

Environmental Allergen Analyses

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Environmental specimens (dust) from indoor home, school, and work-place environments can be evaluated for the content of aeroallergens produced by dust mite, cat, dog, cockroach, and molds, as a means of determining exposure risk and facilitating avoidance therapy. This article examines the variables that influence the levels of these allergens in indoor environments, methods for sampling, clinical laboratory assays used for testing, and interpretation of aeroallergen results for making decisions about remediation. © 1997 Academic Press

Pharmacotherapy, immunotherapy, and allergen avoidance are three strategies that have been employed for managing individuals with immunoglobulin E (IgE)-mediated diseases such as rhinitis and extrinsic asthma. Of these, allergen avoidance or the separation of the patient from the allergen source is potentially the most effective approach for the prevention and long-term control of airway disease. Indoor environments, such as the home, school, and work place, have been the target of intensive efforts to minimize allergen exposure. Americans spend an estimated 30 to 60% of their lives eating, sleeping, working, and relaxing in their homes. The remainder of their productive lives are also spent indoors, either in school or in the work place. Since the home, school, and work place are environments that can be controlled, they have been the subject of extensive remediation efforts to reduce allergen content and promote aeroallergen avoidance. However, to avoid an allergen source, it is necessary to know the allergen's specificity, location, and relative quantity. If the level of allergen is high, the individual with a

severe allergy or extrinsic asthma is often motivated to remediate their environment to minimize the induction of symptoms or a risk of further sensitization. This article focuses on laboratory analyses of environmental dust specimens and the measurement of primary indoor aeroallergens as a means of identifying their sources and levels that place an allergic or asthmatic individual at risk for symptoms or the development of more severe disease.

INDOOR AEROALLERGEN SOURCES

There are over 200 distinct allergen specificities that have been identified as clinically important [1; see article by Esch (1a), elsewhere in this issue]. Of these, a limited number of aeroallergens produced by dust mites, fur-bearing pets and nuisance rodents, indoor insects, and a variety of molds are produced indoors and are considered clinically important in terms of their ability to induce symptoms (see Table 1). Outdoor pollens, molds, and animal danders can also be transported indoors where they may induce allergic symptoms in previously sensitized individuals. The goal of any avoidance program is to minimize all allergen sources to which the inhabitant is known to be allergic. For public buildings such as schools and work places, especially, a global strategy should be adopted to minimize all potential aeroallergen sources, since individuals with asthma or allergies may have a sensitivity to any of the aeroallergens found indoors.

There are a number of variables that influence the presence and quantity of these aeroallergens in an indoor environment. One set of variables includes the

age, prior occupancy history, and location of the residence. Older homes with many previous occupants can suffer water damage which will foster mold growth. A city dwelling can have indoor pets (cats/dogs), cockroaches, and dust mites. Dwellings in rural areas might contain dander from farm/ranch animals and high mold counts emanating from decaying organic matter on fields. A water source near the home such as a lake or river can produce higher humidity, which fosters mold and high pollen counts. A second set of variables relates to the indoor temperature and humidity that can vary throughout the year. Humidity >70% fosters mold growth. Wind and sunshine can increase mold counts in the outdoor air that gets transported indoors. Walls built in contact with dirt hills can transmit moisture, and the number of house plants will influence the indoor humidity. Third, pets that release dander of concern include cats, dogs, guinea pigs, gerbils, hamsters, rabbits, and mice. Danders from outside animals such as cows, pigs, and horses can be brought in on clothing. Currently, the laboratory can measure “indicator” aeroallergens produced by only a limited number of these animals. Fourth, the type of furniture and carpet material in the home will affect the retention of allergens and the ease with which they are removed upon routine cleaning. Furniture material can include wool, feathers, down, kapok, animal hair, and synthetic fibers. Each varies in its aeroallergen retention properties. The type of carpet (wall to wall versus area rug) and its properties (pile height, density) will influence the ease with which they are cleaned of deposited allergen. Finally, the type of heating and cooling system influences the amount of allergen that is circulated through the indoor air. Forced air systems without filters are less desirable than those with extensive in-

line filtration or wall heaters and radiators that do not circulate airborne allergens.

Dust mites, the most common domestic pets (cats and dogs), the cockroach, and mold are indoor aeroallergen sources that can be readily monitored by the clinical immunology laboratory using immunochemical and microbiology assays. Each is discussed briefly in relation to its unique concerns.

Dust Mites

Four species of dust mites can be found in homes in temperate zones: *Dermatophagoides pteronyssinus*, *D. farinae*, *D. microceras*, and *Euroglyphus maynei*. *Blomia tropicalis* is a fifth important mite species that is found in indoor environments in the tropics and the southeastern United States. Of these, *D. pteronyssinus* and *D. farinae* produce >90% of the potent allergens found in dust from homes in North America. Mites excrete potent allergens in their fecal pellets that average 20 μm in diameter (2). These are therefore readily airborne during cleaning and other household activities, but they are sufficiently heavy so that they settle rapidly onto surfaces once the disturbance passes. Other allergens are derived from mite body debris. Mites are effective allergen-producing machines, reportedly generating up to 200 times their body weight in feces during their 2- to 3.5-month life span. Mites breed in mattresses, carpets, and upholstered furniture, where they require humidity and human skin scales or animal dander as nutrients.

Structurally analogous 25-kDa mite proteins, which have been given the designation “group 1” allergens, are produced by *D. pteronyssinus* and *D. farinae*. These proteins, called Der p 1 and Der f 1, are homologs that exhibit similar physical and chemical properties and have extensive cross-reactivity. Investigators using monoclonal antibodies have identified at least five nonrepeating or overlapping species-specific epitopes on Der p 1 and 4 on Der f 1 (3). Both Der p 1 and Der f 1 can be measured in house dust by enzyme immunoassays in nanograms of allergen per gram of dust. The level of Der p 1 and Der f 1 is considered a good “indicator” of the total mite allergenic burden of the dust and an index of potential exposure for dust mite allergic patients within a particular indoor environment. Since it is difficult to predict which of the two species of dust mites may inhabit a particular indoor environment, both Der p 1 and Der f 1 are routinely measured in dust specimens.

TABLE 1

Common “Indicator” Aeroallergens Found in Indoor Environments

Group	Allergen	MW (kDa)
Dust mite	Der p 1	25
Dust mite	Der f 1	25
Cat	Fel d 1	35
Dog	Can f 1	NA
Mouse	Mus m 1	17.8
Rat	Rat n 1	16.7
Cockroach	Bla g 1	25
Cockroach	Bla g 2	36

Note. NA, not available.

Cats

The domestic cat (*Felis domesticus*) is currently the most common household pet in the United States. Different breeds of cats appear to produce structurally related allergens, the most potent of which is Fel d 1, a 35-kDa protein that is produced by the cat's sublingual mucous salivary gland and hair root sebaceous glands (4). Since Fel d 1 adheres to small dust particles ranging from 2 to 10 μm in diameter, they remain suspended in air and decline very slowly when a cat is removed from the environment (5). Fel d 1 appears to be heat stable, and therefore steam cleaning of the carpets and upholstered furniture has little added benefit over routine vacuuming in the removal of cat allergen from the environment. Levels of Fel d 1 in settled dust specimens provide a stable marker for the presence of a cat in the environment and, more importantly, for the presence of clinically significant levels of allergen that can induce symptoms or increased sensitization in cat allergic individuals.

Dogs

The domestic dog (*Canis familiaris*) is the second most popular indoor pet. Its potent allergenic proteins are found in its hair and saliva. The important allergenic dog proteins appear to be more complex than cat allergens in that more than 20 distinct protein bands have been identified by immunochemical assays as potential allergens. Some may be common across species while others may be breed specific (6, 7). Can f 1, a major non-breed specific dog allergen, is used as an indoor marker for the presence of relative dog allergen levels (8). Less is known about the importance of breed-specific dog allergens in terms of their importance in causing allergic disease. Dog allergens have been found widely distributed in schools and public buildings, suggesting that their aerodynamic properties are similar to those allergens produced by cats.

Mice and Rats

Rodents produce allergens that are important sources of occupational asthma and rhinitis in laboratory animal workers (9). It has therefore been suggested that they might also be important causes of chronic extrinsic asthma. A recent study of 1478 children with asthma living in the inner cities of eastern United States metropolitan areas supports this concept, in which it was found that sensitization (skin test reactivity) to mouse and rat epithelial extracts was almost as common as sensitivity to cat and dog

(10). Similar surveys have not been performed in middle class populations, but occasional mouse infestations are common in households and could contribute to the mix of indoor allergens.

Mouse allergenic protein is produced both in salivary glands and in the liver. The 17.8-kDa hepatic protein is excreted in the urine and constitutes over 80% of mouse urinary protein. Specific assays are now available for this protein (11), and routine analysis of home environmental exposure should be possible in the near future.

Two allergens have been identified in rat urine, saliva, and pelt. One, designated Rat n 1.01, was thought to be a prealbumin with an apparent molecular mass of 20–21 kDa. The other, designated Rat n 1.02, was thought to be an α_2 -euglobulin of molecular mass 16–17 kDa. More recent data comparing nucleotide and amino acid sequences now have demonstrated that both allergens are variants of the same protein, α_2 -euglobulin. This 16.7-kDa protein is produced in the liver, where it is androgen-dependent, as well as in a number of exocrine glands (salivary, mammary, preputial, and meibomian), where its production is not androgen-dependent (12–14). Because of this complexity, useful immunoassays of rat allergens that can be applied to the monitoring of home and work environments have only recently become available.

Other Pets

Guinea pigs, horses, cows, ducks, chickens, geese, and goats are other pets that produce potent allergens to which individuals can be sensitized. Most of these are kept outdoors or are housed separately, and while their allergen can be tracked into the home, it does not generally represent a significant problem to the allergic individual. Therefore, assays for their measurement have not been a primary goal of clinical laboratories. Pet bird droppings can contribute to increased levels of fungi and bacteria in the home, but most domesticated birds are well tolerated by atopic individuals. Pets often considered "hypoallergenic" include turtles, lizards, frogs, spiders, toads, salamanders, snakes, tropical fish, and ants. Care should be taken to minimize indoor humidity produced by an aquarium.

Cockroaches

Three of the approximately 50 species of cockroaches are considered important pests in American homes (16). Five others are found in homes, but less frequently. Of these, *Blattella germanica* or the

German cockroach has been most extensively studied as it is considered the cosmopolitan cockroach. Other less well studied cockroaches include the American (*Periplaneta americana*) and the oriental cockroaches (*Blattella orientalis*). Cockroach exposure is known to be a significant risk factor for acute asthma, especially in children from low socioeconomic backgrounds (17). Assays are available to measure the Bla g 1 and Bla g 2, 25- and 36-kDa proteins that serve as good indicators of the presence and relative density of cockroaches in an indoor environment. When cockroach allergens are tested for, dust specimens should be collected in areas where cockroaches are known to breed, such as in kitchens, in bathrooms, or in basements near central heating systems.

Mold

Fungi are plant-like organisms with rigid cell walls, clearly defined nuclei, and no chlorophyll. They commonly grow outdoors on nonliving organic matter such as decaying leaves, grass, tree limbs, and animal droppings, but indoor environments can be heavily contaminated as well. Through asexual and sexual reproduction, fungi produce spores that possess distinct lengths, shapes, and surface characteristics with a diameter in the respirable range of 7–12 μm . The relative humidity, temperature (hot and cold blasts), precipitation, fog, and the state of inversions all influence the levels of mold in the outdoor environment, which in turn influences what is introduced into the indoor environment. Allergenic fungal species have been identified in almost every environment that has been studied. Moreover, a large variety of species can be found in particular environments. *Cladosporium* and *Alternaria* are common outdoor fungi that are also detected in settled dust of indoor environments. *Cladosporium herbarum* and 25 other species of *Cladosporium* thrive in temperate zones, and its spores produce velvety olive green, brown, or greenish gray colonies, depending on the growth conditions. *Alternaria alternata* flourishes in warm, humid environments and grows especially well on textiles and fruits such as tomatoes. Moreover, *Penicillium* and *Aspergillus* are two other molds found indoors that produce clinically potent allergens. *Penicillium notatum* and approximately 200 of other species of *Penicillium* produce dusty blue-green colonies and grow on stale bread, citrus fruits, and apples. Because *Penicillium camembertii* and *Penicillium roquefortii* are used in cheese processing, they may be encountered as food

allergens in moldy cheeses. *Aspergillus* differs from the other common indoor molds in that it thrives in warm environments ($>40^{\circ}\text{C}$), and its growth in buildings tends to peak with indoor heating in the autumn and winter. Further details about each of these molds are presented elsewhere (18).

DUST SPECIMEN COLLECTION AND PROCESSING

In contrast to most clinical laboratory assays that analyze serum, dust collected from surfaces or extracted from the air of an indoor environment is the specimen of choice for aeroallergen measurements. The exact location and method of collection of the dust specimen vary widely as a result of the availability of different vacuum collection devices and dust collectors with different particle exclusion limits. The actual location where an allergic individual has symptoms (e.g., bedroom versus kitchen) and the type of allergen being investigated (e.g., dust mite versus cockroach) will aid in the decision as to which room(s) and site(s) should be sampled. One should select the area where the affected individual spends the majority of his or her time and where the allergen is most likely to be. Dust mite and pet epidermal allergens might be expected most commonly in the bedroom, living room, TV room, and recreation room of private homes. Cockroach allergen often follows food and water sources and is often found in dark spaces such as in kitchens, bathrooms, closets, and unventilated attics. Sites with high humidity, such as the bathroom, laundry room, and basements, are good sources of mold contamination.

If an environment is being evaluated for the first time, the investigator may elect to collect a global dust specimen, which is a single dust composite from all the major regions of the indoor environment. In collecting the specimen, no conscious effort should be made to avoid the collection of textile fibers and lint from carpets and upholstered furniture, human and animal hair, metal items, insect parts, or insoluble particles (stones, sand). The crude dust specimen, once collected, is sent to the clinical laboratory where it is processed through a 50-mesh metal sieve (50 wires/in., each with 0.009-in. diameter and a 0.011-in. pore) that allows particles smaller than 250 μm in diameter to pass through. Virtually all of the allergenic material that can be detected in a dust specimen will reside in the sieved dust specimen. Collection of the dust specimen from carpeted sur-

faces should precede the application of any freshener powders, cleaning solvents, or possible contaminating powders (e.g., baby powder or bicarbonate "carpet fresheners") that may alter the pH of the final dust extract and interfere with the final allergen measurement. Moreover, it is the practice in some European countries to not sieve a crude dust specimen so that the resultant specimen may not be reproducibly weighed prior to extraction and resultant intraspecimen allergen levels can vary significantly.

The dust mite, cat, dog, and cockroach allergens are readily extracted into a physiological saline buffer. A minimum of 100 mg of total fine (sieved) dust should be available for extraction to maximize the accuracy of the allergen measurement. A routine extraction procedure involves the addition of 100 mg of sieved house dust to a tube containing 2 ml of filtered borate-buffered saline. While the extraction process is rapid, with >99% of the allergen being extracted into the buffer within 1 h, most laboratories cap the tube and rotate it end-over-end overnight (12–15 h) at room temperature for convenience. The next morning, solids are centrifuged into a pellet, and the supernatant containing the allergen is quantitatively removed and sterile filtered (0.22 μm) to remove fine particles that have not sedimented. If the specimen is not immediately analyzed, it is stored frozen at -20°C . Allergens in the unprocessed dust specimen appear to be insensitive to direct summer sun for at least 5 days, and once extracted, the allergens appear to be rather insensitive to repeated freeze–thawing (19).

ASSAYS FOR AEROALLERGEN AND MOLD SPORE QUANTITATION

Two types of assays are routinely performed on environmental dust specimens: noncompetitive two-site immunoenzymetric assays on aqueous extracts of fine dust for aeroallergen levels and environmental/microbiological assays for nonviable and viable mold spores.

Immunoassays for Aeroallergen Measurement

The availability of monoclonal antibodies specific for the group 1 indicator aeroallergens produced by the dust mite (Der p 1, Der f 1), cat (Fel d 1), dog (Can f 1), and the German cockroach (Bla g 1) has allowed the establishment of microtiter plate-based two-site immunoenzymetric assays. In these assays,

allergen-specific monoclonal antibodies are coated on microtiter plates (e.g., 10 $\mu\text{g}/\text{ml}$, 0.1 ml per well, in phosphate-buffered saline, 4–16 h, room temperature). Following a buffer wash, the plates are blocked with an irrelevant protein (e.g., bovine serum albumin, 10 $\mu\text{g}/\text{ml}$, 0.1 ml/well), and then the test extract of dust is added to their respective wells and incubated 2 h to overnight. Following an additional buffer wash, bound allergen is detected with a second monoclonal antibody that is labeled with an enzyme. After removal of unbound detection antibody, bound label is detected with a substrate for the enzyme coupled to the antibody with the reaction stopped chemically. Well-characterized reference allergen extracts with known potencies (e.g., *D. pteronyssinus* International Reference NIBSC code 82/518) in either nanograms or units of allergen per milliliter are analyzed in parallel with the test extracts. The allergen standards for mite, cat, and dog have been adequately characterized to express results in mass of protein per milliliter. Cockroach allergen is still expressed in arbitrary units per milliliter. A 6- to 8-point standard curve is constructed and used to interpolate unknown specimen response levels into concentration estimates of allergen. A mathematical correction is made for the weight of the dust extracted and sample dilution to produce a final reportable measurement in nanograms of allergen per gram of sieved dust (Der p 1, Der f 1, Fel d 1) or units per gram of dust (Bla g 1).

Viable Mold Spore Assessment

There are two common strategies for assessing the mold content in an indoor environment. The first approach is based on the assumption that the clinically relevant mold spores are viable, and each is capable of producing a separate colony in a plate containing medium from which mycelia will be visually detectable. Some laboratories routinely quantify the total number of colonies that can grow from a small sample of fine settled dust in a particular medium, and others extend this observation by subculturing a representative subset of the observed colonies to determine the relative amount of the different mold species in the dust. There can be extensive variation in the viable mold spore counts reported among laboratories due to a large number of specimen and assay related variables, which include, among others, the heterogeneity of the dust specimen, the difficulty in accurately weighing a small sample of dust, the variety of different culture media and culture times used (24–48 h), and the

subjective nature of counting the number of mold spore colonies (some overlapping, different sizes). One generally accepted technique involves layering a weighed settled sieved dust sample of 5 mg in PBS–Tween aseptically onto a microbiological culture plate containing Sabouraud's dextrose agar with selected antibiotics (penicillin–streptomycin and gentamicin). Larger dust samples will overcolonize the plate and preclude accurate colony counts within a 1- to 2-day period. The plates are then inverted and incubated at 21°C for up to 36 h. The number of “viable” mold colonies is quantified at 24 (and 36) h, and the colony count at 24 h is corrected for the starting weight of the sample to viable colonies per gram of fine dust.

An alternative approach of environmental mold spore assessment is based on the assumption that all mold spores (viable and nonviable) are clinically important. An air sampler deposits mold spores on a silicone-covered film or glass slide that is then examined microscopically. The type and number of mold spores are identified morphologically by their distinct shapes and sizes. Differences related to the sampler, efficiency of collection for the different spores, collection time, and interinvestigator differences in reading slides can produce large interlaboratory variability.

INTERPRETATION OF RESULTS

The purpose of environmental sampling of any kind is to provide an estimate of disease risk for susceptible populations, either for the purpose of epidemiology and public health or for disease treatment and prevention. In the case of environmental allergens, the susceptible population includes persons who have specific sensitization demonstrated by skin testing or serum IgE antibody to indoor and outdoor allergens and who have allergic rhinitis and asthma. Presumably, these allergens cause disease through inhalation, so the most relevant and obvious measures would be airborne allergens. Since airborne sampling is technically impractical in most indoor environments, settle dust measurements have been substituted, supported by the concept that airborne allergen levels are in equilibrium with sources contained in the settled dust.

Dust Mites

Mite exposure is believed to be a risk factor for the development of respiratory allergy and asthma.

The level of mites can vary among homes within a region, within different rooms in a given home, and within a given home at different times of year as a result of changes in indoor humidity and temperature. Der p 1 and Der f 1 allergen levels of 2000 and 10,000 ng per gram of dust have been proposed as demarcations for the low, moderate, and high risk “action” levels for dust mite allergic individuals. A level of 2000 ng of group 1 dust mite allergen per gram of fine dust roughly equates to 100 mites per gram of dust. Based on supportive clinical studies, 2000 ng of allergen per gram of dust has been assigned as the demarcation between low and significant levels of mite allergen exposure for risk evaluation for IgE-mediated sensitization. Combined Der p 1 and Der f 1 levels below 2000 ng per gram of dust are desirable and place the indoor environment in a low risk category for allergen sensitization. Levels above 10,000 ng per gram are considered very high and a risk for asthma symptoms; levels in this range warrant action if a member of the household is atopic or dust mite allergic.

Pet Epidermal Allergens

Cat (Fel d 1) and dog (Can f 1) are the two pet epidermal allergens most commonly measured in the indoor environment. Cat allergen is detectable in many homes, schools, and public buildings, even those with no indoor cats, most likely a result of transport on clothing from external contact. Fewer data support threshold levels of animal allergens for disease risk. In the studies that have been reported, a settled dust level of 8 µg per gram of settled dust has been selected arbitrarily as an action level for identifying cat allergic subjects at risk. In some (20) but not all studies, high cat allergen levels above 8 µg per gram of fine dust have presented asthma risk to sensitized children. Can f 1 level thresholds are most likely comparable; however, this needs further documentation.

Cockroach

Cockroach allergen has been identified as an important risk factor, especially for individuals with low socioeconomic backgrounds. High levels of cockroach allergen have been especially detected in settled dust of many urban homes. In three epidemiologic surveys in American cities, the presence of Bla g 1 and Bla g 2 allergens in settled dust has been shown to be a risk factor for asthma among sensitized individuals (10, 21, 22). A Bla g 1 level of 2 units per gram has been identified as a useful action

level cutoff to identify environments that place predisposed and sensitized individuals at risk for developing asthma.

Mold

Fungi can be detected in essentially every indoor and outdoor environment. The species and total number of viable spores in the surface dust and in the air tend to vary markedly within a discrete space. In theory, all mold spores (both viable and nonviable) can contain allergenic proteins that may induce symptoms in the appropriately sensitized individual. Therefore, the assessment of the total (nonviable) mold burden in an indoor environment may possess more inherent value than just testing for the number of viable mold spore colonies. Detection of relevant allergens has been complicated by extremely variable expression in fungal colonies, and useful immunoassays are not available for mold indicator allergens at this time. However, both the total and the viable mold spore detection strategies share several common problems. The most important problem relates to difficulty in their interpretation. Since mold is found in almost every environment, should the mold spore level in an indoor environment be compared to a second indoor environment in the same building where the individual does not exhibit symptoms or to the outside air that influences the mold levels found indoors? With the latter approach, sampling outdoor airborne fungi is complicated by highly variable weather conditions, sampling techniques, and variety of the spore shapes, sizes and weights that are present.

At present, no action or target limits have been identified for either viable or total (nonviable) mold spores, above which an environment can be marked as a risk for induction of symptoms or increased sensitization of a mold allergic subject. The relationship between environmental exposure to mold and the induction of symptoms is further complicated by the fact that the mold allergic individual may be sensitized (IgE antibody positive) to a mold species that may not be present in their environment in large amounts. Therefore speciation of the mold can be useful; however, since the same four or five common molds are found in most environments and the results of speciation of viable colonies are rarely definitive (often only genera provided), the added cost and time required for speciation of the viable mold spores have been questioned. It is currently unclear whether a viable spore colony count or the total (viable and nonviable) spore count provides a better indicator for the clinically relevant allergens in the environment.

In a 1988 Baltimore study (23), the viable mold spore levels ranged in private homes from 100 to 25,000 colonies per gram of dust, with a median of 2400 colonies per gram. A total of 36 genera of fungi were microscopically identifiable in this study, with 65% of the colonies being produced by spores from *Penicillium*, *Aspergillus*, *Alternaria*, *Cladosporium*, and *Rhodotorula*. Homes older than 30 years and those with reported mildew had higher total mold colony counts. In another study of 358 homes across the United States, 10% contained very low levels (200–1000 colonies/g) (18). Since 50% of the homes with the highest levels of mold spores in this random sampling had >10,000 viable colonies per gram, this is used as a tentative level above which environmental intervention such as mildew removal, control of indoor humidity, and HEPA filtration of air may be appropriate. Investigators continue to study the relationship between allergic symptoms in mold allergic individuals and measured colony counts or total nonviable mold spores present in the indoor environment.

SUMMARY

To avoid an allergen source, one must know its location and quantity. Laboratory methods are now available to quantify the levels of indicator aeroallergens produced by dust mites, cats, dogs, and cockroaches. Moreover, the level of viable and nonviable mold spores can be used to define the mold burden of an indoor environment. Measurements are performed on dust collected from surfaces or from the air and then processed either by sieving and extraction or by direct deposition on microbiological plates. Once an environment is deemed to be a concern to an allergic or asthmatic individual, remediation can be conducted to reduce the allergen burden. Final environmental testing can be used to confirm that the remediation process has been effective. The allergen burden has thus become an analytical measurement provided by the clinical laboratory that enhances the awareness of the allergic or asthmatic individual about the relative safety of their indoor environment.

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