Health Effects of Mold Exposure in Public Schools

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This paper profiles the impact of mold exposure on the health of students, teachers, and staff in two public elementary schools in Connecticut, and explains how the air quality in each school was tested, and how the health of teachers and students was assessed. It also proposes standards for testing indoor air quality and evaluating the health impact of indoor mold exposure on students, teachers, and staff members.

Introduction

Over the past decade, there has been an increased awareness among clinicians and the general public that sensitivity to mold is a significant cause of allergic diseases. These diseases include allergic asthma, allergic rhinitis, allergic fungal sinusitis, bronchopulmonary mycoses, and hypersensitivity pneumonitis [1•]. The publicity around "sick buildings" has made parents more aware of increased illness at the start of the school year, which has led to the identification of mold contamination in a number of public schools nationwide. Although there has been a dramatic increase in the awareness of the health problems caused by indoor mold exposure, as well as increased resources to remediate these problems, there is a notable lack of standardization for testing indoor air quality.

The extent of mold contamination in public schools has yet to be fully determined. In each school, a wide range of health problems, from minor to very serious, is attributed to indoor mold exposure. In some of these cases, the health issues clear up once the building is remediated. However, in other cases, the patient's health is not regained. For the most part, there has been no consistent method for assessing the health impact of mold exposure among students, teachers, and staff members.

Government agencies and state organizations have also recognized the detrimental impact that exposure to high concentrations of mold can have on an individual's health. The Environmental Protection Agency (EPA) states that molds can trigger asthma attacks in allergic individuals, in addition to immediate or delayed allergic reactions in sensitive individuals [2••]. The Occupational Safety and Health Administration (OSHA) released findings that documented building-related asthma in office workers when mold is present in the workplace [3]. The National Institutes of Health (NIH) have linked environmental molds with allergic rhinitis [4]. The Connecticut Education Association (CEA) declared that 68% of the schools in the state have an air quality problem, and many of the teachers, students, and staff complain of allergic symptoms [5]. The Connecticut State Legislature is considering a bill that addresses air quality in schools [6]. In addition, the Government Accounting Office (GAO) surveyed 10 school districts and estimated that $112 billion is needed to repair or upgrade schools to provide a healthy indoor environment for students [7].

The overall indoor air quality of schools in the United States needs to be examined closely. Mold exposure resulting from moisture damage has run rampant, and is becoming a serious health issue in school-age children and their teachers. Standards are needed to ensure acceptable air quality in schools.

Air Quality and Health: Positions of Government Agencies and State Organizations

Environmental Protection Agency

The EPA provides extensive information about the health impact of indoor air pollution, and is concerned about the air quality in public schools. Their web site states that "20% of the US population, nearly 55 million people, spend their days in our elementary and secondary schools. Studies show that one half of our nation's 115,000 schools have problems linked to indoor air quality. Students are at greater risk because of the hours spent in school facilities, and because children are especially susceptible to pollutants" [2••].

The EPA also provides detailed information about the health hazards of mold-contaminated schools, and has created the "Indoor Air Quality Tools for Schools" kit to help teachers, administrators, and parents identify, repair, and prevent mold problems in schools [2••]. However, they also state that there are no quantitative standards for determining what level of mold contamination is hazardous. Also lacking are standards for testing indoor air quality.

Occupational Safety and Health Administration

The Occupational Safety and Health Administration is committed to providing information about indoor air quality. Microbial contamination of building structures, furnishings, and HVAC system components contribute to poor indoor air quality problems. Their web site states that building-related illnesses can result in serious disease and death, and provides links to the EPA web site for information about mold clean up. OSHA believes that molds can cause skin irritation, in addition to having negative pulmonary, cardiovascular, nervous system, reproductive, and cancer-causing effects [3].

National Institutes of Health

The NIH recognizes the negative health impact of mold, and that grass, weeds, and molds, along with pollens from trees, are a chief cause of seasonal allergic rhinitis. Their web site also links to the EPA web site [4].

Connecticut Education Association

The winter 2001–2002 edition of the CEA's publication *Schoolhouse News* points out that one child in 10 in Connecticut has asthma (a 75%–100% increase over the past 10 years), and 68% of schools in the state have an air quality problem. Many teachers state-wide complain of asthma, chronic sinusitis and runny nose, shortness of breath, cough, inflammation of the vocal chords, headaches, and vertigo occurring or worsening while at work [5].

Connecticut State Legislature

A bill has been raised by the Connecticut State Legislature (HB House Bill No. 5039) that, if passed, will provide assistance and direction to school districts to improve the quality of air in school buildings [6].

Government Accounting Office

In a 1995 report, the GAO surveyed 10,000 schools and site-visited 10 school districts. On the basis of their estimates, $112 billion is needed to repair or upgrade schools to a good, overall condition. One third of the schools, serving 14 million pupils nationwide, reported needing extensive repair or replacement. Sixty percent of schools reported at least one major feature, such as plumbing, in disrepair. More than half the schools reported at least one unsatisfactory environmental condition; many facilities are substandard and need major repairs due to leaking roofs, plumbing problems, and inadequate heating systems [7].

The Medical Literature

Molds

Fungi are able to invade human tissue and can cause inflammatory reactions, especially in immunocompromised individuals [1•]. Current research has shown substantial evidence that exposure to fungi contributes to the development and severity of asthma, allergic rhinitis, and atopic dermatitis in sensitized individuals. It has also demonstrated the relationship between increased spore counts in an environment and the presence of allergic symptoms [8••]. One study by Downs *et al.* [9] showed results that suggest *Alternaria* allergens contribute to severe asthma in areas with high fungal exposure. A study of children 8 to 18 years of age found that asthma symptom scores increased by 10% to 30% for every increase of 1000 spores/m^3 in the environment [10].

In certain circumstances, molds produce mycotoxins; many symptoms and human health effects (including mucous membrane irritation, skin rash, nausea, immune system suppression, acute or chronic liver damage, acute or chronic central nervous damage, endocrine effects, and cancer) have been attributed to inhalation of these mycotoxins. Although more studies are needed to provide a clear picture of the negative health effects of mycotoxins, it is clearly prudent to avoid them [2••].

Some volatile compounds produced by molds, known as microbial volatile organic compounds (mVOCs), are released directly into the air. They have a strong or unpleasant odor. Exposure has been linked to headaches, nasal irritation, and nausea [8••].

Irritation from the physical presence of bio-aerosols or exposure to mVOCs released by molds has been demonstrated. Respiratory effects include rhinitis, asthma, allergies, and hypersensitivity diseases. Building-related asthma has been documented in office workers. Reported cardiovascular effects following exposure to bio-aerosols can manifest as chest pain; nervous system effects manifest as headaches, blurred vision, and impaired judgment. Development of cancer in susceptible people is possible after exposure to certain types of toxogenic fungi and mycotoxins. Considering the carcinogenicity of many fungal toxins, an examination of the risk of chronic inhalation exposure appears justified [2••].

Children and schools

A study by Savilahti *et al.* [11] determined whether exposure to molds resulting from moisture damage in a school affected the health of the children. The authors concluded that moisture damage and exposure to molds increased the indoor air problems of schools, and affected the respiratory health of children.

A subsequent study, also by Savilahti *et al.* [12], assessed the occurrence of IgE sensitization in patients exposed to schools in which there was visible water damage, mold contamination, and complaints of respiratory and skin symptoms. The study revealed elevated IgE values among exposed children, and occurrence of new allergic disease after children started at an infected school. The IgE values indicated a possible relationship between exposure to microorganisms and IgE sensitization. The study concluded that exposure to spores, toxins, and other metabolites of molds may have complex results with unknown immunogenic effects that may act as a nonspecific trigger for allergic sensitization, leading to the development of atopy.

Taskinen *et al.* [13] validate the studies by Savilahti *et al.* [11,12] by concluding that there was evidence of an association between mold contamination and moisture problems in a school building, and the occurrence of respiratory infections, repeated wheezing, and prolonged cough in school children.

Air Quality Testing

Methods

Air quality testing is central to assessing fungal allergens in an indoor environment. The popular Burkard volumetric spore trap (Burkard Scientific, Uxbridge, UK) has long been used to determine outdoor pollen and mold counts. Although it provides equally accurate indoor mold counts, its size (~ 35 lb) and expense (~ $4000) make it impractical for public schools to use.

The Allergenco MK-3 (Allergenco/Blewstone, San Antonio, TX) is a newer model volumetric spore trap. In a current publication, Portnoy *et al.* [14•] compared the Burkard and the Allergenco MK-3 volumetric collectors; their collection characteristics were comparable. At a cost of approximately $1100, the Allergenco MK-3 was found to be more versatile and portable due to its size (~ 4 lb), and therefore, was ideal for indoor testing. The Air-O-Cell Cassette (SKC, Eighty Four, PA) is another volumetric sampler. Although we have not seen data that compare it with the Burkard or Allergenco, it seems to provide comparable results.

Fungal exposure can also be determined by cultures. An Andersen Sampler (Thermo Andersen, Smyrna, GA) is a popular way to collect indoor air samples, from which fungus is grown on culture media and quantified as colony-forming units per cubic meter (cfu/m^3) of air sampled [1•].

Evaluation

Missing from the EPA "Indoor Air Quality Tools for Schools" kit and other similar resources is a proven method to quantify indoor air quality. The EPA suggests a visible mold inspection and checking for moldy odors. Although this will identify many mold contamination problems, it is highly subjective, and lacks the scientific basis that many school boards may need before embarking on an expensive remediation program.

With decades of outdoor air sampling data, there are widely accepted categories of mold and pollen exposure, ranging from healthy levels to levels that will create health problems in sensitive individuals. Local news stations regularly provide the outdoor pollen and mold counts, and categorize them as low, medium, or high. There are now accepted definitions for indoor air quality. In a recent study by Bush and Portnoy [8••], an unhealthy indoor environment was defined as a volumetric mold contamination count greater than 1000 spores/m^3.

For fungal cultures, Etzel [15•] states that acceptable levels for airborne fungi are approximately 200 cfu/m^3. This is exclusive of toxigenic fungi, which are considered unacceptable in indoor air in any amount.

Mycotoxins

In a recent study, Jarvis [16] reported increasing evidence of health risks associated with damp buildings and homes in which high levels of microbes are found. Evidence is accumulating that certain toxogenic molds are a risk for human health through inhalation exposure. *Stachybotrys chartarum* (*atra*) is considered one of the more serious threats to people living and working in water-damaged buildings. This mold has a long history of causing animal toxicoses. In recent years, it has been associated with infant pulmonary hemosiderosis, resulting from exposure to spores of this fungus in the home. *S. atra* produces a variety of potent toxins and immunosuppressants, including a novel class of diterpenes (atranoens) of unusual structure. More research is needed to determine the impact on health resulting from inhalation of these mold spores.

According to Hussein and Brased [17], mycotoxins are secondary metabolites of mold that result in illnesses in humans. Aflatoxins, ochratoxins, trichothecenes, zearelenone, fumonisins, tremorgenic toxins, and ergot alkaloids are the mycotoxins of greatest importance. Some molds are capable of producing more than one mycotoxin, and some mycotoxins are produced by more than one fungal species.

According to a recent paper by Etzel [18], there are approximately 400 known mycotoxins. Exposure can occur through ingestion, inhalation, and dermal contact. The most potent mycotoxin is aflatoxin B_1, which is produced by *Aspergillus flavus* and *A. parasiticus*. Aflatoxin exposure, in addition to chronic effects, can sometimes result in acute aflatoxicosis with vomiting, abdominal pain, hepatitis, and death. The study further revealed that *Fusarium* and *Stachybotrys* species produce mycotoxins called trichothecenes, which can produce alimentary toxic aleukia when ingested by humans. *S. chartarum* (*atra*) spores, which grow on any cellulose product in the presence of water, are disseminated into indoor air when the fungus is disturbed. Trichothecenes have been proven to suppress the immune system, and can lead to increased susceptibility to a variety of infectious diseases.

Schools Studied

Methods

For the two schools profiled here, air quality was tested across the school building, and the health of the students, faculty, and staff was evaluated. A validated questionnaire was used to measure allergic symptoms in teachers in order to obtain a quantitative assessment of symptoms in unhealthy environments. The total scores on the questionnaire range from 0 (no symptoms) to 125 (very severe

Table 1. Questionnaire scores for McKinley Elementary School

Patient	Before illness	At height of symptoms	Currently
Teacher #1	40	85	63
Teacher #2	19	119	89
Custodial employee	5	74	63

symptoms). For a typical allergic patient, scores before treatment generally range from 45 to 50 [19,20].

McKinley Elementary School

McKinley Elementary School (Fairfield, CT) is a school of 450 students, ages 5 to 11. It was built in the 1930s, with an addition built in the 1950s. Over the past 15 years, there have been numerous complaints of illnesses, both usual and unusual in nature, from students and faculty. During the 1999 to 2000 school year, the school nurse documented all symptoms that were reported to her. She stated that approximately 40% of the students, teachers, and staff reported the following symptoms: fatigue, dizziness, postnasal drip, sinus headache and pressure, nasal blockage, skin rashes, earache, eye itching and burning, sore throat, wheezing, sneezing, chest tightness, and green or yellow nasal mucus [21].

Twelve teachers were evaluated, and three representative cases are discussed here in detail. A Special Education teacher with a history of mild-to-moderate asthma and allergic rhinitis had been teaching at McKinley Elementary School since 1991. Her initial symptoms included burning eyes, chronic cough, headaches, fatigue, and irritability. These symptoms progressed to debilitating fatigue, severe vertigo, hair loss, and ocular migraines. As the school year progressed, her symptoms and overall health worsened. She was forced to leave teaching in November 1998 on medical leave; she has been away from the school now for more than 4 years and has still not regained her health (Table 1).

Another teacher with a history of allergic rhinitis, asthma, and sinusitis became extremely ill after working for the first 2 months of the 2000 to 2001 school year. While teaching at McKinley, she suffered from moderate to severe allergic reactions. Her symptoms included postnasal drip, cough, eye symptoms, wheezing, fatigue, sore throat, sinus pain, urticaria, and facial rashes. She also experienced severe asthma attacks that required trips to the emergency room. She was out of work 2 weeks in October 2000. When she returned, McKinley had been closed and she was moved to a different school. She experienced a severe facial rash when she was exposed to her supplies from McKinley (Table 1).

In September 2000, a custodial employee was involved in the removal of the mold-infested carpets, and assisted in the initial clean up. He developed a severe cough and was diagnosed by a pulmonologist with asthma and reactive airway disease. He was diagnosed in August 2001 with chronic sinusitis and allergic rhinitis. His symptoms included shortness of breath, wheezing, visual problems, hemoptysis, and the inability to concentrate. He was forced to stop working in July 2001 due to failing health, and began seeing a psychiatrist in October 2001 for depression. He is unable to work, and reports that he has seen a little improvement since leaving the school (Table 1).

Testing of McKinley School

The initial testing of McKinley Elementary School occurred when a student developed asthma 1 month after school opened in September 2000; the student's parents insisted that it be environmentally tested.

On October 2, 2000, OSHA performed biologic sampling at McKinley. OSHA testers collected fungal cultures using the Andersen sampler and found that the total quantity of colony-forming units in approximately 70% of the indoor sampling exceeded the total quantity of colony-forming units in the outdoor sampling. However, all the indoor samples exceeded 200 cfu/m^3. The testing also revealed that the total quantity of colony-forming units found in the indoor sample collected from the faculty room was three times greater than the total quantity of colony-forming units found in the outdoor ambient air sample (Fig. 1).

Several types of molds were detected in the indoor samples that were not detected in the outside sample, suggesting potential sources of contamination inside the school. The five molds found indoors that were not found outdoors are *Alternaria*, *Boytrytis*, *Curvularia*, *Epicoccum*, and *Stachybotyrus*. Molds that were found outdoors and indoors included *Aspergillus*, *Cladosporium*, and *Penicillium*; the levels of *Aspergillus* and *Penicillium* were higher in some of the indoor rooms than outdoors. *Fusarium* was found outdoors but not indoors.

On November 5, 2000, Turner Environmental (Concord, NH) tested several rooms in McKinley by using an Air-O-Cell Cassette for volumetric spore counts. The count in one room was 53,000 spores/m^3. This is high for any indoor environment, and was much higher than other rooms tested in the school (Fig. 2).

Discussion

Mold exposure clearly has a negative impact on health, particularly in atopic patients. More than 40% of the students, teachers, and staff at McKinley Elementary School reported various symptoms, many of which have not been alleviated even though their exposure has ended.

Most of the public schools in Connecticut were built in the 1960s and 1970s. Many (including McKinley) were built on wetlands, with flat roofs that tended to leak. Over the years, carpets have been installed to cut down on noise and cover floors with asbestos tiles. It is not surprising that McKinley Elementary School became contaminated with mold. What has been surprising to the town is that the

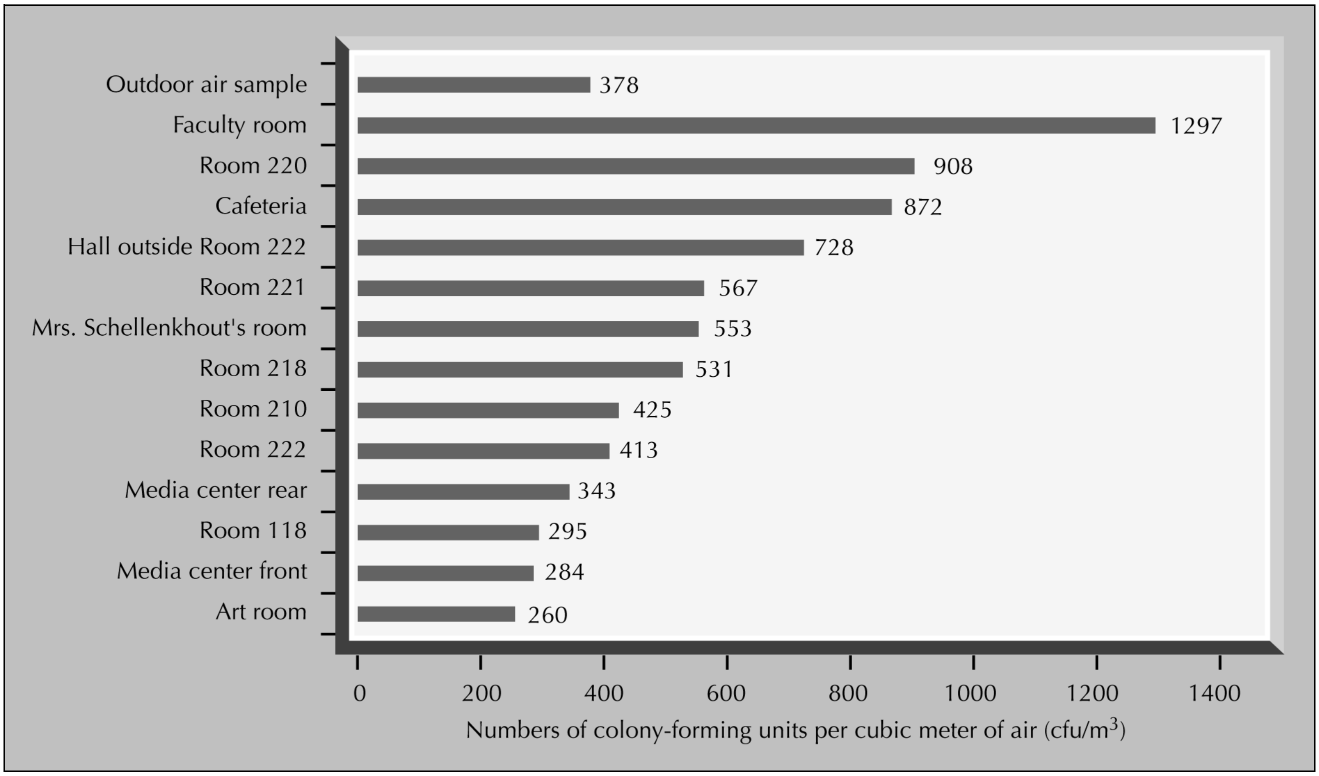

Figure 1. Air quality results for McKinley Elementary School, October 2, 2000. (*Data from* the Occupational Safety and Health Administration.)

contamination is so extensive that the school must be razed and rebuilt at a cost of $21 million.

The Occupational Safety and Health Administration did not define the extent of the problem and did not instruct the Board of Education in Fairfield on how to remediate the school, so the Board began remediation while school was in session. The parents and teachers became outraged that the remediation was taking place during school hours, exposing their children to even higher levels of mold. With the help of the media, the parents were able to get the school closed and the children moved to different schools. The Board of Education was also forced to perform further evaluations of the school.

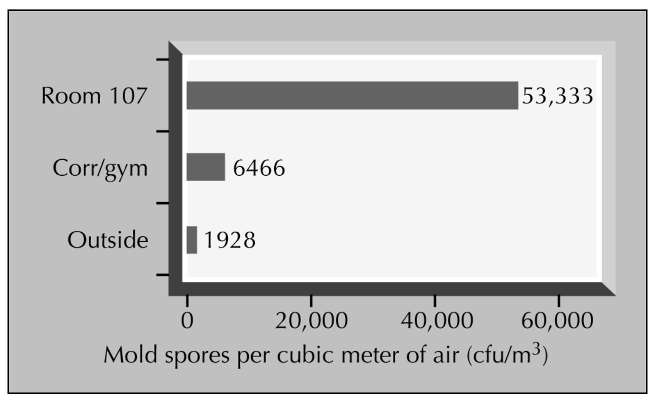

Figure 2. Total mold spore counts for McKinley Elementary School, November 5, 2000. (*Data from* Turner Environmental, Concord, NH.)

John F. Kennedy Elementary School

A patient with allergic rhinitis and recurrent sinusitis suspected that a mold problem at her work environment may be contributing to her illnesses; she was a teacher at John F. Kennedy Elementary School (Milford, CT). The school was tested on January 11, 2001, using the Allergenco MK-3, and was found to be mold-contaminated (Fig. 3). A validated questionnaire was offered to the teachers in the school, 52% of whom responded (Table 2).

Three case reports of two teachers and one student at JFK Elementary School are discussed. Some of their symptoms are clearly allergic in nature and some may be attributed to mycotoxin exposure (Table 3).

The first teacher began to experience sinus pressure, headaches, dizziness and vision change, rashes, diarrhea, constipation, and eczema. In December 2000, she was diagnosed with scleroderma; in February 2002, she was confined to her home. She has been at home ever since, and the scleroderma has improved by approximately 25%. Her allergy-related symptoms are listed in Table 3.

A healthy 12-year-old boy who was a student in the above teacher's class began to suffer from headaches, colds, fatigue, achy joints, chest pains, Raynaud's disease, and pneumonia during the 2000 to 2001 school year. In January 2001 he was diagnosed with scleroderma. He was homebound-tutored beginning in March 2002, and has seen improvement in his scleroderma since leaving the school. His allergy-related symptoms are found in Table 3.

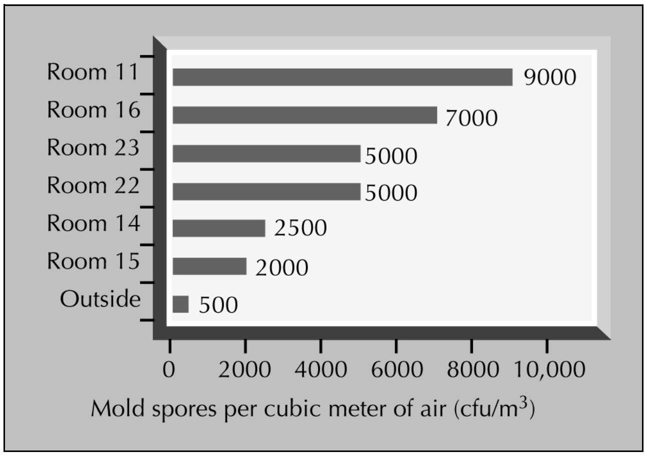

Figure 3. Total mold spore count for John F. Kennedy Elementary School, January 11, 2001.

The second teacher at JFK Elementary School had been sick for 3 years while working at the school. Her symptoms ranged from headaches, raspy voice, dizziness, watery and itchy eyes, congestion due to multiple sinus infections, nausea, rashes, and abdominal cramping. She was skin test-positive to molds (*Aspergillus*, *Penicillium*, *Candida*, and *Alternaria*) and dust mites. She avoided the building for 1 week in December 2001 and her symptoms improved significantly, but when she returned to the school, her symptoms returned within 24 hours. She took a 2-week leave and again began to improve. Upon return, her classroom was changed and she continued to work in the same building until March, when she developed a severe rash while spending several hours in the school library (Table 3).

Table 2. Results of a validated questionnaire given to teachers at John F. Kennedy Elementary School

Symptom	Respondents with symptom, %
Sinus headache	88
Postnasal drip	79
Sore throat	75
Fatigue	67
Nasal blockage	67
Sneezing	63
Green mucus	63
Eye symptoms	54
Coughing	54
Phlegm	54
Irritability	50
Eye burning	50
Skin itching	46
Clear mucus	46
Watery eyes	46
Dizziness	42
Trouble sleeping	38
Loss of sense of smell	38
Ear aches	38
Wheezing	29
Snoring	25
Shortness of breath	25
Chest tightness	21
Chest pain	4

Discussion

The school was evaluated and found to have a mold problem, and is being remediated. Ceiling tiles and carpeting are being removed and the roof is being repaired, at a total cost of more than $600,000.

The first two cases deal with a serious health issue. Scleroderma (systemic sclerosis) is a generalized disorder of connective tissue characterized by fibrosis of the skin and distinctive involvement of internal organs (usually the heart, lungs, kidney, and gastrointestinal tract). The accumulation of extracellular matrix causes a chronic and disabling condition. The etiology and pathogenesis of this disorder is unknown, affecting approximately four times as many women as men. Scleroderma is diagnosed worldwide and affects all racial groups. Although all age groups may be affected, its onset is most often between the ages of 30 and 50 years. Reports of familial occurrences are uncommon, and most cases occur sporadically without propensity for season, occupation, geographic location, or socioeconomic status. Only a weak association links the pathogenesis of scleroderma to exposure to environmental toxins. There are approximately 300,000 cases of scleroderma in the United States, with approximately two to 20 new cases per million individuals reported annually. There are approximately 2500 new cases diagnosed in a given year; therefore, the data suggest that scleroderma remains an uncommon disorder.

Recently, our practice recognized that two individuals who had been evaluated for a new onset of symptoms consistent with an allergic disorder had also recently been diagnosed with scleroderma by a rheumatologist. It was noted that both of the individuals spent weekdays in the same elementary school classroom, recently identified as having an unacceptable concentration of certain mold spores. Given the circumstances, we concluded that further statistical investigation was warranted.

Conservatively, we estimated that there are 10 new cases of scleroderma per million (10^6) individuals per year (or one new case per 10^5 individuals per year). Statistical analysis would suggest that the probability of two individuals being diagnosed with scleroderma from the same classroom of 30 individuals, regardless of age, sex, race, or region, is exceedingly rare. The probability that a specific combination of mutually exclusive (one person cannot both "have" and "not have" a disease), independent events will occur can be determined by using the binomial distribution, a method of calculating probability when there are only two possible outcomes, such as "healthy" or "unhealthy." The binomial coefficient, derived from the binomial theorem and Pascal's triangle, is represented as nCk, where $n = 30$ (total number of individuals) and $k = 2$ (total number of times the specific event occurred).

Table 3. Questionnaire scores for John F. Kennedy Elementary School

Patient	Before illness	At height of symptoms	Currently
Teacher #1	8	31	2
Teacher #2	4	88	13
Student #1	4	32	7

Mathematic computation using this method determined that the probability (P) of this event occurring by chance was not likely ($P < 0.000004$). Where:

$$P = {}_{K}C^{n}\,[(1/10^5)^2] \times [(1 - 1/10^5)^{28}]$$

$$\text{and } {}_{K}C^{n} = \frac{N!}{K!\,(N - K)!}$$

$$P = [(30!)/(30 - 2)!] \times [(1/10^5)^2] \times [(1 - 1/10^5)^{28}]$$

The third case illustrates the effect of a mold-contaminated environment on an atopic individual. Her symptoms were typical of allergic reactions. When she was removed from the environment, she began to see significant improvements in her symptoms.

Conclusions

Allergists are well suited to help in this area of increasing national concern because they are able to combine expertise in diagnosing and treating the symptoms that accompany mold exposure with expertise in testing and analyzing air quality. This combined experience enables us to set standards for evaluating the air quality in public schools.

Too many of the public school buildings in the United States are in unsatisfactory physical condition. All schools, especially those with carpeting or a history of water damage, should be tested annually for fungal contamination. Testing should be performed using volumetric air sampling because semiquantitative culture sampling alone does not give a true reflection of the extent of fungal contamination. However, this testing will not be effective without standards for evaluating the results. Unified standards need to be set: a building must be considered unhealthy if the indoor mold counts exceeds 1000 spores/m^3 of air.

Testing for total mold spore counts with the Allergenco MK-3 is an easy and inexpensive way to initially evaluate a mold-contaminated environment. If a problem is found, the next step should be an assessment of the environment using the Anderson Air Sampler. This will allow for more specific mold identification, especially for identifying *Aspergilius*, *Penicilium*, *Stachybotrys*, and other relevant molds. Additional testing, if it becomes necessary, would include bulk sample testing, wall cavity testing, and carpet testing.

There should also be a consistent method for assessing the health impact of mold exposure among students, teachers, and staff, and to what extent these health problems are reversible. The validated Rhinitis Outcomes Questionnaire can effectively and inexpensively gather good data about the health impact of exposure to mold from students, teachers, and faculty.

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