Stachybotrys: relevance to human disease

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Learning Objectives: Recent public concern about the danger of environmental fungi has focused attention on one particular mold, *Stachybotrys*. The purpose of this review is to examine and critique the published literature on *Stachybotrys* for objective scientific and clinical evidence of disease caused by the presence of this fungal organism in the environment.

Data Sources: Data were obtained from all published research and reviews of *Stachybotrys* indexed in MEDLINE since 1966.

Study Selection: The publications used for this review were those that contained information about human health effects of this microorganism. The critique of these publications is the author's.

Results: *Stachybotrys* is a minor component of the indoor mycoflora, found on certain building material surfaces in water-damaged buildings, but airborne spores are present in very low concentrations. Published reports fail to establish inhalation of *Stachybotrys* spores as a cause of human disease even in water-damaged buildings. A possible exception may be mycotoxin-caused pulmonary hemorrhage/hemosiderosis in infants, although scientific evidence to date is suggestive but not conclusive. Based on old reports ingestion of food prepared from *Stachybotrys*-contaminated grains may cause a toxic gastroenteropathy. No convincing cases of human allergic disease or infection from this mold have been published.

Conclusions: The current public concern for adverse health effects from inhalation of *Stachybotrys* spores in water-damaged buildings is not supported by published reports in the medical literature.

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INTRODUCTION

There are close to 100,000 recognized species of fungi. They exist throughout the habitable world, and airborne spores of many species are present in respirable air. Recognized human diseases of fungal origin occur through one of three mechanisms: infection, allergy, or toxicity (Table 1). In each case, a specific disease can be traced to a particular species of mold.

Recently, there have been concerns expressed that the mere presence of molds in indoor air may cause an illness characterized by 1) multiple nonspecific symptoms and/or generalized malaise and fatigue, or 2) immunosuppression resulting in susceptibility to viral and bacterial respiratory infections.

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These concerns have centered particularly on one fungal genus, *Stachybotrys*, which is increasingly being implicated as a cause of human disease and often called the "fatal fungus."[1]

STACHYBOTRYS

Nomenclature

Stachybotrys is a deuteromycete (Table 2). There are a number of species, but the one most commonly encountered is referred to as *S. atra*, *S. chartarum*, or *S. alternans*. These are three synonyms for the same species.

Characteristics of the Organism

Stachybotrys is a greenish-black, sooty-looking saprophytic mold that grows on nonliving organic material, especially cellulose, under conditions of high humidity and low nitrogen content, in common with *Aspergillus fumigatus* and *niger*, *Cladosporium herbarum*, *Alternaria alternata*, and others. It is a slow-growing organism, both in nature and on laboratory media, where it may compete poorly with other rapidly growing fungi. Microscopically, there are clusters of phialides at the tips of conidiophores. The spores (conidia) are produced from the tips of the phialides and collect in wet masses, dying promptly on release into the air.

Stachybotrys is rarely recovered from outdoor air samples. It is also difficult to find in undisturbed indoor air. Because of its affinity for cellulose, it is found in nature on substrates of plant origin, but under very wet conditions. As a strong decomposer of cellulose, it favors decaying plant materials. Species with spores in chains are referred to as *Memnoniella*.

STACHYBOTRYS IN THE NATURAL ENVIRONMENT

Outdoors

Although *Stachybotrys* is rarely found in outdoor air (and when found, is present in low quantities), it is potentially an important contaminant of agricultural produce. The fungus has been cultured from soil[2] and substrates rich in cellulose, such as hay and straw, cereal grains, plant debris, rice paddy grains, combine harvester wheat and sorghum dusts,[3] and broad bean (*Vicia faba*) seeds.[4] In each case, *Stachybotrys* is accompanied by many other genera of fungi, and it is usually not the dominant one. Urea application as a source of nitrogen fertilization of soil promotes the growth of numerous fungi, including *Stachybotrys*.[5]

Stachybotrys has also been cultured from the hair of large mammals, including cow, dog, donkey,[6] and the skin surface of cynomolgus monkeys.[7] As in the case of plant contamination, it is found on these animals along with other fungi, especially *Cladosporium*.

Indoors

Stachybotrys spores may be recovered from indoor air samples, but generally

Table 1. Human Diseases Caused by Fungi

Infection
Systemic
Localized
Allergy
Atopy (especially asthma)
Hypersensitivity pneumonitis
Toxicity
Unverified claims of:
Nonspecific symptoms
Susceptibility to respiratory viral and bacterial infections by immunosuppression

only where there is significant water damage and visible mold growth on building surfaces. Even under these conditions, its concentration is very low compared with the more common *Penicillium* and *Aspergillus* species. In one study[8,9] it was found in the air of 2.9% of homes in southern California, and the mean concentration was only 0.3 spores/m^3.

Evaluation and quantitation of indoor molds can be done by several methods on both surface and air samples. Air sampling routinely uses either the Rotorod Sampler (Sampling Technologies, St. Louis Park, MN) or Andersen sampler (Andersen Samplers, Atlanta, GA). Microscopic examination is used to identify and quantitate spores by their characteristic morphology, or gross inspection and counting of fungal colonies is performed on culture plates.[9] Recently, the polymerase chain reaction technology has been used to uncover evidence of a particular fungus in biologic or other material when the expected quantity is especially small.[10]

Stachybotrys spores are found worldwide in or on a variety of indoor items, especially organic substrates rich in cellulose. These include urea-formaldehyde foam insulation, fiberboard, gypsum board, carpets, jute, vinyl and paper wall coverings, and other indoor building materials,[11–13] especially those containing wood or paper materials. They have been recovered from a variety of dust and lint samples, and even from the tobacco in cigarettes.[14] In all cases, *Stachybotrys* is only a minor component of the mycoflora, which usually features *Penicillium*, *Aspergillus*, and *Trichoderma* species, as well as Gram-negative bacteria and even *Mycoplasma*.

Table 2. *Stachybotrys* Classification

Class:	Deuteromycete
Order:	Moniliaceae
Family:	Dematiaceae
Genus:	*Stachybotrys*
Species:	*atra (chartarum, alternans)*

Air samples from 48 US schools contained similar fungal genera as in outdoor air, with *Cladosporium*, *Penicillium*, *Chrysosporium*, *Alternaria*, and *Aspergillus* comprising 95% of the total. In some schools *Penicillium* air concentrations were higher indoors, and *Stachybotrys* was present on some visibly wet and mold-contaminated carpet and wall surfaces.[15]

STACHYBOTRYS TOXINS

Definition

Toxicity refers to the pathologic effect of a specific chemical on a living organism.[16] Any chemical, whether natural or synthetic, is potentially toxic or nontoxic, depending upon the recipient organism and the conditions of exposure, such as concentration, duration, and route. Toxicity is further defined by the method used to detect the pathophysiologic or anatomic effect.

Toxicity is thus not an absolute property of any chemical even if it is referred to as a "toxin," but instead, it is dependent upon the factors mentioned above. Further, a toxic potential can be exploited therapeutically, as in the case of the many currently used antibiotics and immunosuppressant drugs isolated from certain species of fungi. In fact, some *Stachybotrys* toxins (satratoxins) inhibit bacteria, Actinomycetes, and other fungi,[17] and could in the future be potentially available as antimicrobial drugs.

Mycotoxins

All fungi produce and liberate an array of chemicals that are necessary for their survival, nourishment, and propagation under a range of conditions. Biosynthesis of these chemicals depends upon, and therefore varies with, the age of the hyphae, available nutrients, and the physical environment. Each chemical can be termed a mycotoxin when it can be shown to have a particular adverse physiologic effect on another living organism (animal, plant, or other microorganism) under appropriate conditions of exposure.

Chemistry

Numerous *Stachybotrys* mycotoxins have been characterized and studied by many laboratories over many years (Table 3). There are more than 40 tetracyclic sesquiterpenes, collectively know as trichothecenes. The same or similar ones are also produced by *Fusarium*, *Acremonium*, *Trichoderma*, *Trichothecium*, *Myrothecium*, and *Cylindrocarpon* species. *Stachybotrys* also synthesizes spirocyclic lactones, cyclosporins, stachybotrylactams, and both constitutive and induced enzymes with potential toxic properties. Various assays systems are used for their de-

Table 3. *Stachybotrys* Toxins

Macrocyclic trichothecenes
3-Acetyl-deoxynivalenol
Citrinine
Deoxynivalenol
Diacetoxyscirpenol
Isosatratoxin F, G, S, H
Kampanols
Nivalenol
Phenylspirodrimanes (9)
Roridin A
Satratoxin F, G, H
T-2-Tetraol
T-2 Toxin
Verrucarin A
Verrucarol
Vomitoxin
Enzymes
β-Glucanase
1,3-Endoglucanases
Farnesyl-protein transferase
Sesquiterpenes: K-76, K-76 COOH
SMTP-3, -4, -5, -6
Stachybocins A, B, and C
Stachybotramide
Stachybotrin C
Staplabin
Staplabin analogs: SMTP-7 and -8
Triprenyl phenol metabolites

tection,[13] including chemical, physicochemical, and biologic methods.

Biologic Effects

The biologic effects of the many chemicals produced by *S. chartarum (atra)* have been extensively studied. Most of them vary among different strains of the organism. Some of these activities are summarized here.

Cytotoxicity. A number of macrocyclic trichothecenes (satratoxins), including isosatratoxin G and *S*-isosatratoxin H, inhibit protein synthesis and cause direct cellular cytotoxicity in numerous experimental systems in animals and plants both in vitro and in vivo. In some cases, this is mediated through apoptosis by activation of protein kinases.

Metabolic Effects. The activities of enzymes of major metabolic pathways, glycolysis, the pentose phosphate pathway, and the tricarboxylic acid cycle, are altered by *S. chartarum* toxins in vitro. Enzymes that have been found to be affected include aldolase, succinate dehydrogenase, and glucose-6-phosphate dehydrogenase.

Hemolysis. Some *S. chartarum* conidia display hemolytic activity at 37° C when cultured on sheep's blood agar.

Plasmin Effects. A triprenyl phenol from *Stachybotrys*, designated staplabin, stimulates plasminogen activation, the binding of plasminogen to fibrin, and fibrinolysis.

Effects on the Lung. S. chartarum conidia and a trichothecene, isosatratoxin F, depress choline incorporation into fetal rabbit alveolar type II cells. Intratracheal exposure of mice to the trichothecene increases newly secreted alveolar surfactant and accumulates used forms of surfactant.

Immunologic Effects. Stachybotrys mycotoxins have been extensively studied for evidence of humoral and cell-mediated immune suppression and prolonged allograft survival.

K-76, a sesquiterpene, and its oxidation product, K-76 COOH, a monocarboxylic acid derivative, inhibit complement activity, mainly on C5, by inhibiting the generation of EAC1,4b,2a,3b,5b from C5 and EAC1,4b,2a,3b, and accelerating the decay of EAC1,4b,2a,3b,5b. They also inhibit some of the reactions of C2,C3,C6,C7, and C9 with their respective preceding intermediates. Both compounds also strongly inhibit hemolysis through the alternative pathway of complement activation by cobra venom factor. They also reduce both natural killer cell activity and antibody-dependent cell-mediated cytotoxicity, enhance responses to phytohemagglutinin A and lipopolysaccharide, inhibit the response to conconavalin A, and increase the numbers of circulating CD8+ T-lymphocytes. These and other immune-modulating properties can be found in other fungi and bacteria isolated from indoor environments. Some fungal isolates from indoor air are able to trigger histamine release by non-immunoglobulin (Ig)E-mediated mechanisms.

Cytokine Effects. Satratoxins G, H, F, and other mycotoxins from *Stachybotrys* affect interleukin 2 (IL-2) production and viability in mouse T cells. IL-2 concentrations increase at low concentrations and are depressed at higher concentrations of satratoxins.

Effects on Cholesterol. Several triprenyl phenol metabolites isolated from cultures of *Stachybotrys* were found to be inhibitors of pancreatic cholesterol esterase, reducing cholesterol absorption and serum total cholesterol when fed to rats, without causing a significant change in the high-density lipoprotein cholesterol level. This may be the same compound previously reported as a nematocidal agent. One fungal metabolite, stachybotramide, modulates the activity of cholesteryl ester transfer protein to stimulate the transfer of high-density lipoprotein to low-density lipoprotein.

Neurologic Effects. Stachybotrin C induces significant neurite outgrowth and enhances cell survival in primary culture of cerebral cortical neurons.

Other Effects. Stachybocins A, B, and C are endothelin receptor antagonists and inhibit HIV-1 protease.

HUMAN DISEASES CAUSED BY *STACHYBOTRYS*

Infection

To date, no case of a human systemic or local infection caused by any species of *Stachybotrys* has been reported, even in immunosuppressed patients.

Allergy

Kozak et al[9] cited the case of a 4-year-old asthmatic boy whose asthma improved when he was removed from his home. *Stachybotrys* was found in a water-damaged bedrooom carpet, but not in air samples. Although *Stachybotrys* allergy was suspected as the cause of his asthma, no allergy testing was reported.

There is no case of hypersensitivity pneumonitis caused by *Stachybotrys* in the published literature. Because of the unusually high levels of inhaled antigen required in its pathogenesis,[18] *Stachybotrys* as the cause of this disease would be most unlikely, considering the extremely low airborne levels of *Stachybotrys* spores in homes or buildings, even where there are obvious sources of the fungus identified on water-damaged surfaces.

Toxicity

Human stachybotryotoxicosis has been the subject of clinical investigation and speculation for many years. The suspected routes of exposure are ingestion, inhalation, and skin contact.

By Ingestion. The possibility of human toxic effects from ingestion of *Stachybotrys* arises because of a recognized toxic disease in animals and because of the observed effects of ingestion of *Fusarium*-contaminated grains in Japan and former USSR, referred to as "alimentary toxic aleukia."

In Siberia in the 1930s, horses fed barley, corn, and wheat stored under winter snow developed gastrointestinal hemorrhages and ulcerations, accompanied by agranulocytosis, ulcers around the mouth, inflammation of the respiratory tract, fever, and failure of blood clotting. Many animals died within days to weeks after the onset of illness. The disease was traced to *Stachybotrys* infestation of the fodder, and later the condition was reproduced

experimentally by feeding horses *Stachybotrys* organisms added to fresh hay or by feeding them a pure culture of the fungus. It has affected other large farm animals, such as sheep, cows, swine, deer, and calves as well. The condition in animals typically follows a heavy rainfall and is often characterized by hemorrhage in other visceral organs in addition to the alimentary tract.[19-24]

At the time of the original observations by veterinarians and later,[25] a similar disease occurred in some of the local farmers in contact with mold-contaminated hay or straw. Since the 1940s, however, no additional human case reports or epidemics have been published, although it remains a threat to farm animals.

By Inhalation. In the last few years there has been great concern about water-damaged building-related illnesses caused by *Stachybotrys* mycotoxins. These concerns center on two possible clinical presentations: 1) multiple subjective "health complaints" and 2) acute pulmonary hemorrhage in infants.

A publication in 1986[26] reported that five members of a family and their maid "were subject to a variety of recurring maladies," although repeated examinations were negative. *S. atra* was cultured from an aqueous suspension of 6,000 L air, and an undescribed "crude test" was said to show the presence of trichothecene. An ethanol extract of *S. atra* containing debris from an air duct was fatal when injected into weanling rats and adult mice, but there were no appropriate controls. The authors concluded, nevertheless, that the family illness was caused by airborne trichothecenes from *Stachybotrys*.

An epidemiologic study was reported in 1996 of workers in an office building in which *S. atra* was cultured from water-contaminated surface samples. Subjects were limited to those seen in an occupational health clinic and were not randomly selected. Their medical histories were obtained from a health complaint questionnaire which elicited numerous specific and nonspecific symptoms, but physical examinations were not reported. IgE RAST to *S. atra*, *Aspergillus*, *Penicillium*, and *Cladosporium* was performed, as were several immunologic tests. The investigators concluded that some workers had experienced an allergic or immunotoxic disease from "toxigenic" *S. atra* or other "atypical" fungi.[27]

A two-building complex comprising a county courthouse in Florida sustained considerable water damage. Fungi, including *Stachybotrys*, were recovered on bulk samples of water-damaged materials. A "trace" of *Stachybotrys* spores was found in 1 of 24 quiescent air samples, but none in two aggressively stirred air samples. Indoor total airborne mold concentrations were only 50% of those in the outdoor air, with *Aspergillus versicolor* predominant at the time the building was occupied. After the building was vacated, *A. versicolor* and *Aspergillus glaucus* predominated. *Stachybotrys* was recovered from surface sampling of books in the law library but not in the room air. All fungal recoveries (including *Stachybotrys*) were higher after building remediation. An epidemiologic study used subjects selected by volunteering and not by random selection. "Interstitial lung disease" was diagnosed solely by the patient's history, if 2 of 3 symptoms (fevers, myalgias, chest symptoms) were reported. Spirometry but no physical examinations were performed. The presence of IgG and IgE RAST to molds did not relate to either symptoms or "diagnosis." The report nonetheless concluded that this was a building-associated disease from exposure to *S. chartarum* and *A. versicolor*.[28]

Multiple-symptom health complaints, especially "neurobehavioral and upper respiratory tract" were elicited in a survey of workers in a water-damaged office building.[29] Symptoms improved after the workers were removed from the environment. Fungal contamination with *S. atra* was found in 1 of 5 surface samples, and *S. atra* spores in 1 of 19 air samples. Although *Stachybotrys* mycotoxin was the suspected cause of the symptoms, the authors concluded that the limitations of epidemiologic methods made this difficult to investigate and confirm.

A geographic cluster of 10 cases of acute pulmonary hemorrhage/hemosiderosis occurred among infants between 1 and 8 months of age living in a localized inner-city area of Cleveland, Ohio, between January 1993 and December 1994. The disease was successfully treated in the hospital but recurred in five of the infants shortly after they returned home. One infant died. Based on epidemiologic evidence of severe water damage resulting in fungal indoor growth in the homes of the patients, the illness was believed to be caused by mycotoxin from inhaled *Stachybotrys*. Between 1993 and 1998, a total of 37 infants had been diagnosed with idiopathic pulmonary hemorrhage in metropolitan Cleveland, with 12 deaths, including 7 originally diagnosed as sudden infant death syndrome. Thirty of them lived in a limited area of older housing, water damage, and household exposure to *S. chartarum* and other fungi. These investigators felt that the rapidly growing lungs of young infants were vulnerable to the toxigenic molds because adults in the household were unaffected. *S. chartarum* and the closely related fungus *Memnoniella echinata* recovered from these homes were believed to be responsible for these cases because of their similar and highly toxic trichothecene mycotoxins.[30-34]

More than 100 additional cases of acute idiopathic pulmonary hemorrhage with or without hemosiderosis in which *Stachybotrys* was present in the home have been reported in infants throughout the United States over the past 5 years after the publications on the cluster of cases in Cleveland. In several cases, the organism was also recovered from the patient's lung.[35-37]

Although the Cleveland experience has been widely disseminated and is responsible for an intense search for *Stachybotrys*-associated disease elsewhere, two expert panels commissioned by the United States Centers for Disease Control and Prevention recently found serious flaws in the studies and concluded that the evidence for *Stachybotrys* as the cause of pulmonary hemorrhage in the infants was not

proven. Specifically, case and control homes differed and sampling methods were not standardized; there was no case definition of the disease; results of some of the data were skewed by extremely high outlying values; and the disease was not felt to be consistent with idiopathic pulmonary hemosiderosis because of the acute onset, limited age range, and absence of iron deficiency. There were concerns about quantitation of water damage and the clinical significance (vs contamination) of the exposure measurements of *Stachybotrys* or its toxins. It was concluded that "a possible association between acute pulmonary hemorrhage ... and [mold] exposure ... was not proven."[38]

By Contact. There is one report of fingertip skin inflammation in three women handling moldy horticulture pots made of recycled paper that had visible black masses of *Stachybotrys* conidia, as well as *Chaetomium perithecia* and other fungi. The illness, described as painful, inflamed efflorescences at the fingertips, followed by scaling, was attributed to the effect of a mycotoxin. However, no tests were reported to determine the etiologic agent or the mechanism (allergic or irritant contact dermatitis, toxicity, or infection). Interestingly, handling these pots released up to 7,500 conidia per cubic meter of air, although there was no report of respiratory or systemic disease under these conditions![39]

ANIMAL DISEASE MODELS

Experimental *Stachybotrys* mycotoxicosis in mice is limited to only a few published reports. In one study, intranasal exposure to spores of *S. atra* containing satratoxins caused severe intraalveolar, bronchiolar, and interstitial inflammation with hemorrhagic exudation in the alveolar and bronchiolar lumen. The spores without satratoxins induced a similar but milder inflammation.[40] The injection of spores into mice resulted in decreased platelet counts but an increase in leukocytes, erythrocytes, and red cell indices. There was no pathology in the spleen, thymus, or intestines, and no IgG antibodies to *S. atra* were detected.[41] In another study, *S. chartarum* was grown in aluminum dishes in closed exposure chambers corresponding to 2.8 times the calculated loading dose that would cover all surfaces in a normal room with mold. Despite airflow that was 4-fold greater than found in normal homes, there was almost no sensory irritation, bronchoconstriction, or pulmonary irritation effects using a sensitive mouse bioassay in which the airway reactions were measured plethysmographically.[42]

DISCUSSION

There is a clear discrepancy today between the public perception and the current available scientific and clinical evidence concerning the toxic health effects of *Stachybotrys*, especially as it affects occupants of buildings that have sustained water damage from leakage or groundwater intrusion.

Human stachybotryotoxicosis from ingestion of the fungus was first reported as an epidemic in the 1930s in Soviet farmers who were in close contact with contaminated barley straw. Since then, reports of possible human disease have been largely restricted to a variety of illnesses believed to be caused by water-damaged buildings. These reports fall into two distinct categories of illness: 1) a presumed excess numbers of "health complaints," rather than a specific disease and 2) a specific disease-acute pulmonary hemorrhage/hemosiderosis in very young infants.

There are several publications describing epidemiologic investigations of workers in office buildings in which a mixed fungal growth, including *Stachybotrys*, is recovered after rain or groundwater damage. Typically, the workers respond to a health questionnaire with numerous health complaints, especially neuropsychologic and upper respiratory symptoms, many of which are also reported by workers in unaffected buildings. Some of these investigations include a range of laboratory tests that are of a screening nature, rather than those designed to confirm objective evidence of a specific disease in the workers. Physical examinations to uncover further objective evidence of pathology are notably absent from these reports. Concluding that their complaints or symptoms are caused by inhalation of *Stachybotrys* and/or its toxin is usually based on finding the organism on building surface samples and absent or low levels of spores in the air. Based on the extremely low levels of airborne *Stachybotrys* spores in all reported cases, however, it remains extremely doubtful that there would be sufficient exposure to cause an effect, even if the recovered fungus is able to produce a relevant mycotoxin. Self-reported but objectively unsubstantiated improvement on removal of the worker from the building is cited in some of these studies as confirmation of a mycotoxic disease. This presumptive illness, therefore, does not qualify as a "building-related illness" with defined clinical and pathophysiologic features.[43] It is more reminiscent of the idiopathic environmental intolerance phenomenon ("multiple chemical sensitivities"), in which nonspecific ill health or subjective symptomatology are attributed to normal indoor environmental chemicals.[44]

Stachybotrys, like any other fungus, has the capacity to generate a very large number and variety of chemicals with toxic potential to humans, provided that the exposure is sufficient. The range of toxic effects demonstrated in laboratory animals and in vitro cellular systems makes it difficult to predict a particular profile of pathology that one might expect in humans under conditions of heavy exposure. However, the effect of unintentional ingestion of *Stachybotrys*-contaminated feed by large animals recognized by veterinarians and even confirmed in deliberate challenge studies can serve as a guide to at least one possible consequence of human ingestion of the mycotoxin. Although these reports and studies are now quite old and lack modern scientific sophistication, these horses and other animals suffered a specific condition characterized primarily by gastrointestinal hemorrhage.

The same clinical presentation occurred in farmers who also accidentally consumed *Stachybotrys*-contaminated food, and this is consistent with at least one recognized toxic property of this fungus.

The report from Cleveland of pulmonary hemorrhage from presumed inhalation of airborne *Stachybotrys* spores occurring as a cluster of cases in which the epidemiology revealed that water damage from flooding of old, poorly maintained inner-city homes was a significant risk factor for the disease is certainly consistent in principal with the cases associated with ingestion of *Stachybotrys*. The fact that older children and adults living in the same homes with the affected infants failed to get sick suggests that the infant's immature lungs lack some chemical, physiologic, or anatomic protection yet to be discovered. Although the criticisms of the study of these infants are valid and require caution in interpreting the findings, the association of this specific illness with inhalation of *Stachybotrys* spores and/or its toxin (in contrast to nonspecific health complaints in adults) is biologically reasonable. Further, acute pulmonary hemorrhage can be readily diagnosed by objective findings, and is serious and potentially fatal.

CONCLUSION

Fungi are a major component of the biosphere. They adapt especially well to varying environmental conditions by synthesizing chemical products with biologic activities that are called mycotoxins. These have the potential for adverse effects on the health of humans and other animals. Despite present popular concerns, *Stachybotrys* is not unique in this regard. It is a minor part of the indoor mycoflora, growing well on cellulose and therefore found on certain building material surfaces in water-damaged buildings. Even under these conditions, airborne spores are usually absent or present in extremely low concentrations.

The potential adverse health effects of *Stachybotrys* toxins will remain a concern. However, a critical review of the current published reports of possible human disease from inhalation of *Stachybotrys* spores does not yet establish a clear-cut cause and effect relationship to warrant the degree of concern now expressed by such terms as "fatal fungus."[1] The endemic cases of pulmonary hemorrhage with or without hemosiderosis in Cleveland are the most suggestive because some of the established in vitro properties of satratoxins could be consistent with the clinical disease, although the epidemiologic data have been called into question. However, reports of building-associated subjective illnesses attributed to *Stachybotrys* cultured from surfaces where water damage occurred in the building are not compelling. A recent extensive literature review reached a similar conclusion.[45]

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