
Methods and effectiveness of indoor environmental control

Peyton A. Eggleston, MD

Learning Objectives: The purpose of this review is to describe recommended methods of decreasing exposure to indoor allergens.

Data Sources: Data were obtained from published studies and reviews.

Study Selection: The reviewed studies met these criteria: 1) measurement of environmental allergens; 2) selection of participants with clearly defined allergic airway disease confirmed by detection of allergen-specific immunoglobulin E; and 3) clearly defined clinical and environmental outcomes. The studies were conducted as controlled clinical trials and the results between treated and control groups were compared with appropriate statistics.

Results: The results of these studies show that installing allergen proof encasings and washing bedding frequently reduces house-dust mite exposure by 10-fold or more and significantly improves clinical measures of asthma. Washing pets reduces allergen levels temporarily. Excluding the pet from the bedroom while installing allergen-proof encasings and operating air cleaner reduces airborne allergens although having no significant effect on allergic symptoms. Cockroach populations can be controlled for over 6 months and allergens can be reduced with controlled pesticide application and cleaning, but clinical correlates have not been reported. Methods to improve adherence to environmental control measures have not been tested but effective methods can be recommended from literature on medication adherence.

Conclusions: For patients allergic to indoor allergens, reasonable recommendations include installation of allergen-impermeable encasings, frequent laundering of bedding, removing furred pets from the home, and controlling of cockroach populations with effective pesticides using the principles of integrated pest management.

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INTRODUCTION

Environmental allergen avoidance has long been a standard recommendation for the management of the allergic asthmatic. Recently, it has become possible to identify and isolate allergens in the indoor environment, resulting in the assay procedures that have allowed us to estimate exposure variations and to conduct epidemiologic studies to demonstrate a strong association between exposure and sensitization to indoor allergens and chronic asthma.^{1,2} The epidemiologic associations have been found in many areas of the world, although the responsible al-

lergens differ in different locations, ie, house-dust mites in coastal humid areas, animals in Scandinavia or in higher elevations where there are few mites and cockroaches compared with US inner cities. In addition, the identification has allowed intervention procedures to be tested. The effectiveness of procedures that have long been recommended could be tested and sometimes abandoned as a result. Those procedures found to reduce allergens have been tested in clinical trials to test their effectiveness in reducing asthma symptoms and physiology. In the case of many allergens, clinical trials have demonstrated that avoidance measures directed at single allergens can reduce asthma morbidity. Specific intervention methods and the research supporting them have been reviewed in more detail elsewhere,^{3–5}

and it is the purpose of this paper to summarize this information reviewed in more detail elsewhere.

HOUSE-DUST MITES

In most temperate parts of the world, house-dust mites are a major source of indoor allergens. Mite ecology and its role in asthma has been reviewed elsewhere.^{1,2} For remediation, it is important to remember that mites infest fabrics and require constant humidity and warm temperatures, so they are found in the highest concentration in bedding. The allergens associated with mites are largely found in large particles that require vigorous disturbance to become airborne and do not remain airborne for long.

Environmental control measures for mites have been extensively reviewed.^{4,5} As seen in Table 1, allergen-proof encasings are the simplest and most effective avoidance measures known, providing a physical barrier to house-dust mite allergens in bedding.^{6,7} Effective pillow covers are available for under \$15 whereas mattress covers cost approximately 40 to \$60, and are readily available through mail order houses and health and linen sections of large retail stores. When combined with weekly laundering of bed linens, barriers can reduce mite allergen levels by two orders of magnitude.⁸ Such reductions have been shown to reduce medication requirements, symptoms, and other measures of asthma morbidity.⁹ Washing allergen from bedding with water is effective, and detergents increase cleaning efficiency slightly.¹⁰ Dry cleaning will kill mites but is less effective in removing allergens at the same time.¹¹ Vacuum cleaning is included to provide bulk dust removal,¹² because the concentration of mite allergen per

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Table 1. Mite Control Measures

First line	Encase mattress and pillows with finely woven or vapor permeable, nonwoven fabric covers Wash bedding, including comforters, blankets, duvet weekly Remove stuffed animals from bed Maintain room humidity <50% relative humidity Vacuum frequently
Second line	Replace carpets Acaracides (benzylbenzoate) Denaturants (tannic acid) Remove carpet from other rooms

Where it is practical, cleaning bedding with hot water (>130°C) will kill mites, whereas weekly washing will remove mite allergen.

gram of settled dust does not change with vacuuming.

Although mite populations increase with humidity and during humid seasons,¹ attempts to reduce indoor humidity adequately to improve mite allergen control have given mixed results.^{13,14} Carpeting and furniture may become infested with mites, but treatment of these sites does not seem to improve asthma symptoms in clinical trials. Thus, as removing carpets contributes to the complexity and clinical unacceptability of allergen avoidance procedures, this should be a much lower priority than bedding treatments. Similarly, the use of acaracides and denaturants have not been shown to be particularly effective in reducing allergen concentrations in homes, so they are also given lower priority.

ANIMALS

Animal allergens are small molecular weight proteins found in animal secretions such as saliva, sebum, perianal glands, and urine; many of them belong to the structural family called lipocalyins which may serve the purpose of sensing or transporting pheromones.^{15,16} The allergens are carried on small particles (>20% smaller than 5 µm) that remain airborne for long periods. The particles also adhere to many surfaces and are widely distributed both by the animals and by persons and clothing that contact the animals.^{17,18} Recent studies in Scandinavia demonstrate that children from homes with pets contaminate schoolrooms¹⁸ and may create an environment that can precipitate

asthma in sensitized children¹⁹; these same studies documented further distribution from the school into the homes of children without pets. Thus, although levels are higher in homes of pet owners and in the presence of animals, the air and fabrics in homes without pets are contaminated with animal allergens.

The only proven method of reducing animal allergen concentration indoors is to remove the animal (Table 2). Even then, it takes 6 months or more for cat allergen concentrations in settled dust to decrease to levels similar to those found in homes in which pets have been excluded from the home.²⁰ Measures short of this have not proven to reduce either settled dust or airborne allergen levels appreciably. Washing the pet has been suggested as a method of reducing Fel d 1 levels in a home; subsequent research has shown that the reductions that can be achieved are small and the weekly baths will not reduce the levels of airborne allergen measured before the bath.^{21,22}

Although it is sensible to use high-efficiency air filters,^{23,24} and to try to create a safe room, the evidence does

not support the effectiveness of this recommendation. In one study,²⁵ a single air cleaner was used in the bedroom, with a small change over 3 months in airborne concentrations but no change in symptoms. In another study,²⁶ air cleaners were placed in the bedroom and living room, resulting in a significant change in bronchial hyperresponsiveness but no change in symptoms. Protein denaturants such as tannic acid have been shown to reduce cat allergen concentrations in settled dust,²⁷ but the clinical significance of these reductions is not known.

COCKROACHES

Of the many species of cockroach, only the German, American, Oriental, and brown-banded cockroaches commonly infest homes.²⁸ Multiple allergens have been identified associated with the cockroach and several of them sensitize 60 to 80% of allergic patients who are exposed. The allergens are found in many parts of the cockroach, including the gastrointestinal tract, secretory glands, and striated muscles. Those in the gastrointestinal tract are introduced in the environment in feces and in saliva that the insect regurgitates to begin digestion of its food. Females lay egg cases that can develop into adults several weeks after successful extermination. In addition, the cockroach seeks narrow hiding places and leaves contaminating debris that remains after successful extermination. This wide distribution is probably why allergens are distributed widely in infested homes and may remain in settled dust for many months after successful extermination (Table 3).^{29,30}

Table 2. Removal of Pet Allergens

First line	Do not bring a pet into the home Find an existing pet a new home
Second line	Restrict pet to one area of the home Wash pet frequently Create safe room in bedroom Do not allow pet into the room Remove carpeting in the room Install allergen-proof bedding covers Use an efficient air cleaner

Table 3. Removal of Cockroach Allergens

Exterminate with effective insecticide
Clean thoroughly with detergent and water
Vacuum thoroughly
Keep food stores in plastic containers or in refrigerator
Clean snack food debris
Wash dishes daily
Place trash outside daily
Place bait traps
Seal cracks and crevices

Extermination is best managed by a professional pest control company. The pesticides contained in sprays and bait stations contain lower concentrations of pesticides and are appropriate for light infestations. Generally, pest control companies will apply new, highly effective pesticides as odorless gel baits that are environmentally friendly (Table 4). These measures should eliminate roaches for 3 to 6 months.³¹ After extermination, the home must be thoroughly cleaned to remove allergen from roach hiding places, woodwork, kitchen surfaces, fabrics, and rugs.³² Allergen levels in bedding are generally similar to floors, so avoidance should include allergen-proof mattress covers and repeated laundering of bedding. To prevent reinfestation, food sources must be kept in sealed containers and dishes must be cleaned frequently. Bait traps available in groceries and hardware stores are effective in preventing reinfestation and in treating light infestation. These recommendations have been shown to reduce cockroach allergen 80 to 90%,^{29,33} but research has not been

completed to determine the health effects of this reduction.

ADHERENCE TO ENVIRONMENTAL AVOIDANCE

Relatively little research has been done on adherence or compliance with recommendations, but the little that has been done is not encouraging. With clinic-based recommendations, Korsaard³⁴ found only 17% of clinic patients had installed mattress and pillow covers. Huss et al³⁵ confirmed these figures and showed that intensive education could increase this figure to only 39%. In an immunotherapy study in which participants demonstrated better than 95% compliance with medications, only 48% of families had installed a mattress cover as instructed.³⁶

Clinically, several steps have been shown to improve compliance with medications,³⁷ and it seems sensible to use the same techniques to try to increase compliance with allergen avoidance. First, recommendations should be simple, carefully explained in terms of the details and the rationale of their use. Adherence depends on a partnership between patient and physician, in which the physician provides advice and encouragement. This certainly requires attention to the patient's sensitivity as demonstrated by a skin test or RAST, and may require that some of the patient's sensitivities are ignored.

Remember that the clinical trials of environmental control that have been conducted have all shown significant improvement when exposure to a single

allergen, usually house-dust mite, was adequate to reduce symptoms, medication use, and bronchial hyperresponsiveness. For a given allergen, stick to the first-line recommendations. In followup visits, ask about progress with the recommendations just as you would ask whether medication was effective and whether the patient was taking it correctly. Then, give positive reinforcement, emphasizing what has been done, rather than what has not been done. Help solve problems such as availability of the recommended equipment, its use, and problems encountered.

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Table 4. Performance of Available Pesticides

		Toxicity*	Effectiveness†
Organophosphates	Dursban	+++	++
Pyrethrins	Permethrin	++	+++
Avermectins	Avert	+	+++
	MaxForce A		
Fipronil	Combat FC	++	+++
Hydromethylnon	MaxForce	++	+++
Boric acid		++	+

* Toxicity is rated according to median lethal dose values in animal studies: + >10,000, ++ <10,000, +++ <1000.

† Effectiveness is rated according to percent kill in experimental studies: + = 25-50%, ++ = 50-90%, +++ >90%.

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Requests for reprints should be addressed to:
Peyton A. Eggleston, MD
Professor of Pediatrics
CMSC 1102
Johns Hopkins Hospital
600 North Wolfe Street
Baltimore, MD 21287
E-mail: pegglest@jhmi.edu