



Dust mite allergens in the office environment

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Abstract (riepilogo)

An attempt is made to evaluate the extent of dust mite infestation and its contribution to the health complaints in office settings. This methodology recommended for residential dwellings was evaluated for use in the work environment. Der p I allergen-specific ELISA was chosen as a primary method. A liquid chromatography method for guanine is suggested as a backup method to cover a few cases where other mite species may be encountered. The levels of dust mite allergens were measured in 14 offices in response to numerous health complaints. Approximately 1/2 of the offices investigated were identified as having a dust mite population. Four offices showed levels of Der p I in the dust greater than 1 ug/g. In 2 offices, the dust mite allergens were the source of the health complaints. In the other 2 offices, dust mite allergens were one of the contaminants in the office environment. In all cases, the infestation of dust mites in the offices was localized to a few specific work areas. Office chairs were the primary location where dust mites thrived.

Testo completo

The objective of this study was to evaluate the extent of dust mite infestation and its contribution to the health complaints in office settings. The methodology recommended for residential dwellings was evaluated for use in the work environment. Der p I allergen-specific ELISA was chosen as a primary method. A liquid chromatography method for guanine is suggested as a backup method to cover a few cases where other mite species may be encountered. The levels of dust mite allergens were measured in 14 offices in response to numerous health complaints. Approximately one-half of the offices investigated were identified as having a dust mite population. Four offices showed levels of Der p I in the dust greater than 1 mu g/g. In two offices, the dust mite allergens were the source of the health complaints. In the other two offices, dust mite allergens were one of the contaminants in the office environment. In all cases, the infestation of dust mites in the offices was localized to a few specific work areas. Office chairs were the primary location where dust mites thrived. The remedial measures included regular cleanup of all fabric-covered office furnishings. Steam cleaning was recommended to eliminate dust mite populations.

In performing indoor air quality investigations for many years in Oregon, there has been a number of cases in which no cause for the complaints of the occupants could be identified. In every case, National Institute for Occupational Safety and Health, Occupational Safety and Health Association, and American Industrial Hygiene Association (AIHA) protocols for Indoor Air Quality Investigations were followed.(1-3) The results gave no definite answer as to the cause of what were genuine complaints of ill health. The symptoms were usually eye, nose, and throat irritation; headache, and in some instances atopic dermatitis. In our effort to solve these elusive cases, we extended our investigations to include dust mite allergens as one potential source of the problems.

In 1964, mites of the genus *Dermatophagoides* were recognized as contributors to the allergic character of household dust.(4) From that time on, a great deal of effort has been directed toward the characterization of specific allergens in house dust as well as the development of methodology and epidemiology.(5-12) There are 10 species of pyroglyphid mites known to occur in house dust out of which four species predominate, namely *Dermatophagoides pteronyssinus*, *D. farinae*, *D. microceras*, and *Euroglyphus maynei*.(13) In the United States, the climate and environmental conditions favor two species, *D. pteronyssinus* and *D. farinae*. *D. pteronyssinus* is most common in the Pacific Northwest because of the relatively high humidity year-round. Dust mite *D. farinae* may be found in drier parts of the Northwest because this species is known to survive under adverse conditions.(10)

House dust may contain high levels of dead skin cells, providing feeding opportunities for the dust mites. Fabrics are known to be an ideal collection medium for dust and subsequently an area for dust mite propagation. The specific causative agents for the allergic reaction are found in mite feces and in the body fragments of dead mites. There are three major allergens of *D. pteronyssinus* that have been identified so far, as well as several others only recently investigated.(13) Der p I is the most extensively studied and best characterized of the allergens. It occurs in high concentration in mite feces and to a lesser extent in body parts as opposed to Der p II, which appears to be at a relatively higher concentration in mite bodies.(13) Der p I is a heat-sensitive glycoprotein of molecular weight 24,000.(5)

According to published reports,(14,15) most present-day children are exposed to significant levels of dust mite allergen in their homes. In addition, a review of the levels of dust mite allergen found in homes over the period 1950 to 1980 showed a dramatic increase in these levels.(16) These may be some of the reasons for the observed increase in the incidence of childhood asthma and may be the source of sensitization for the general population. Dust mite allergens cause symptoms in sensitized individuals such as sneezing; watery nasal discharge; nasal obstruction (allergic rhinitis); redness, watering, and itching of the eyes (conjunctivitis); wheezing and difficulties in breathing (asthma, apnea); and atopic dermatitis.

For dust mites to reach a population density sufficient to cause problems for people, certain conditions must be met: a food source of skin cells, a humidity of greater than 45%, and a temperature between 65 and 80deg F (18-27deg C). These conditions could easily be met in offices in the Northwest.

There are only a limited number of articles dealing with dust mite allergens in the workplace.(10,17,18) In some offices the environmental conditions for dust mite proliferation may exist for at least part of the year, so that the possibility of dust mite allergens in the workplace should not be ignored.

We present here the results of a number of indoor air pollution surveys dealing with dust mite allergen presence in office environments and our evaluation of the methodology for assessing exposure. In addition, an indirect method for estimating exposure to mites by measurement of guanine is also presented.

EXPERIMENTAL METHODS AND MATERIALS sampling of Dust

Sampling for dust was performed using the Andersen Sampler pump (Atlanta, Ga.) with a flow rate of 1 ft sup 3 /min (28.3 L/min) with a three-piece 37-mm standard aerosol cassette that contained a 0.8-mu m mixed cellulose ester filter and backup pad. Sampling was carried out with the cassette open-faced. Samples were collected from fabric-covered chairs, partitions, hand rests for keypads, and carpets. On the average, three cassettes per chair or three cassettes per square meter of other surfaces were used. This procedure provided sufficient dust, approximately 1.0 g, for all necessary testing, and prevented overloading of the filters. The dust was further processed by sieving through a 300-mu m sieve to get fine dust for testing.

Determination of Der p I by ELISA

The ELISA procedure described by Luczynska et al.(11) was used in all of our surveys. Sieved dust, 100 mg, was extracted overnight in 2 mL of borate-buffered saline solution (4.5 g NaCl, 0.15 g boric acid, 0.19 mL 1 N NaOH, pH adjusted to 8.0, and diluted to 1 L with water). ELISA plates were coated with 100 µL/well of a coating liquid, commercially obtained, that was composed of a 50% SAS cut of 5H8 (anti-Der p I) ascites (protein concentration 10 µg/mL) in 0.05 M carbonate-bicarbonate buffer, pH 9.6, and left overnight at 4deg C. All subsequent incubations were at room temperature. The plates were washed twice with phosphate-buffered saline (PBS)-Tween (8.0 g NaCl, 0.20 g KH sub 2 PO sub 4 , 1.15 g Na sub 2 HPO sub 4 , 0.20 g KCl, 0.5 mL Tween 20, diluted to 1 L with water) and incubated with 1% bovine serum albumin (BSA) in PBS-Tween for 30 minutes. After an additional two washes with PBS-Tween, 100 µL of extracts of dust samples (dilutions of 1:5 and 1:10) and a set of standard solutions of Der p I (UVA/03) (concentration range 0.05-250 ng/mL) in 1% BSA in PBS-Tween were added to the wells. The plates were incubated for 1 hour and washed five times with PBS-Tween and then incubated with 100 µL/well of biotinylated-4Cl (16 ng/well) in 0.2 M phosphate buffer, pH 7.5, for 1 hour. After a further five washes, 100 µL/well of streptavidin-peroxidase (Sigma S5512, reconstituted in 1 mL water, 0.25 µg/well) was added and incubated for 30 minutes. The plates were again washed five times with PBS-Tween. To each well was added 100 µL of a 0.01 M solution of 2,2'-azino-di-(3-ethylbenzthiazoline sulfonic acid) in citrate-phosphate buffer (5.64 g citric acid, 5.84 g Na sub 2 HPO sub 4 *7H sub 2 O in 1 L water) that was made to 0.03% hydrogen peroxide immediately before use. The reaction was stopped after 5 minutes by adding 100 µL/well of 0.002 M sodium azide, and the plates were read at 414 nm. The limit of detection (LOD) for Der p I by this test was found to be 0.05 µg/g of dust.

All reagents and streptavidin-peroxidase used for the ELISA were purchased from Sigma Chemical Company (St. Louis, Mo.). A kit to perform the ELISA was purchased through Dr. Martin Chapman, Division of Allergy and Clinical Immunology, Health Sciences Center, Box 225, Charlottesville, Virginia 22908. This kit contained the monoclonal antibody for Der p I (5H8), the cross-reacting monoclonal antibody (4Cl) that had been biotinylated, and a standard for Der p I of 2500 ng/mL. Disposable ELISA plates (Corning, 96-well, flat bottom, polystyrene, no. 25801) were from VWR Scientific (Seattle, Wash.). ELISA plates were read using an OTC 400 plate reader (Organon Teknika Corp., Durham, N.C.).

Determination of Guanine by Liquid Chromatography

For guanine testing, 100 mg of sieved dust was shaken for 15 minutes with 5 mL of an alkaline/alcohol extraction mixture (6.4 g NaOH dissolved in 1 part methanol:5 parts water, to give 1 L). The clear supernatant liquid was diluted to one-tenth concentration and analyzed using liquid chromatography. For low levels, the analysis was performed using the undiluted supernatant.

The liquid chromatography system consisted of a Waters (Milford, Mass.) Millennium 2010 chromatographic system supplied with a Waters 996 Photodiode Array Detector. The liquid chromatography conditions were as follows: column, Intersil 5 µm ODS-2, 150 mm X 4.6 mm, Metachem Technologies, Inc.; mobile phase, 0.1 M triethylamine acetate, pH adjusted to 4.5 with acetic acid; flow rate, 1.0 mL/min(19); detector, photodiode array, 248 nm used for quantification; temperature, 30deg C; and injection volume, 10 µL.

The confirmation of guanine was performed by spectral matching.(20) The spectrum of the sample was matched against an existing standard spectrum for guanine. To quantitate the degree of difference between spectra, the spectral contrast technique was used. The calculations were carried out by Millennium software in which match angles and match thresholds are computed. Match angles were compared, and when the match angles were less than the match threshold, no difference in spectral shape had been detected. In cases in which the match angles were greater than the match threshold, the spectra were not from the same compound.

All solvents used for liquid chromatography were reagent grade or better. The purines and pyrimidines for standards were purchased from Sigma Chemical Company. Figure 1 shows the chromatogram and the spectrum of a standard containing 5.24 µg/mL guanine with a retention time of 4.27 minutes for guanine. (Figure 1 omitted)

Data Presentation

All samples collected were statistically analyzed assuming a log normal distribution because it best describes the variations of occupational environmental data. (21,22) The geometric mean was calculated by replacing Not Detected values with LOD/2. In cases where more than one building was surveyed, the significance of the difference between buildings was tested using the Student's t-test.

RESULTS AND DISCUSSION

One of the major obstacles in performing evaluations for dust mite exposure in the work environment has been the choice of sampling and analytical methodology. From the extensive work done on dust mite allergen measurements in private homes, there appears to be a serious drawback with using the collection of air samples as a means of assessing problems with dust mite allergens. Dust mite fecal and body particles settle fairly rapidly after disturbance because of their particle size of 10-40 µm. No correlation between airborne concentrations of allergens and sensitivity or symptoms could be found. For this reason, the International Association of Allergology and Clinical Immunology recommends sampling of dust collected in settled reservoirs within the house for evaluation of exposure to mite allergens.(13) The same considerations have been applied by us in deciding on the sampling strategy in the workplace. However, any physical disturbance of dust will result in particles being temporarily airborne. Particles of 10-40 µm may be deposited within the respiratory tract. According to the American Conference of Governmental Industrial Hygienists' recently adopted criteria for inhalable dust, 77% of the particles with an aerodynamic diameter of 10 µm will be inhalable and 50% will be thoracic.(23)

There are several ways to assess the dust for potential mite allergen exposure. One is to perform counts of mites using light microscopy. This technique is not practical for routine analysis as it requires acarological expertise and may not always indicate the levels of mite allergens in the dust. Some studies have shown that the levels of allergen in the dust remain high even after the number of mites has decreased.(10)

The second type is the measurement of a specific allergen (e.g., Der p I) using ELISA methods with species-specific monoclonal antibodies for binding the allergen and a group-specific monoclonal antibody for detection and quantification. This procedure can now be performed routinely, and it more directly correlates with an allergic reaction in individuals exposed to the dust.(4,13)

The extracts from dust mite samples contain a large number of components that seem to elicit an allergic response in humans.(13) Groups I and II allergens are the best characterized so far. Their properties are quite different in both structure and biochemical function. Most mite-allergic humans will react to either group I or group II allergens, or both. In a study of airborne house dust, it was reported that the group I allergens were carried on particles of 10 µm diameter or higher. Group II allergen was also found in both particles of 10 µm diameter and higher, as well as in substantial quantities in particles of less than 10 µm diameter.(24) Although there are available methods to measure groups I and II allergens, most of the reported literature cites the group I allergen method as the method for assessing exposure to dust mites.

The ELISA for the Der p I allergen was chosen to be the primary test in view of the fact that *D. pteronyssinus* is the predominant mite for this area. The test is highly specific for Der p I, showing a low cross-reactivity (1-2%) between Der p I and Der f I over a wide range of concentrations.(11)

To cover potential cases where dust samples may have *D. farinae* as a significant mite species, we added to our methodology the determination of guanine in the dust samples. Guanine is a major component of mite feces and body parts and thus is an indirect indication of mite allergen concentration.

The determination of guanine in house dust gained popularity in the 1980s because of the availability of a colorimetric paper test (ACAREX) that provided a low cost and simple way of testing household dust.(25-29) For these reasons, we attempted to use a colorimetric test in our initial surveys. From the very beginning of our testing, we observed a high number of false-positive results showing numerous interferences due to substances present in chairs and carpets. As a consequence of these findings, we were reluctant to rely on this type of testing as a means of evaluating the exposure to dust mite allergen in the workplace.

The method for measuring guanine in dust extracts had to be more specific to provide a reliable means of judging the allergenicity of the dust. The current state of the art of liquid chromatography meets the above requirements. As an additional improvement, a photodiode array detector was used to confirm peak purity for guanine.

Liquid chromatography analysis for guanine is simple, accurate, and easy to perform in a standard industrial hygiene laboratory and matches more closely the types of analyses performed than ELISA testing does. For this reason, it may be useful as an analytical method for dust mite evaluations. In the office environment, most of the guanine found would be related to dust mites and spiders. Other sources such as human hair, nail fragments, and human dander are known to contain extremely low levels of guanine and would not contribute in a substantial way to the amount of guanine in dust.(16,25)

There are no documented health-based standards for airborne concentrations of dust mite allergens in the work environment and only recommendations by the International Association of Allergology and Clinical Immunology and the World Health Organization for limits in residential dwellings. These recommendations for threshold levels of exposure to dust mite allergen were first proposed in 1987 and confirmed in 1990.(13) According to the guidelines, exposure to dust containing 2 $\mu\text{g/g}$ of group I mite allergens or 0.6 mg/g of guanine is considered to increase the risk of sensitization and the development of asthma and bronchial hyperactivity in affected individuals. Exposure to dust containing 10 $\mu\text{g/g}$ of group I allergens or greater than 2.5 mg/g of guanine represents a higher level of risk and increased chance of acute attacks of asthma. A study by Price et al.(15) reported a significant correlation between sensitivity to the mites and levels of allergen in carpets at 0.5 $\mu\text{g/g}$. This suggests that a much lower level of allergen was required to avoid sensitization. From all available data on dust mite allergens, it is clear that a concentration of Der p I of greater than 2 $\mu\text{g/g}$ of dust or guanine greater than 0.6 mg/g of dust found in the work environment should be of concern. The levels above 0.5 g/g of dust should be noted in view that a certain percentage of individuals may react to much lower levels of allergens in dust. In addition to the allergen concentration in the dust, the exposure generating potential of the source should be considered.

The concentration of Der p I or guanine in the dust depends on the density of the particles. Dust collected from fabrics covering chairs or partitions tends to have lower density than the dust coming from carpets, which frequently contains sand, grit, and coarse fibers. This may lead to apparent lower concentrations of Der p I or guanine in carpet dust. A valid comparison of allergen or guanine levels can be made only among samples from similar sources.

In all, we performed the dust mite allergen and guanine evaluations in 14 places of employment. The types of offices surveyed ranged from a small hospital office to large office buildings. They varied in geographic location and type of maintenance. A total of 127 samples were collected. A summary of the data is shown in Table I. (Table I omitted) Sampling was conducted during different seasons of the year. Of the 14 places surveyed, 5 were found that showed levels of Der p I greater than 1.0 $\mu\text{g/g}$, which indicated mite infestation, and an additional four that had levels of Der p I greater than 0.5 $\mu\text{g/g}$ and less than 1.0 $\mu\text{g/g}$. The remainder, five offices, showed low levels of Der p I below 0.5 $\mu\text{g/g}$.

Housekeeping practices were reviewed and revealed a number of deficiencies. All of the offices had a protocol for floor cleaning but none had provisions for regular cleaning of chairs, partitions, or other fabric-coated office furnishings. As a result, the amount of dust collected from furnishings for a 1-minute sampling time was much higher than from carpets. The dust collected on individual chairs contained high amounts of skin cells. Figure 2 shows chromatograms of original undiluted extracts obtained from office chair dust samples. (Figure 2 omitted) Several components in the extract originated from skin cells (Scan B), including the one eluting at 4.34 minutes, closely matching the retention time of 4.27 minutes for guanine. This eluate was a potential interference in guanine determination and may have been the reason for the poor correlation between guanine and Der p I concentrations observed for lower levels of both analytes in the sample.

Guanine, however, has a distinctly different spectrum from this other component. The interference can thus be minimized by performing spectral matching as a qualitative analysis.(20) The extract of Sample Number 1 in Scan A showed a high degree of spectral match with guanine, whereas Sample Number 2, Scan C, failed the test, indicating coelution of a small amount of guanine with a component from skin cells. For higher levels of guanine in dust samples, greater than 0.6 mg/g , the original extract was further diluted, making the contribution from this particular eluate negligible.

To illustrate the dust mite problems in the office environment, the authors present three cases that had the highest individual sample readings, Surveys 2, 3, and 8. Because each office had its special features, the results and discussion are presented as separate cases.

Case 1

The office was located in a remodeled masonry building. It had 14 employees dispersed in two separate work areas. Each employee's station was separated by movable fabric-coated partitions. Approximately two months before the indoor air evaluation, an outside drain plugged and flooded the office. The rain runoff entered the back door, soaking approximately 10 ft sup 2 of carpet. This area was professionally cleaned about 24 hours later. Soon after this incident, complaints regarding the indoor air quality began. The occupants complained of symptoms of ill health and poor air circulation. They frequently experienced itchy watery eyes and nose and respiratory difficulties. One of the employees had skin problems characterized by severe itching of exposed and unexposed skin that would diminish within the hour after leaving work.

Before conducting the sampling for dust mite allergen, a thorough investigation of the heating, ventilating, and air-conditioning system was made, as well as a search for chemical and bioaerosol sources for indoor air problems. All findings were negative, and the health-related symptoms persisted.

Qualitative observation revealed that the general cleanliness in the office was poor; carpets were covered with office debris and heavily stained and had an accumulation of dust in the corners. Chairs in individual workstations were stained, with dust accumulated in the crevices of the fabric. The humidity ranged from 45 to 55% with an average temperature of 76degF (24.4deg C).

Ten work areas were sampled. For each workstation, samples were collected from the desk chair and surrounding floor. In addition, when appropriate, samples were taken from partitions and fabric-covered keypad hand rests. The results of sampling and analysis for Der p I allergen are presented in Table II. (Table II omitted) An insufficient amount of dust was collected to determine guanine levels, with the exception of the desk chair for Employee A, which gave 0.3 mg/g , and for the keypad hand rest for Employee G, which gave 0.2 mg/g for guanine concentrations.

The results indicate localized dust mite infestation. The highest concentrations of allergen in the dust were observed for Employee G, showing 3.27 $\mu\text{g/g}$ of Der p I from the chair and levels greater than 0.5 $\mu\text{g/g}$ in the carpet and keypad hand rest. The level of dust mite allergen of 1.72 $\mu\text{g/g}$ on the partition in the area of Employee A was from a partition frequently leaned on by Employee A to speak with other staff members. In the work area of Employee H, levels of

dust mite allergen greater than 0.5 $\mu\text{g/g}$ were also observed. All three employees were in close physical proximity to one another. These findings matched closely the symptoms and complaints of the employees. Employees A and G had, by far, the most severe complaints of ill health; that included, in addition to respiratory problems, persistent itching on both exposed and unexposed skin. Two employees requested and underwent routine allergy testing. They were both found to have positive reactions to the workplace dust as well as to a number of other allergens, such as cat allergen and mold. Their workstations were in close proximity to the two areas of mite infestation.

The control measures recommended by the industrial hygienist to correct the problem consisted of regular vacuum cleaning of fabric-covered surfaces to prevent accumulation of dust. For the furniture found to be infested, hot water or steam cleaning (temperature greater than 55deg C or 130deg F) of fabrics to eliminate mites was recommended.(13)

Until recently, a powder containing benzyl benzoate (e.g., the commercial miticide Acarosan) was suggested in the management of dust mite allergies in homes.(16,29,30) The carpets were sprayed with the miticide, allowed to dry, and then vacuumed to remove both dead dust mites as well as excreta. In a recently published report, benzyl benzoate was indicated as a possible anti-asthmatic drug.(31) This finding would preclude any recommendation to use this procedure, for obvious safety reasons.

In the follow-up phase of the survey conducted by telephone interview, it was learned that the desk chair used by Employee G (the highest reading of Der p I) had been taken out of service. The carpet and partitions had been steam cleaned to control mite populations and remove allergen-contaminated dust from work areas. Steam cleaning of furniture was not routine and will be repeated only if the complaints of ill health arise again. These control measures resulted in the resolution of indoor air quality problems for this particular office.

Case 2

The second case was a county agency housed in two physically separate buildings. Building 1 was a three-story office building constructed in 1975, housing a variety of governmental agencies. The survey covered approximately 37 employees located on the second floor of Building 1. Building 2, also a subject of our survey, was a recently remodeled historic building with 39 employees occupying the building for approximately 1 year.

Overall, the offices in Building 1 gave the appearance of being overcrowded and dingy, with many poorly lit areas. Furnishings, including chairs, partitions, and carpeting, were original to the building and were showing wear and tear. A lack of adequate vacuuming under and around the desks was evident. The janitorial services provided included light vacuuming twice a week and were often limited to the aisles and open floor areas. Each small cubicle assigned as the work area for an employee created dead air space for most occupants and short-circuited the ventilation system.

In contrast to Building 1, the overall appearance of Building 2 was bright, spacious, and clean. Carpeting was relatively free of settled dust. Individual cubicles were separated from one another by 4-foot walls, which were typically decorated with house plants and various objects. Most of the office furniture, including chairs, had come from Building 1.

Building 1 had a long history of employee complaints. Seventy-three percent of the occupants rated the indoor air quality in their office as unacceptable. Aside from complaints of temperature extremes, lack of fresh air, and inadequate lighting, employees had general health complaints. These included upper respiratory irritation, sinus problems, congestion, coughing, and throat irritation as well as headache, fatigue, drowsiness, and eye irritation. By contrast, in Building 2, only 38% of the occupants rated the indoor air quality as unacceptable. The health complaints were much the same as in Building 1.

In Building 1, 12 employees who had physician-diagnosed health histories of either allergies, asthma, or both attributed the symptoms they experienced to occupancy of the building, with alleviation observed during times away from the building. Eleven employees who had confirmed health histories of either allergies, asthma, or both did not associate their health problems with the building. In Building 2, seven similarly diagnosed sensitive employees attributed their health problems to the building. Sampling for dust mite allergens was conducted in both offices. The results are summarized in Table III. (Table III omitted)

The highest level of Der p I was obtained from the dust of the chair of Employee G, reaching 7.00 $\mu\text{g/g}$ of dust. Guanine levels for the same dust samples are also summarized in Table III. The amount of dust collected from the area of Employee G was inadequate to test for guanine in addition to Der p I. Hence, only the concentration of Der p I is presented. The rest of the results show that lower levels of dust mite allergen correspond to lower levels of guanine. Employees A-D had confirmed allergies to dust mite allergen and were treated by a physician for these allergies. The dust from the chair of Employee C had a level of Der p I of 0.89 $\mu\text{g/g}$. In addition, Employee E had pre-existing chronic respiratory problems. The rest of the employees, F-T, did not report having allergies or other health problems they associated with Building 1.

The results in Table III revealed a source of high levels of dust mite allergen in the offices in Building 1. Because such dust can trigger a reaction in sensitive individuals, its presence in Building 1 may be considered a contributing factor to the reported health problems.

In Building 2, only Employee K reported sensitivity to dust mite allergen. The results for Der p I show a measurable amount of 0.53 μg allergen/g of dust for this work location, confirming the presence of dust mites. The test for significance at the 95% level for Der p I allergen concentration showed no statistically significant difference between the two buildings ($p < 0.05$).

The industrial hygienist recommended treatment of upholstered furniture and immediate surroundings to eliminate the allergen. Steam cleaning of all carpeted areas was also recommended. In a follow-up interview, it was learned that the steam cleaning had been done and that all office chairs were replaced, thus removing the primary source of dust mite allergens. Fewer health-related complaints were noted. However, the original complaints related to ventilation, lack of fresh air, and lighting remained, indicating a need for addressing these serious problems.

Case 3

The third case occurred in a large office. The two buildings that were warehouses had been retrofitted in 1989 to accommodate its current function as an office building. Each building had approximately 42,000 ft² of floor area and was occupied by 225 employees. General housekeeping, dusting and vacuuming, was done daily. However, the fabric-covered chairs and dividers had never been cleaned or vacuumed. The humidity averaged 50% and the temperature 75deg F (24deg C).

The industrial hygiene survey was a thorough evaluation to address complaints of employees of poor air quality and symptoms that included severe rashes, migraine headaches, dryness of throat, dry itchy eyes, sinus infections, and respiratory problems. The sampling for Der p I was limited to the employees with the most severe symptoms and health complaints, some of whom were medically evaluated with asthma. The amount of dust collected from each chair was extremely high, indicating a major deficiency in the cleanup procedure for the furniture.

The results of dust sampling are presented in Table IV, which gives the concentrations of Der p I allergen and guanine in all samples. (Table IV omitted) One of the samples originating from the desk chair of Employee B, Building 1, reached the concentration of 2.08 $\mu\text{g/g}$ of Der p I allergen. This is a level recognized as having a potential to increase the risk of sensitization and bronchial hyperreactivity. A measurable level of 0.51 $\mu\text{g/g}$ was detected in the chair of Employee

A, who was in close proximity to Employee B. The low levels found in the carpet may be the result of regular vacuuming and cleaning. The reading for guanine from the desk chair of Employee B was 0.90 mg/g, showing confirmation of the relationship between Der p I and guanine reported already in the literature for household dust.

Building 2 had one work area, Employee F, with Der p I levels of 0.61 μ g/g. The readings for guanine, with the exception of the work area of Employee B, were low, with a low level spectral match. The test for significance at the 95% level for Der p I allergen concentration showed no statistically significant difference between the two buildings ($p < 0.05$).

The pattern of infestation of mites in only one area (Employee B, Building 1) was further investigated to determine its possible cause. All chairs in this office released a large amount of dust during sampling and were in proximity to each other, making the finding puzzling. In a follow-up investigation, it was learned that Employee B, suffering from episodes of skin rash, stuffy nose, and eye irritation, attempted to solve her problem by installing a humidifier with a filter in her work area approximately one month before our sampling.

There is a question as to whether the higher humidity in her area may have resulted in the mite infestation and propagation in that period of time. The higher humidity would certainly favor the mite infestation and could become a problem in the future.

The housekeeping measures recommended by the industrial hygienist included regular cleaning of all fabric-covered furniture annually. A water-based detergent and a solvent-based cleaner, when needed, would reduce dust levels and remove visible stains.

In the follow-up phase of the survey, it was learned that the office chair with the highest level of dust mite allergen was replaced and the humidifier removed from this workstation. Employee B was still experiencing symptoms of stuffy nose and eye irritation; however, she no longer had skin rashes.

The three cases presented above illustrate the pattern of mite infestation that was typical for all offices investigated. Only certain areas in offices showed elevated levels of Der p I in the dust, whereas the other workstations a short distance away did not have the problem. No explanation could be found to account for most of these findings, although a localized variability in humidity could not be ruled out. The environmental conditions during our sampling, including temperature and humidity, and the maintenance procedures seemed to be the same throughout a given office. Because of this pattern, it would be easy to miss the infestation source when doing dust mite sampling in offices. As a minimum, the workstations of employees experiencing symptoms associated with dust mite allergens should be addressed.

Because of limitations of resources and mandated operating procedures, we did not have an opportunity to perform follow-up sampling for dust to fully confirm the efficiency of recommended remedial measures.

CONCLUSIONS

The presence of dust mites in the office environment has been investigated to account for a number of unsolved indoor air quality complaints. Based on the results of our study the following conclusions can be made.

- (1) Some of the problems in the office environment may be traced to the presence of dust mite allergens in the settled dust. Dust mite allergen can be the source or a contributing factor in office environment health complaints.
- (2) Two analytical methods can be used to evaluate the allergic character of the dust. The preferred method is an ELISA for Der p I allergen because it directly reflects the allergenicity of the dust when *D. pteronyssinus* is the dominant allergenic species. The second indirect method is determination of the guanine content of the dust. The sample analysis for guanine should be performed by liquid chromatography with purity check of eluting compounds.
- (3) The highest levels of mite allergen have been found in the dust from office chairs, whereas the lowest levels came from carpets. An individual's chair is physically closest and tends to collect most of the human dander. In addition, office chairs received much less maintenance than office carpets.
- (4) Out of 14 offices investigated, 9 were identified as having a dust mite population. The pattern of infestation observed has been found to be localized to specific workstations and not uniformly spread throughout the office.

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