate, cerumen impaction and abnormal auditory perception from the mold exposure.

Possible reasons

Based on the presence of 21 toxic molds inside the workplace and systemic exposure of three mycotoxins, we can deduce with high certainty that the adverse health effects of the subject were from the exposure to toxic molds and related biotoxins. Readers are directed to Saghir *et al.* [7] for the description of the toxic molds and mycotoxins found at the subject's workplace and detected in his urine and feces. Mycotoxins detected in the subject's system were consistent with molds responsible for producing those mycotoxins found inside his workplace. The subject worked in a mold-infested food processing facility which is an ideal place for molds to grow with abundant nutrients and ideal moisture and temperature, especially when extremely strict hygiene standards are not enforced. The subject was apparently exposed to low levels of molds and mycotoxins for his entire working years at the food processing facility; moreover, his conditions were exacerbated from the very high acute exposure and his genetic predisposition at five HLA/DR/DQ gene alleles resulting in higher susceptibility to molds and mycotoxins. Due to this genetic predisposition, the subject could not eliminate mycotoxins efficiently from his systems compared to individuals with normal HLA/DR/DQ gene alleles [18]. This put him at even greater risk because mycotoxin would likely have stayed in his system (blood and tissues) for an extremely long period of time turning even an acute or short period of exposure into a chronic exposure. Predisposition in HLA/DR/DQ gene(s) results in extremely slow elimination of mycotoxins from the system taking years to completely eliminate them even after a single acute exposure that occurred during cleaning the closet [18]. The acute exposure likely resulted in crossing the threshold of toxicity of mycotoxins as the subject was exposed to low level of molds and mycotoxins during the entire time while working at the food processing facility.

Conclusions

Molds and mycotoxins are not only known to cause many

adverse health effects in immunocompromised individuals and in people with genetic predisposition in HLA/DR/DQ gene alleles [8,18-23] but also to healthy individuals following repeated exposure to levels above the safety threshold as shown in this report. The safety threshold for molds and mycotoxins may vary among individuals based on the types of molds/mycotoxins, dose, frequency and duration of exposure, gender, age, genetic predisposition, health, dietary status, and interactions with co-exposure with other toxicants. Exposure to mycotoxins in association with gut dysbiosis-related (alteration in gut microbiota) disruption in gut barrier function and increased intestinal permeability of bacterial liposaccharides (LPS) further increases absorption/systemic bioavailability of mycotoxins. Increased intestinal permeability of LPS likely contributes to several chronic human diseases including diabetes, colorectal cancer, and degenerative neurological diseases (e.g., Alzheimer's and Parkinsons's diseases from inflammation and increases blood brain barrier permeability of LPS), especially in immunocompromised individuals [20,24-32]. Higher penetration of mycotoxins to central nervous system due to LPS-induced inflammation and increased blood brain barrier permeability also exacerbate neurological effects of mycotoxins. Mycotoxins exposure can also increase susceptibility to microbial diseases [24].

There is growing evidence that increased moisture from climate change (i.e., higher temperatures, increased evaporation/precipitation, flash floods) along with population growth are causing an increase in fungal growth, sporulation, allergies, and infections in humans [18,33-37]. Geographic range of pathogenic mold species is also expanding due to the climate change resulting in the emergence of diseases in areas where they had never been reported earlier [38-41]. Treatment of fungal infections is difficult due to the availability of extremely limited numbers of antifungal drugs, increasing resistance against available drugs, unavailability of vaccines, ability of molds to produce large quantities of infectious spores, and not requiring host-to-host contact for infection [39-41].

Even though, some of the serious health impacts of toxic molds is still debated among healthcare workers and researchers due to the lack of a proven direct link between exposure and disease (dose-response relationship) in the published peer-reviewed scientific literature, molds are recognized to cause hypersensitivity and modulate immune system following exposure. This is not only the specific concern for individuals with preexisting immune system impairments and genetic predisposition but also to many healthy individuals [18,20,24,25,28,30,31]. Even with the knowledge of wide-ranging effects of molds and mycotoxins on health, we have poor understanding of mycotoxin-mediated adverse health effects. Therefore, better understanding and management of mold- and mycotoxin-related human health issues is paramount.

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