

## Improving indoor environments: Reducing allergen exposures

Peyton A. Eggleston, MD *Baltimore, Md*

Homes cannot be made allergen free, but exposure to the major indoor allergens can be reduced. All reduction recommendations are based on the principle of reducing or isolating the source, and certain recommendations can be made on the basis of published evidence. House dust mite avoidance measures include fitting allergen-proof mattress and pillow encasings, washing bedding regularly, and reducing humidity. Furred pet avoidance requires removal of the pet from the home, followed by thorough and repeated cleaning; room air cleaners, washing the pet, and isolating the pet from a bedroom are ineffective alternatives. Cockroach allergen avoidance begins with effective pest control, followed by thorough and repeated cleaning; 1 to 2 months are required to eliminate roaches, and an additional 4 to 6 months are required to remove residual allergen. Once allergen levels have been reduced, continued efforts are necessary to maintain the home free of allergen sources. (*J Allergy Clin Immunol* 2005;116:122-6.)

**Key words:** *Environment, aeroallergen, allergen exposure, allergen, dust mites, pets, cockroach*

Although it is impossible to make indoor environments allergen free, we have learned a great deal in the last several decades about effective methods to decrease excessive indoor allergen exposure. We have adapted the principles of exposure assessment and exposure reduction from those developed in occupational settings<sup>1</sup> to home environments. As shown in schematic form in Fig 1, one of these principles is that an exposure dose is dependent both on the concentration inhaled into the respiratory tract and the duration of the exposure. The best estimates of exposure dose have proved to be allergen concentration in bedding, although recent technology<sup>2</sup> might allow us to better estimate the inhaled dose. Another principal is that

### Abbreviation used

HEPA: High-efficiency particulate air

the most effective method of reducing exposure dose is to remove the source of the contaminant. In practice, some sources (house dust mites and cockroaches) have been easier to remove than others (pets). When the source cannot be removed, pollutant removal should start as close to the source as possible.

A number of excellent and complete reviews have summarized the details of allergen reduction<sup>3-5</sup> and their health effects on sensitized individuals, and therefore this review will concentrate on recent advances in reducing exposures, without summarizing the health effects.

### HOUSE DUST MITE

House dust mite allergens are carried on relatively large particles (10-30  $\mu\text{m}$ ) that do not remain airborne for long. The mites infest fabrics (especially bedding), are not particularly mobile, and have fastidious growth requirements, making the source elimination relatively easy. At the top of the list of effective methods to reduce house dust mite is allergen-proof encasings fitted to the mattress and pillow.<sup>3-5</sup> These covers are available by mail or in retail stores and are breathable, comfortable, and nearly 100% exclusive.<sup>6</sup> More than a dozen clinical trials of allergen-proof encasings have been published that were at least 3 months long and reported mite allergen levels in bedding.<sup>7-21</sup> All of these trials report reduced allergen concentrations, but the degree of allergen reduction varied widely, from 39% to 99.9% (median, 89%), as did the final allergen concentrations achieved (range, 0.01-8.50  $\mu\text{g/g}$ ; median, 0.77  $\mu\text{g/g}$ ). It is not clear why such a wide range of effectiveness was seen in these trials, but the variations were not easily explained by the level of mite contamination, and many of the trials included bedding laundry, tannic acid, or acaricides. In addition, bedding allergen levels have been shown to continue to decrease with observations up to a year, suggesting that repopulation of bedding cover fabric is not common.

Other first-line measures include thorough vacuum cleaning and washing all bedding (sheets, blankets, comforters, and bedspreads). Vacuuming reduces the bulk of household dust and reduces the overall exposure burden

From the Department of Pediatrics, Johns Hopkins University.

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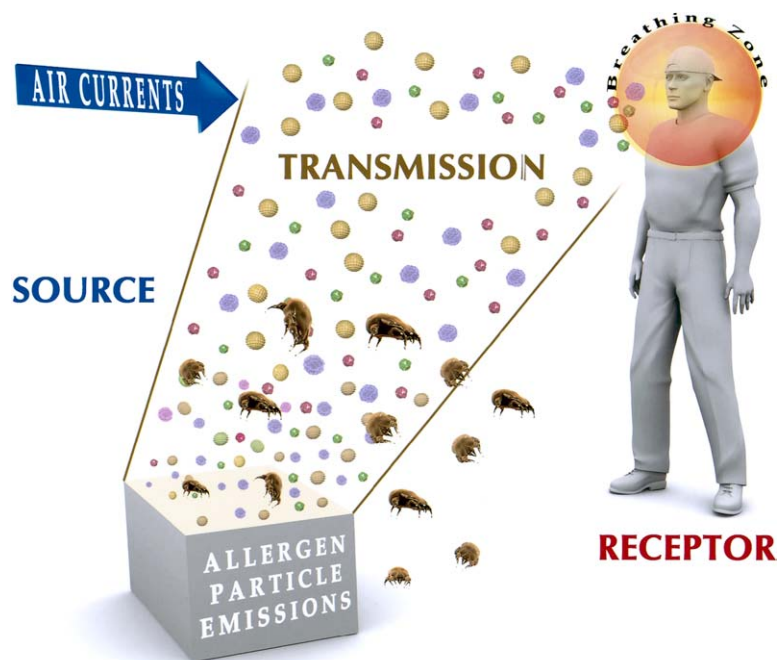
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Reprint requests: Peyton A. Eggleston, MD, Department of Pediatrics, Johns Hopkins Hospital, CMSC 1102, 600 North Wolfe St, Baltimore, MD. E-mail: pegglest@jhmi.edu.

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**FIG 1.** Schematic of allergen emission, transmission, and airway exposure on the basis of the model developed for occupational pollutant exposure. Adapted with permission from Corn.<sup>1</sup>

but does not change the concentration of allergen (ie, micrograms per gram of settled dust).<sup>22</sup> Washing sheets, pillowcases, blankets, and mattress pads at least weekly in warm water with detergent and with 8- to 10-minute cycles removes virtually all mite and animal allergen.<sup>23</sup> Dry cleaning<sup>24</sup> and prolonged tumble drying<sup>25</sup> effectively kill mites but are less effective at removing allergens.

Second-line measures include relocating the bedroom, application of acaricides (eg, benzyl benzoate), dehumidification, and removal of wall-to-wall carpeting. Relocating the patient's bedroom out of the basement has been recommended, but the only reported study of basement carpets found that mite allergen concentrations were almost identical to those of carpets elsewhere in the home.<sup>26</sup> Removing fabrics, such as curtains and furniture, seems logical because they might support mite growth, but this has not been shown to increase the effect of vacuuming and bedding covers alone. Removing wall-to-wall carpeting is difficult but justifiable because house dust mite levels are higher in wall-to-wall carpet compared with those seen in uncarpeted areas, and bedroom floor levels are reduced when carpeting is removed.<sup>18</sup> Acaricides are effective in the laboratory, but field trials have generally found that carpet dust mite allergen is reduced minimally, probably because it is so difficult to get the material into the deepest areas of the carpet.<sup>27</sup> The evidence supporting measures to reduce indoor humidity is inconsistent. Trials in England showed that portable dehumidifiers<sup>28</sup> were not able to reduce median humidity significantly, and mite allergen levels did not change. Central heat exchangers<sup>29</sup> were able to maintain indoor relative humidity at less

than 40% for the 4 months that they were used, but mite allergen levels in carpets and bedding did not decrease. Arlian et al<sup>30</sup> installed large portable dehumidifiers in Midwestern US homes and showed that approximately half of the homes were able to maintain relative humidity at less than 51% throughout a 2-year period. Mite allergen in bedding was not measured, but mites and mite allergen in the carpets from these homes decreased 78%. Surprisingly, air conditioning alone was not able to reduce indoor humidity enough to affect mite growth significantly.

## PET ALLERGEN AVOIDANCE

Animal allergens are carried on small particles that remain airborne and are remarkably adherent to surfaces and clothing.<sup>31</sup> Because the source is so mobile in a home, inclined to heavily contaminate a favorite chair or bed, and because families are reluctant to get rid of the pet, source elimination is almost impossible. An atopic patient who is sensitized to cat or dog allergen should not live with a pet in their home. Air filters should be helpful in reducing exposure to airborne pet allergen particles. Their stickiness leads to widespread distribution, so that animal allergen can be found in public buildings, such as schools,<sup>32,33</sup> and in homes without a pet, although concentrations are 10 to 1000 times higher in homes with a pet.<sup>34</sup>

Once a pet has been removed from the home, allergen levels in settled dust decrease to those seen in homes without cats over 4 to 6 months.<sup>35</sup> Levels decrease much more quickly if extensive environmental control measures

are undertaken, such as removal of carpets, upholstered furniture, and other reservoirs from the home. Cat allergen might persist in mattresses for years after a cat has been removed from a home,<sup>36</sup> and therefore the purchase of new bedding or impermeable encasements should also be recommended.

Because so many patients are unwilling to remove their pet, even if they themselves are sensitized, many compromise measures have been suggested. De Blay et al<sup>37</sup> demonstrated significant reductions in airborne Fel d 1 with a combination of air filtration and washing the cat, but later studies showed that the decrease lasted only a few days.<sup>38</sup> The use of room high-efficiency particulate air (HEPA) filters might reduce airborne levels somewhat. When these units are placed in living rooms, airborne levels of cat and dog allergen have been shown to decrease by almost 90%<sup>39,40</sup> over a period of hours, but similar reductions were seen in control experiments when the units were not running, so that there was no net effect attributable to HEPA air filtration. A later report extended treatment for a year,<sup>41</sup> demonstrating persistent 90% reductions in allergen levels in both the treatment and control groups. Asthma improved to a statistically greater extent in the treatment group. Both groups also used a HEPA-filtered vacuum cleaner, but settled dust animal allergen levels did not decrease. Another report described a safe room from which the cat was excluded, and vigorous environmental control measures, such as vacuuming, mattress and pillow covers, carpet removal, and room air filters, were tested.<sup>42</sup> In this case airborne levels decreased 43% over 3 months, and settled dust allergen levels did not change.

## RODENT ALLERGEN AVOIDANCE

Mouse allergen is carried on particles that are small and remain airborne<sup>43</sup>; like other animal allergens, they are widely distributed and commonly found in homes that are not infested with mice.<sup>44</sup> On the other hand, families are much more willing to help eliminate the source, making exposure control that much easier. Although the pesticides might be applied in almost any form, the method preferred by pest control companies in inhabited buildings is termed *integrated pest management*; this includes targeted application of pesticides, together with plugging access cracks and crevices and protection of food sources to reduce the risk of reinfestation. Like other animal allergens, elimination of the source must be followed by vigorous and sustained cleaning to remove allergen. A controlled clinical trial of this approach was reported that included dusting a tracking powder with inandione, a low-toxicity pesticide, in wall voids and pipe chases, as well as placing snap traps.<sup>45</sup> Access holes were filled with copper mesh and caulk sealant, and the family was educated to vacuum aggressively with HEPA-filtered vacuum cleaners, to clean surfaces carefully with mild detergents, and to continue pest control measures. Mus m 1 concentrations in combined dust samples from the floor

and bed decreased by 42% (from 5.2 to 2.2 ng/g), whereas levels from control homes actually rose.

## COCKROACH ALLERGEN AVOIDANCE

Cockroach allergen particles have properties similar to those of mite allergens; 74% to 80% of aeroallergens are associated with particles larger than 10  $\mu\text{m}$  that are detectable mainly after vigorous activity and settle rapidly.<sup>46</sup> Because the cockroach is highly mobile, allergen is spread widely through a home in bedding, as well as in kitchens; allergen is concentrated in hiding places behind appliances and in cracks and crevices, creating a unique reservoir that is difficult to access.

Cockroach allergen removal begins with insecticide treatment to reduce the allergen source.<sup>47</sup> Pesticides incorporated in gels or baits are placed selectively in areas with high insect concentrations and traffic. In addition, bait traps with pesticides, such as abamectin and hydramethylnon, are available to consumers that are just as effective as the gel baits if used properly. Typically, successful treatments provide significant reduction within 2 weeks, with the maximal effect by about 1 month and sustained reductions for 3 to 6 months or even longer if families change cleaning practices to remove food sources that will attract reinfestation. These practices include cleaning grease and other food debris from the kitchen, storing food in plastic containers or in a refrigerator, and eliminating food debris from the television room or bedroom. Even with household cleaning after extermination, cockroach allergen persists for months after successful pest control.

Field trials of allergen reduction methods have shown that cockroach populations can be reduced by more than 90% in most cases,<sup>47</sup> whereas allergen levels in settled dust and bedding decrease slowly over about 6 months. Although allergen might be completely eliminated from settled dust in less infested homes, in heavily contaminated areas, with Bla g 1 or Bla g 2 concentrations of greater than 100 U/g settled dust, treated rooms still contain allergen at levels that have been associated with disease. The first large field trial that included cockroach allergen control<sup>48</sup> found trivial reductions in cockroach allergen concentrations in treated homes. In a recently reported intervention that included integrated pest management, mattress and pillow encasings, HEPA room air filters, and HEPA-fitted vacuum cleaners in inner-city homes in 7 US cities, cockroach allergen Bla g 1 decreased by 44%, but initial concentrations only averaged 0.2 U/g; similar changes were seen in the control group, and therefore the net change was not significant.<sup>49</sup> Arbes et al<sup>50</sup> combined education, bait trap placement, and hydramethylnon gel bait placement with integrated pest management principles. They reported a 67% reduction of cockroach allergen in bedding and an even larger decrease in bedding; they commented that the careful placement of gel baits guided by inspection was essential to their success.

## SUMMARY

Effective methods of reducing most indoor allergens have been developed and tested. Each allergen source, house dust mites, pets, rodents, and cockroaches, requires a somewhat different approach, but currently recommended methods and readily available materials can reduce home exposures substantially.

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