*Practice parameter*

# Environmental assessment and exposure reduction of cockroaches: A practice parameter

**Jay Portnoy, MD, Ginger L. Chew, ScD, Wanda Phipatanakul, MD, MS, P. Brock Williams, PhD, Carl Grimes, HHS, CIEC, Kevin Kennedy, MPH, Elizabeth C. Matsui, MD, MHS, J. David Miller, PhD, David Bernstein, MD, Joann Blessing-Moore, MD, Linda Cox, MD, David Khan, MD, PhD, David Lang, MD, Richard Nicklas, MD, John Oppenheimer, MD, Christopher Randolph, MD, Diane Schuller, MD, Sheldon Spector, MD, Stephen A. Tilles, MD, Dana Wallace, MD, James Seltzer, MD, and James Sublett, MD**

***Chief Editors*: Jay Portnoy, MD, Ginger L. Chew, ScD, Wanda Phipatanakul, MD, MS, P. Brock Williams, PhD, Carl Grimes, Kevin Kennedy, MPH, and J. David Miller, PhD**

***Members of the Joint Task Force on Practice Parameters*: David Bernstein, MD, Joann Blessing-Moore, MD, Linda Cox, MD, David Khan, MD, David Lang, MD, Richard Nicklas, MD, John Oppenheimer, MD, Jay Portnoy, MD, Christopher Randolph, MD, Diane Schuller, MD, Sheldon Spector, MD, Stephen A. Tilles, MD, and Dana Wallace, MD**

***Practice Parameter Workgoup*: James Sublett, MD, co-chair, Kevin Kennedy, MPH, co-chair, Charles Barnes, PhD, Ginger L. Chew, ScD, Carl Grimes, HHS, CIEC, Elizabeth C. Matsui, MD, MHS, Jeffrey D. Miller, MD, J. David Miller, PhD, Wanda Phipatanakul, MD, MS, James Seltzer, MD, and P. Brock Williams, PhD**

**This parameter was developed by the Joint Task Force on Practice Parameters, representing the American Academy of Allergy, Asthma & Immunology (AAAAI); the American College of Allergy, Asthma & Immunology (ACAAI); and the Joint Council of Allergy, Asthma & Immunology. The AAAAI and the ACAAI have jointly accepted responsibility for establishing "Environmental assessment and remediation: a practice parameter." This is a complete and comprehensive document at the current time. The medical environment is a changing environment, and not all recommendations will be**

Disclosure of potential conflict of interest: J. Portnoy is a speaker for Thermo Fisher and Mylan and has consultant arrangements with Thermo Fisher and Sanofi. W. Phipatanakul has received research support from the National Institutes of Health (NIH). C. Grimes is employed by Health Habitats LLC. K. Kennedy has received research support from Public Health Service and is an instructor for Healthy Housing Solutions and the Indoor Air Quality Training Institute. E. C. Matsui has received payment for lectures from Indoor Biotechnologies and has received the Phadia Research Foundation Award. D. Bernstein has received research support from TEVA, Genentech, Pfizer, Merck, Meda, GlaxoSmithKline, Array, Cephalon, and MedImmune and has provided legal consultation or expert witness testimony in cases related to anaphylaxis, contact dermatitis, and occupational asthma. J. Blessing-Moore has received research support and is a speaker for Meda; is a speaker for Alcon, Teva, Sunovion, Genentech/Novartis, Merck, and AstraZeneca; is a committee member of the American College of Chest Physicians, the American College of Allergy, Asthma & Immunology (ACAAI), the American Academy of Allergy, Asthma & Immunology (AAAAI), and the American Thoracic Society. L. Cox has received consulting fees from Stallergenes, has received travel support from the AAAAI, has received fees for participation in review activities from Circassia and Novartis, has received payment for writing or reviewing the manuscript from the Blue Cross Blue Shield Technology Evaluation Center, is a board member for the American Board of Allergy and Immunology, has consultant arrangements with the Food and Drug Administration Allergenic Products Advisory Committee, has provided expert testimony in cases related to chronic cinguteria, and has received payment for lectures from the Southeastern Allergy Asthma Immunology Association and Virginia AAIS. D. Khan is a speaker for Genentech, Merck, Baxter, and Viropharma; has received research support from the Vanberg Family Foundation and the NIH/National Institute of Mental Health; is the Allied Health Chair for the ACAAI; and is a member of the Joint Task Force on Practice Parameters for the Joint Council of Allergy, Asthma & Immunology. D. Lang is a speaker for Genentech/Novartis, GlaxoSmithKline, and Merck; has consultant arrangements with GlaxoSmithKline, Merck, and Aerocrine; and has received research support from Genentech/Novartis and Merck. R. Nicklas is a committee chair, volunteer, and fellow of the ACAAI. J. Oppenheimer has consultant arrangements with GlaxoSmithKline, AstraZeneca, and Mylan; has received research support from AstraZeneca, GlaxoSmithKline, Novartis, Boehringer Ingelheim, and MedImmune; has provided legal consultation/expert witness testimony for a malpractice defense; and is a member of the American Board of Allergy and Immunology. C. Randolph is a speaker for GlaxoSmithKline, TEVA, Viropharma, Merck, and Dey; has received research support from GlaxoSmithKline, Merck, Amgen, and Genentech/Novartis; and is a consultant for AstraZeneca and Meda. S. Spector is employed by the California Allergy & Asthma Medical Group, has consultant arrangements with ISTA Pharmaceutical, is a speaker for Novartis and Merck, and has received research support from AstraZeneca, GlaxoSmithKline, Cephalon, Amgen, Sanofi, and Targacept. S. A. Tilles has consultant arrangements with SRXA, Sunovion, and Hyrox; has received research support from Astellas, Amphastar, MedImmune, Cephalon, Genentech, Merck, TEVA, Sunovion, Boehringer Ingelheim, Nutricia, Array, Rigel, and AstraZeneca; is Associate Editor of *AllergyWatch* and the *Annals of Allergy*; is Assistant Editor of the Joint Task Force on Practice Parameters; and is on the Executive Committee for the Seattle Food Allergy Consortium. D. Wallace has received honoraria for talks from the ACAAI; is a speaker for TEVA and Myland Labs; is an advisor for Sanofi and Sunovion; is on the Executive Committee of the ACAAI; and is on the Board of Directors for the World Allergy Organization. J. Seltzer is on the speaker's bureau and has consultant arrangements with GlaxoSmithKline, is owner of Indoor Hygienic Technologies Corporation, has provided expert witness testimony/legal consultation in cases related to indoor environmental illness, and is on the speaker's bureau for TEVA Pharmaceuticals. J. Sublett has received payment for lectures from GlaxoSmithKline, Merck, Sunovion, and Teva and has stock/stock options with AllergyZone LLC. The rest of the authors declare that they have no relevant conflicts of interest.

Reprint requests: Joint Council of Allergy, Asthma & Immunology, 50 N Brockway St, #3-3, Palatine, IL 60067. E-mail: grupes@jcaai.org.

Received for publication January 3, 2013; revised March 27, 2013; accepted for publication April 22, 2013.

0091-6749

http://dx.doi.org/10.1016/j.jaci.2013.04.061

**appropriate for all patients. Because this document incorporated the efforts of many participants, no single person, including those who served on the Joint Task Force, is authorized to provide an official AAAAI or ACAAI interpretation of these practice parameters. Any request for information about or an interpretation of these practice parameters by the AAAAI or ACAAI should be directed to the Executive Offices of the AAAAI, the ACAAI, and the Joint Council of Allergy, Asthma & Immunology. These parameters are not designed for use by pharmaceutical companies in drug promotion. The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention (CDC). (J Allergy Clin Immunol 2013;■■■:■■■-■■■.)**

***Key words:*** *Allergy, cockroach, sensitization, disease, morbidity*

*To read the Practice Parameter in its entirety, please download the online version of this article from www.jacionline.org. Please note that all references cited in this print version can be found in the full online document.*

## CONTRIBUTORS

The Joint Task Force has made a concerted effort to acknowledge all contributors to this parameter. If any contributors have been excluded inadvertently, the Task Force will ensure that appropriate recognition of such contributions is made subsequently.

## WORKGROUP CO-CHAIRS

**James Sublett, MD**
Family Allergy and Asthma
Louisville, Kentucky

**Kevin Kennedy, MPH**
Environmental Health Program
Children's Mercy Hospital
Kansas City, Missouri

## JOINT TASK FORCE LIAISON

**Jay M. Portnoy, MD**
Section of Allergy, Asthma & Immunology
Children's Mercy Hospital
Professor of Pediatrics
University of Missouri–Kansas City School of Medicine
Kansas City, Missouri

## JOINT TASK FORCE MEMBERS

**David I. Bernstein, MD**
Department of Clinical Medicine and Environmental Health
Division of Allergy/Immunology
University of Cincinnati College of Medicine
Cincinnati, Ohio

**Joann Blessing-Moore, MD**
Department of Medicine and Pediatrics
Stanford University Medical Center
Department of Immunology
Palo Alto, California

**David A. Khan, MD**
Department of Internal Medicine
University of Texas Southwestern Medical Center
Dallas, Texas

**David M. Lang, MD**
Allergy/Immunology Section
Division of Medicine
Allergy and Immunology Fellowship Training Program
Cleveland Clinic Foundation
Cleveland, Ohio

**Richard A. Nicklas, MD**
Department of Medicine
George Washington Medical Center
Washington, DC

**John Oppenheimer, MD**
Department of Internal Medicine
New Jersey Medical School
Pulmonary and Allergy Associates
Morristown, New Jersey

**Jay M. Portnoy, MD**
Section of Allergy, Asthma & Immunology
Children's Mercy Hospital
Department of Pediatrics
University of Missouri–Kansas City School of Medicine
Kansas City, Missouri

**Christopher C. Randolph, MD**
Department of Pediatrics
Yale Affiliated Hospitals
Center for Allergy, Asthma, & Immunology
Waterbury, Connecticut

**Diane E. Schuller, MD**
Department of Pediatrics
Pennsylvania State University Milton S. Hershey Medical College
Hershey, Pennsylvania

**Sheldon L. Spector, MD**
Department of Medicine
UCLA School of Medicine
Los Angeles, California

**Stephen A. Tilles, MD**
Department of Medicine
University of Washington School of Medicine
Redmond, Washington

**Dana Wallace, MD**
Department of Medicine
Nova Southeastern University College of Osteopathic Medicine
Davie, Florida

## PARAMETER WORKGROUP MEMBERS

**Charles Barnes, PhD**
Allergy Research
Children's Mercy Hospitals & Clinics
Kansas City, Missouri

**Ginger L. Chew, ScD**
Centers for Disease Control and Prevention (CDC)
National Center for Environmental Health
Healthy Homes and Lead Poisoning Prevention Branch
Atlanta, Georgia

**Carl Grimes, HHS, CIEC**
Indoor Air Quality Association
Healthy Habitats LLC
Denver, Colorado

**Elizabeth C. Matsui, MD, MHS**
Department of Pediatrics
Johns Hopkins School of Medicine
Baltimore, Maryland

**Jeffrey D. Miller, MD**
Department of Pediatrics
New York Medical College
Valhalla, New York

**J. David Miller, PhD**
Department of Biochemistry
NSERC Industrial Research Chair
Carlton, University
Ottawa, Ontario, Canada

**Wanda Phipatanakul, MD, MS**
Department of Pediatrics
Harvard Medical School
Children's Hospital, Boston
Division of Allergy and Immunology
Boston, Massachusetts

**James M. Seltzer, MD**
Reliance Medical Group
Department of Allergy/Immunology
Worcester, Massachusetts

**P. Brock Williams, PhD**
Allergy/Immunology Faculty
University of Missouri–Kansas City School of Medicine and Children's Mercy Hospitals & Clinics
Kansas City, Missouri

## INVITED REVIEWERS

**William Busse, MD**
Madison, Wisconsin

**Peyton Eggleston, MD**
Islesford, Maine

**Janna Tuck, MD**
Cape Girardeau, Missouri

## CLASSIFICATION OF RECOMMENDATIONS AND EVIDENCE

### Recommendation rating scale

| Statement | Definition | Implication |
|---|---|---|
| Strong recommendation (StrRec) | A strong recommendation means the benefits of the recommended approach clearly exceed the harms (or that the harms clearly exceed the benefits in the case of a strong negative recommendation) and that the quality of the supporting evidence is excellent (grade A or B).* In some clearly identified circumstances, strong recommendations might be made based on lesser evidence when high-quality evidence is impossible to obtain and the anticipated benefits strongly outweigh the harms. | Clinicians should follow a strong recommendation unless a clear and compelling rationale for an alternative approach is present. |
| Recommendation (Rec) | A recommendation means the benefits exceed the harms (or that the harms clearly exceed the benefits in the case of a negative recommendation) but the quality of evidence is not as strong (grade B or C).* In some clearly identified circumstances, recommendations might be made based on lesser evidence when high-quality evidence is impossible to obtain and the anticipated benefits outweigh the harms. | Clinicians should also generally follow a recommendation but should remain alert to new information and be sensitive to patient preferences. |
| Option (Opt) | An option means that either the quality of evidence that exists is suspect (grade D)* or that well-done studies (grade A, B, or C)* show little clear advantage to one approach versus another. | Clinicians should be flexible in their decision-making regarding appropriate practice, although they might set bounds on alternatives; patient preference should have a substantial influencing role. |
| No recommendation (NoRec) | No recommendation means there is both a lack of pertinent evidence (grade D)* and an unclear balance between benefits and harms. | Clinicians should feel little constraint in their decision-making and be alert to new published evidence that clarifies the balance of benefit versus harm; patient preference should have a substantial influencing role. |

### Category of evidence

- Ia Evidence from meta-analysis of randomized controlled trials
- Ib Evidence from at least 1 randomized controlled trial
- IIa Evidence from at least 1 controlled study without randomization
- IIb Evidence from at least 1 other type of quasi-experimental study
- III Evidence from nonexperimental descriptive studies, such as comparative studies
- IV Evidence from expert committee reports, opinions or clinical experience of respected authorities, or both

### Strength of recommendation*

- A Directly based on category I evidence
- B Directly based on category II evidence or extrapolated recommendation from category I evidence
- C Directly based on category III evidence or extrapolated recommendation from category I or II evidence
- D Directly based on category IV evidence or extrapolated recommendation from category I, II, or III evidence
- LB Laboratory based
- NR Not rated

## RESOLUTION OF POTENTIAL CONFLICTS OF INTEREST

The Joint Task Force recognizes that experts in a field are likely to have interests that could come into conflict with developing a completely unbiased and objective practice parameter. A process has been developed to prevent potential conflicts from influencing the final document to take advantage of that expertise.

At the workgroup level, members who have a potential conflict of interest either do not participate in discussions concerning topics related to the potential conflict, or if they do write a section on that topic, the workgroup completely rewrites it without their involvement to remove potential bias. In addition, the entire document is reviewed by the Joint Task Force, and any apparent bias is removed at that level. Finally, the practice parameter is sent for review both by invited reviewers and by anyone with an interest in the topic by posting the document on the Web sites of the ACAAI and the AAAAI.

## HOW THIS PRACTICE PARAMETER WAS DEVELOPED

### The Joint Task Force on Practice Parameters

The Joint Task Force on Practice Parameters (JTF) is a 13-member task force consisting of 6 representatives assigned by the AAAAI, 6 by the ACAAI, and 1 by the Joint Council of Allergy and Immunology. This task force oversees the development of practice parameters; selects the workgroup chair or chairs, and reviews drafts of the parameters for accuracy, practicality, clarity, and broad utility of the recommendations for clinical practice.

### The Environment Practice Parameter Workgroup

The Environment Practice Parameter workgroup was commissioned by the JTF to develop practice parameters that address environmental assessment and remediation. The co-chairs (James Sublett, MD, and Kevin Kennedy, MPH) invited workgroup members who are considered experts in the field of environmental assessment and contaminant reduction to participate in the parameter development. Workgroup members have been vetted for financial conflicts of interest by the JTF, and their conflicts of interest have been listed in this document and are posted on the JTF Web site at http://www.allergyparameters.org. Where a potential conflict of interest is present, the potentially conflicted workgroup member was excluded from discussing relevant issues.

The charge to the workgroup was to use a systematic literature review in conjunction with consensus expert opinion and workgroup-identified supplementary documents to develop practice parameters that provide a comprehensive approach for identifying and managing environmental exposures and their health effects based on the current state of the science.

### Protocol for finding evidence

A search of the medical literature was performed by searching PubMed between 1960 and September 2012 for the term cockroach, resulting in 5743 references. These were further restricted to citations, with the terms *cockroach* and *allergy* resulting in 983 total references. The number of citations with the terms *cockroach* and *allergy* increased starting in 1994 and since 2000 have averaged 50 per year. All reference types were included in the results. References identified as being relevant were searched for additional references, and these also were searched for citable references. In addition, members of the workgroup were asked for references that were missed by this initial search. Although the ideal type of reference would consist of a randomized, double-blind, placebo-controlled study, the topic of this practice parameter is represented by very few such studies. Consequently, it was necessary to use observational studies, basic laboratory reports, and regulatory requirements to develop a document that addresses most of the issues included in this practice parameter.

## GLOSSARY

### Terms related to exposure

*Contaminant:* Any substance that has the potential to cause harm to a building's occupants. Cockroach contaminants include allergens, chitin, endotoxin, and other substances released from cockroaches during their lifetime.

*Facilitating factors:* Conditions that facilitate production of contaminants by a source. Examples for cockroaches include moisture, food, warmth, and shelter.

*Reservoirs:* These are contained spaces or microenvironments in which contaminants can accumulate for subsequent release into the environment. Cockroach reservoirs include mattresses, carpeting, bedding, and contaminated building materials.

### Terms related to interventions

*Abatement:* Defined as a diminution in amount, degree, or intensity. Abatement includes removing, treating, or isolating reservoirs of contaminants and could include the use of air filtration, vacuuming or removal of carpeting, use of denaturing chemicals, and removal of contaminated building materials.

*Integrated pest management:* A strategy to reduce cockroach contaminant exposure by using a combination of abatement,

source reduction, and mitigation with the goal of reducing the ability of the environment to support a population of cockroaches.

*Mitigation:* The process of removing facilitating factors, either completely or partially, so that production of contaminants will no longer be facilitated. Mitigation often is the immediate first step toward exposure reduction so that production of cockroach contamination does not continue. Once mitigation is done, restoration and remediation can commence.

*Source control:* The process of reducing or eliminating cockroaches. Once cockroaches are removed, the exposure will decrease over time as the previously released contaminants are removed from the environment.

## PREFACE

"Environmental assessment and exposure control of cockroaches: a practice parameter" is the next installment in a series of practice parameters that deal with important exposures that contribute to health problems. Future practice parameters on specific exposures are planned for fungi, dust mites, and irritants.

The health effects of cockroach exposure, as with furry animals and rodents, progresses through 3 stages: development of specific IgE (sensitization), development of clinical disease (sensitivity), and increased morbidity with ongoing exposure. These health outcomes can be measured by using 2 different types of clinical investigation. The most direct way to demonstrate a causal relationship between exposure to cockroach allergens and health outcomes is to randomly expose persons to different amounts of cockroach allergen over time in their homes and determine the likelihood of having specific IgE, disease, or worsening disease with continued cockroach exposure. Obviously, it is neither feasible nor ethical to perform this type of ideal study.

To be practical, the approach generally used in studies of cockroach-related health effects is to observe persons with different amounts of exposure to cockroach either prospectively as a cohort or as a cross-section. The prevalence of the target outcome (sensitization, disease, and morbidity) is used to determine the relationship between exposure and development of health effects. Although this does not prove causality, it does provide an estimate of the association between exposure to cockroach allergen and health as long as all other exposures are adjusted for in the statistical analysis.

Another approach to proving causality between exposure and health is to study persons who have already experienced or are at risk of experiencing health effects presumably caused by cockroach exposure in that they are sensitized, have a disease, or are experiencing morbidity because of exposure. Interventions designed to reduce cockroach allergen exposure are implemented, and measurements confirm that exposure is indeed reduced significantly. The effect of this reduced cockroach exposure on the target health outcomes can then be observed to estimate an association between the exposure and health. The advantage of this approach is that if environments are randomly assigned to receive reduced exposure, a causal relationship can be inferred regarding the health effects on occupants of those environments. The benefit of this approach is that it provides evidence for the effectiveness of the intervention and evidence that the intervention is clinically beneficial and that cockroach exposure was the likely cause of the health problem.

The evidence for causality provided by these 2 approaches (exposure being associated with disease vs reduction of exposure being associated with improvement in disease) is not the same. An environment that has low cockroach exposure might differ from an environment that had high exposure that was reduced with an intervention. The intervention might reduce other exposures, or the high-exposure environment might have other health-affecting exposures that are not removed by the intervention. For that reason, health benefits associated with an environment with intrinsically low cockroach exposure are considered separately from those that are due to a cockroach reduction intervention environment in this practice parameter.

The first type of evidence, which is mainly observational, is discussed in the health effects section of this practice parameter. Recommendations are made to keep exposure as low as possible to prevent sensitization, prevent development of disease, and reduce ongoing morbidity in sensitized persons. What we do not know is whether interventions that keep exposure low are as effective at improving health as simply living in an environment with naturally low exposure from the beginning. The recommendation could be modified to state that one should move to a low-cockroach environment rather than trying to reduce exposure in the environment in which one lives; however, that would not be practical.

On the other hand, the beneficial effect of cockroach allergen exposure reduction is discussed in the section on interventions because evidence that certain interventions are effective is integrally linked to the evidence that this improves health. Although the summary statements in this section might appear to mirror those in the health effects section, they really are distinct. These statements primarily involve reducing exposure to improve health as opposed to health effects from living in environments that have low exposure, either naturally or after an intervention, to prevent morbidity.

There are cut point values that have been proposed from numerous studies on allergens in dust. These cut points are levels above which there is an increased risk of allergy sensitization or reactions in sensitized subjects. For cockroach, indoor levels of less than 2 U/g Bla g 1 or 2 U/g Bla g 2 (which is equivalent to 0.08 μg/g Bla g 2) are associated with a lower risk of sensitization and symptoms on exposure. Although cut points are mentioned throughout this practice parameter, it should be kept in mind that these generally represent median values observed, usually in a single study. A dose-response curve for Bla g 1 exposure and sensitization did not support the use of a single value above which sensitization is inevitable but rather indicated increasing sensitization rates as exposure increased.[1]

## SUMMARY STATEMENTS

1. Exposure to cockroach allergen in homes should be minimized to reduce the risk of cockroach sensitization (StrRec, B Evidence)
2. Exposure to cockroach allergens should be minimized to reduce the risk that sensitized children will develop allergic disease. (Rec, C Evidence)
3. Cockroach allergen exposure should be minimized to reduce the risk of asthma morbidity in already sensitized subjects. (Rec, B Evidence)
4. Patients with possible cockroach allergy should be asked whether they have seen cockroaches in their homes. (Rec, C Evidence)
5. Patients with suspected atopy and likely cockroach exposure should be evaluated for sensitization to cockroach

allergens by skin prick testing or measurement of specific IgE directed toward cockroach-derived allergens. (StrRec, D Evidence)
6. Factors that facilitate the growth and persistence of cockroach populations, such as food and water, paths of ingress, and microenvironments that can provide shelter, should be mitigated to reduce the cockroach carrying capacity of the environment. (StrRec, D Evidence)
7. The extent and duration of a cockroach infestation should be monitored by using strategically placed sticky traps. (StrRec, D Evidence)
8. Pesticides should be used judiciously and ideally should be applied by a professional exterminator as part of an integrated pest management program. (Rec, C Evidence)
9. Boric acid is an effective pesticide; however, surviving cockroaches can produce more allergen after exposure. (Rec, C Evidence)
10. Measurement of cockroach allergen in dust can be considered for building occupants at increased risk of cockroach sensitization or sensitivity though routine clinical use of this information has not been sufficiently studied. (Opt, D Evidence)
11. Reservoirs of cockroach contaminants should be cleaned or removed to prevent additional exposure to occupants. (StrRec, A Evidence)
12. Integrated pest management with a combination of interventions appears to be the most effective method for preventing and eliminating cockroach infestations. (StrRec, B Evidence)
13. Integrated pest management should be used to decrease cockroach exposure to reduce asthma morbidity. (StrRec, A Evidence)
14. Immunotherapy with cockroach extracts can be considered; however, it has only been evaluated in a limited number of studies, an effective dose is not known, and it is not clear how effective the treatment is for asthma or rhinitis. (Opt, C Evidence)

## EXECUTIVE SUMMARY

Of the 4500 species of cockroach, approximately 30 are associated with human habitation, and 4 are known to be pests, including the oriental cockroach *(Blatta orientalis)*, German cockroach *(Blattella germanica)*, American cockroach *(Periplaneta americana)*, and brown-banded cockroach *(Supella longipalpa)*. Cockroaches can be found in any building that has a means of ingress, a source of water, food, adequate temperature, and shelter for their survival. Because cockroaches prefer small tight environments, they can be present without the occupant's awareness until the infestation becomes extensive. While most of the studies of cockroaches and asthma have focused on inner-city environments, it is clear that cockroaches (aka, Palmetto bugs, water bugs) can also be found in homes, schools, and other buildings that are located in suburban and rural environments regardless of the socioeconomic status of occupants.

At least 10 allergens have been isolated from the German cockroach *B germanica*, many of which exhibit extensive cross-reactivity with other cockroach genera, such as *Periplaneta*, *Blatta*, and *Supella* species. A major allergen, Bla g 1, exhibits cross-reactivity with allergens from other insects, including fruit flies and mosquitoes. Produced in the midgut, Bla g 1 is found in cockroach frass (fecal material) and has allergenic activities, as well as the ability to upregulate expression of protease-activated receptors and enhance $T_H2$ cytokine production. Because the molecule is a polymer with various numbers of repetitions, its molecular weight is highly variable, and hence concentrations of Bla g 1 are expressed as units per gram of dust rather than micrograms per gram of dust. Another important allergen, Bla g 2, also cross-reacts with mosquito and fungal allergens. With a molecular weight of 36 kDa, Bla g 2 levels in environmental samples can be expressed in micrograms per gram of dust. The other cockroach allergens also have important properties that are described in this practice parameter. Bla g 7 (and Per a 7), which is tropomyosin, is considered to be a panallergen because it cross-reacts with numerous inhalant allergens from arthropods, such as dust mites, and foods, such as crustaceans and mollusks. In addition to allergens, cockroaches also are a source of chitin, which has proinflammatory activities and can induce cells to produce $T_H2$ cytokines.

The health effects of cockroach allergen exposure include sensitization (production of specific IgE), sensitivity (symptoms when sensitized people are exposed), and morbidity in that respiratory diseases get worse with ongoing exposure. Prevention of these health effects requires that exposure be reduced to the lowest levels achievable. A cutoff of 0.04 μg/g dust for Bla g 2 has been proposed as a threshold below which sensitization is prevented, although levels greater than 0.08 μg/g are associated with development of disease and symptoms; however, the evidence for this is based on observational studies of patients exposed to levels greater than and less than these cutoffs. The problem with these types of studies is that the length of exposure causing an increase in risk is unknown, and they do not demonstrate that reduction of cockroach exposure reduces that risk. In addition, use of a specific cutoff does not provide the shape of the dose-response curve.

Patients should be asked whether they have seen cockroaches in their homes. Because it is possible for cockroaches and their allergens to be present without the occupant's awareness, it also might help to ask patients at increased risk of cockroach exposure to place sticky traps to monitor for occult infestations and to measure Bla g 1 or Bla g 2 levels in a sample of dust obtained by patients from their vacuum cleaners. Levels of greater than 0.04 μg/g Bla g 2 indicate that cockroaches are present or at least that they have been present in the recent past. Such a finding should be used to trigger additional investigation into the cockroach status of the patient's home.

In addition, those with atopy and likely exposure should be evaluated for possible sensitization by using either percutaneous allergy tests or measurement of cockroach-specific IgE antibodies. It is not known whether use of intracutaneous tests improves the diagnostic performance of skin tests for cockroach sensitization. However, if cockroaches are present, evidence suggests that abatement measures should be undertaken regardless of whether a subject is sensitized.

Exposure assessment and reduction involve identification and removal of facilitative factors, such as means of ingress, food, water, and shelter, as well as extermination of the cockroaches themselves. Cockroach numbers can be monitored by using strategically placed sticky traps. This provides information about the number of cockroaches present, as well as the duration of the infestation, which can be determined by the number of different stages of development found in the captured cockroaches. Pesticides should be used judiciously and ideally should be

applied by a professional exterminator. The effectiveness of the extermination can be monitored with sticky traps.

Once the cockroaches and facilitative factors are removed, it is necessary to remove reservoirs of cockroach allergen, or exposure of occupants will continue. Reservoir concentrations of cockroach allergen can be measured by using dust samples collected both before and after the intervention. Bla g 1 levels ideally should be reduced to less than 2 U/g and Bla g 2 levels to less than 0.08 μg/g dust to reduce the risk of occupants for symptoms and morbidity from exposure.

Abatement, or reduction of exposure that comes from reservoirs, includes several steps. These include cleaning of carpets with a high-efficiency particulate air vacuum cleaner or complete removal of carpets if contamination cannot be removed by vacuuming, use of mattress covers, or ideally removal of cockroach-infested mattresses and ongoing monitoring for a recurrence of the cockroach infestation.

Integrated pest management is the combination of each of these interventions into a comprehensive program. Integrated pest management has been shown to significantly reduce cockroach exposure and to improve health in occupants for at least 1 year after the interventions had ceased, provided that ongoing monitoring is used to detect a recurrence. Integrated pest management has been used in schools in which cockroach exposure was significantly reduced as well.

There have been a few studies of cockroach immunotherapy; however, their design was not adequate to determine whether it is clinically effective and, even if it were, what the optimal dose would be. For that reason, cockroach immunotherapy is optional.

# Environmental assessment and exposure reduction of cockroaches: A practice parameter

**Jay Portnoy, MD, Ginger L. Chew, ScD, Wanda Phipatanakul, MD, MS, P. Brock Williams, PhD, Carl Grimes, HHS, CIEC, Kevin Kennedy, MPH, Elizabeth C. Matsui, MD, MHS, J. David Miller, PhD, David Bernstein, MD, Joann Blessing-Moore, MD, Linda Cox, MD, David Khan, MD, PhD, David Lang, MD, Richard Nicklas, MD, John Oppenheimer, MD, Christopher Randolph, MD, Diane Schuller, MD, Sheldon Spector, MD, Stephen A. Tilles, MD, Dana Wallace, MD, James Seltzer, MD, and James Sublett, MD**

***Chief Editors*: Jay Portnoy, MD, Ginger L. Chew, ScD, Wanda Phipatanakul, MD, MS, P. Brock Williams, PhD, Carl Grimes, Kevin Kennedy, MPH, and J. David Miller, PhD**

***Members of the Joint Task Force on Practice Parameters*: David Bernstein, MD, Joann Blessing-Moore, MD, Linda Cox, MD, David Khan, MD, David Lang, MD, Richard Nicklas, MD, John Oppenheimer, MD, Jay Portnoy, MD, Christopher Randolph, MD, Diane Schuller, MD, Sheldon Spector, MD, Stephen A. Tilles, MD, and Dana Wallace, MD**

***Practice Parameter Workgroup*: James Sublett, MD, co-chair, Kevin Kennedy MPH, co-chair, Charles Barnes, PhD, Ginger L. Chew, ScD, Carl Grimes, HHS, CIEC, Elizabeth C. Matsui, MD, MHS, Jeffrey D. Miller, MD, J. David Miller, PhD, Wanda Phipatanakul, MD, MS, James Seltzer, MD, and P. Brock Williams, PhD**

**This parameter was developed by the Joint Task Force on Practice Parameters, representing the American Academy of Allergy, Asthma & Immunology (AAAAI); the American College of Allergy, Asthma & Immunology (ACAAI); and the Joint Council of Allergy, Asthma & Immunology. The AAAAI and the ACAAI have jointly accepted responsibility for establishing "Environmental assessment and remediation: a practice parameter." This is a complete and comprehensive document at the current time. The medical environment is a changing environment, and not all recommendations will be appropriate for all patients. Because this document incorporated the efforts of many participants, no single person, including those who served on the Joint Task Force, is authorized to provide an official AAAAI or ACAAI interpretation of these practice parameters.**

Disclosure of potential conflict of interest: J. Portnoy is a speaker for Thermo Fisher and Mylan and has consultant arrangements with Thermo Fisher and Sanofi. W. Phipatanakul has received research support from the National Institutes of Health (NIH). C. Grimes is employed by Health Habitats LLC. K. Kennedy has received research support from Public Health Service and is an instructor for Healthy Housing Solutions and the Indoor Air Quality Training Institute. E. C. Matsui has received payment for lectures from Indoor Biotechnologies and has received the Phadia Research Foundation Award. D. Bernstein has received research support from TEVA, Genentech, Pfizer, Merck, Meda, GlaxoSmithKline, Array, Cephalon, and MedImmune and has provided legal consultation or expert witness testimony in cases related to anaphylaxis, contact dermatitis, and occupational asthma. J. Blessing-Moore has received research support and is a speaker for Meda; is a speaker for Alcon, Teva, Sunovion, Genentech/Novartis, Merck, and AstraZeneca; is a committee member of the American College of Chest Physicians, the American College of Allergy, Asthma & Immunology (ACAAI), the American Academy of Allergy, Asthma & Immunology (AAAAI), and the American Thoracic Society. L. Cox has received consulting fees from Stallergenes, has received travel support from the AAAAI, has received fees for participation in review activities from Circassia and Novartis, has received payment for writing or reviewing the manuscript from the Blue Cross Blue Shield Technology Evaluation Center, is a board member for the American Board of Allergy and Immunology, has consultant arrangements with the Food and Drug Administration Allergenic Products Advisory Committee, has provided expert testimony in cases related to chronic cinguteria, and has received payment for lectures from the Southeastern Allergy Asthma Immunology Association and Virginia AAIS. D. Khan is a speaker for Genentech, Merck, Baxter, and Viropharma; has received research support from the Vanberg Family Foundation and the NIH/National Institute of Mental Health; is the Allied Health Chair for the ACAAI; and is a member of the Joint Task Force on Practice Parameters for the Joint Council of Allergy, Asthma & Immunology. D. Lang is a speaker for Genentech/Novartis, GlaxoSmithKline, and Merck; has consultant arrangements with GlaxoSmithKline, Merck, and Aerocrine; and has received research support from Genentech/Novartis and Merck. R. Nicklas is a committee chair, volunteer, and fellow of the ACAAI. J. Oppenheimer has consultant arrangements with GlaxoSmithKline, AstraZeneca, and Mylan; has received research support from AstraZeneca, GlaxoSmithKline, Novartis, Boehringer Ingelheim, and MedImmune; has provided legal consultation/expert witness testimony for a malpractice defense; and is a member of the American Board of Allergy and Immunology. C. Randolph is a speaker for GlaxoSmithKline, TEVA, Viropharma, Merck, and Dey; has received research support from GlaxoSmithKline, Merck, Amgen, and Genentech/Novartis; and is a consultant for AstraZeneca and Meda. S. Spector is employed by the California Allergy & Asthma Medical Group, has consultant arrangements with ISTA Pharmaceutical, is a speaker for Novartis and Merck, and has received research support from AstraZeneca, GlaxoSmithKline, Cephalon, Amgen, Sanofi, and Targacept. S. A. Tilles has consultant arrangements with SRXA, Sunovion, and Hyrox; has received research support from Astellas, Amphastar, MedImmune, Cephalon, Genentech, Merck, TEVA, Sunovion, Boehringer Ingelheim, Nutricia, Array, Rigel, and AstraZeneca; is Associate Editor of *AllergyWatch* and the *Annals of Allergy*; is Assistant Editor of the Joint Task Force on Practice Parameters; and is on the Executive Committee for the Seattle Food Allergy Consortium. D. Wallace has received honoraria for talks from the ACAAI; is a speaker for TEVA and Myland Labs; is an advisor for Sanofi and Sunovion; is on the Executive Committee of the ACAAI; and is on the Board of Directors for the World Allergy Organization. J. Seltzer is on the speaker's bureau and has consultant arrangements with GlaxoSmithKline, is owner of Indoor Hygienic Technologies Corporation, has provided expert witness testimony/legal consultation in cases related to indoor environmental illness, and is on the speaker's bureau for TEVA Pharmaceuticals. J. Sublett has received payment for lectures from GlaxoSmithKline, Merck, Sunovion, and Teva and has stock/stock options with AllergyZone LLC. The rest of the authors declare that they have no relevant conflicts of interest.

Reprint requests: Joint Council of Allergy, Asthma & Immunology, 50 N Brockway St, #3-3, Palatine, IL 60067. E-mail: grupes@jcaai.org.

Received for publication January 3, 2013; revised March 27, 2013; accepted for publication April 22, 2013.
0091-6749
http://dx.doi.org/10.1016/j.jaci.2013.04.061

**Any request for information about or an interpretation of these practice parameters by the AAAAI or ACAAI should be directed to the Executive Offices of the AAAAI, the ACAAI, and the Joint Council of Allergy, Asthma & Immunology. These parameters are not designed for use by pharmaceutical companies in drug promotion. The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention (CDC).**

***Key words:*** *Allergy, cockroach, sensitization, disease, morbidity*

## CONTRIBUTORS

The Joint Task Force has made a concerted effort to acknowledge all contributors to this parameter. If any contributors have been excluded inadvertently, the Task Force will ensure that appropriate recognition of such contributions is made subsequently.

## WORKGROUP CO-CHAIRS

**James Sublett, MD**
Family Allergy and Asthma
Louisville, Kentucky

**Kevin Kennedy, MPH**
Environmental Health Program
Children's Mercy Hospital
Kansas City, Missouri

## JOINT TASK FORCE LIAISON

**Jay M. Portnoy, MD**
Section of Allergy, Asthma & Immunology
Children's Mercy Hospital
Professor of Pediatrics
University of Missouri–Kansas City School of Medicine
Kansas City, Missouri

## JOINT TASK FORCE MEMBERS

**David I. Bernstein, MD**
Department of Clinical Medicine and Environmental Health
Division of Allergy/Immunology
University of Cincinnati College of Medicine
Cincinnati, Ohio

**Joann Blessing-Moore, MD**
Department of Medicine and Pediatrics
Stanford University Medical Center
Department of Immunology
Palo Alto, California

**David A. Khan, MD**
Department of Internal Medicine
University of Texas Southwestern Medical Center
Dallas, Texas

**David M. Lang, MD**
Allergy/Immunology Section
Division of Medicine
Allergy and Immunology Fellowship Training Program
Cleveland Clinic Foundation
Cleveland, Ohio

**Richard A. Nicklas, MD**
Department of Medicine
George Washington Medical Center
Washington, DC

**John Oppenheimer, MD**
Department of Internal Medicine
New Jersey Medical School
Pulmonary and Allergy Associates
Morristown, New Jersey

**Jay M. Portnoy, MD**
Section of Allergy, Asthma & Immunology
Children's Mercy Hospital
Department of Pediatrics
University of Missouri–Kansas City School of Medicine
Kansas City, Missouri

**Christopher C. Randolph, MD**
Department of Pediatrics
Yale Affiliated Hospitals
Center for Allergy, Asthma, & Immunology
Waterbury, Connecticut

**Diane E. Schuller, MD**
Department of Pediatrics
Pennsylvania State University Milton S. Hershey Medical College
Hershey, Pennsylvania

**Sheldon L. Spector, MD**
Department of Medicine
UCLA School of Medicine
Los Angeles, California

**Stephen A. Tilles, MD**
Department of Medicine
University of Washington School of Medicine
Redmond, Washington

**Dana Wallace, MD**
Department of Medicine
Nova Southeastern University College of Osteopathic Medicine
Davie, Florida

## PARAMETER WORKGROUP MEMBERS

**Charles Barnes, PhD**
Allergy Research
Children's Mercy Hospitals & Clinics
Kansas City, Missouri

**Ginger L. Chew, ScD**
Centers for Disease Control and Prevention (CDC)
National Center for Environmental Health
Healthy Homes and Lead Poisoning Prevention Branch
Atlanta, Georgia

**Carl Grimes, HHS, CIEC**
Indoor Air Quality Association
Healthy Habitats LLC
Denver, Colorado

**Elizabeth C. Matsui, MD, MHS**
Department of Pediatrics
Johns Hopkins School of Medicine
Baltimore, Maryland

**Jeffrey D. Miller, MD**
Department of Pediatrics
New York Medical College
Valhalla, New York

**J. David Miller, PhD**
Department of Biochemistry
NSERC Industrial Research Chair
Carlton, University
Ottawa, Ontario, Canada

**Wanda Phipatanakul, MD, MS**
Department of Pediatrics
Harvard Medical School
Children's Hospital, Boston
Division of Allergy and Immunology
Boston, Massachusetts

**James M. Seltzer, MD**
Reliance Medical Group
Department of Allergy/Immunology
Worcester, Massachusetts

**P. Brock Williams, PhD**
Allergy/Immunology Faculty
University of Missouri–Kansas City School of Medicine and Children's Mercy Hospitals & Clinics
Kansas City, Missouri

## INVITED REVIEWERS

**William Busse, MD**
Madison, Wisconsin

**Peyton Eggleston, MD**
Islesford, Maine

**Janna Tuck, MD**
Cape Girardeau, Missouri

## CLASSIFICATION OF RECOMMENDATIONS AND EVIDENCE

### Recommendation rating scale

| Statement | Definition | Implication |
|---|---|---|
| Strong recommendation (StrRec) | A strong recommendation means the benefits of the recommended approach clearly exceed the harms (or that the harms clearly exceed the benefits in the case of a strong negative recommendation) and that the quality of the supporting evidence is excellent (grade A or B).* In some clearly identified circumstances, strong recommendations might be made based on lesser evidence when high-quality evidence is impossible to obtain and the anticipated benefits strongly outweigh the harms. | Clinicians should follow a strong recommendation unless a clear and compelling rationale for an alternative approach is present. |
| Recommendation (Rec) | A recommendation means the benefits exceed the harms (or that the harms clearly exceed the benefits in the case of a negative recommendation) but the quality of evidence is not as strong (grade B or C).* In some clearly identified circumstances, recommendations might be made based on lesser evidence when high-quality evidence is impossible to obtain and the anticipated benefits outweigh the harms. | Clinicians should also generally follow a recommendation but should remain alert to new information and be sensitive to patient preferences. |
| Option (Opt) | An option means that either the quality of evidence that exists is suspect (grade D)* or that well-done studies (grade A, B, or C)* show little clear advantage to one approach versus another. | Clinicians should be flexible in their decision-making regarding appropriate practice, although they might set bounds on alternatives; patient preference should have a substantial influencing role. |
| No recommendation (NoRec) | No recommendation means there is both a lack of pertinent evidence (grade D)* and an unclear balance between benefits and harms. | Clinicians should feel little constraint in their decision-making and be alert to new published evidence that clarifies the balance of benefit versus harm; patient preference should have a substantial influencing role. |

### Category of evidence

Ia Evidence from meta-analysis of randomized controlled trials
Ib Evidence from at least 1 randomized controlled trial
IIa Evidence from at least 1 controlled study without randomization
IIb Evidence from at least 1 other type of quasi-experimental study
III Evidence from nonexperimental descriptive studies, such as comparative studies
IV Evidence from expert committee reports, opinions or clinical experience of respected authorities, or both

### Strength of recommendation*

A Directly based on category I evidence
B Directly based on category II evidence or extrapolated recommendation from category I evidence
C Directly based on category III evidence or extrapolated recommendation from category I or II evidence
D Directly based on category IV evidence or extrapolated recommendation from category I, II, or III evidence
LB Laboratory based
NR Not rated

## RESOLUTION OF POTENTIAL CONFLICTS OF INTEREST

The Joint Task Force recognizes that experts in a field are likely to have interests that could come into conflict with developing a completely unbiased and objective practice parameter. A process has been developed to prevent potential conflicts from influencing the final document to take advantage of that expertise.

At the workgroup level, members who have a potential conflict of interest either do not participate in discussions concerning topics related to the potential conflict, or if they do write a section on that topic, the workgroup completely rewrites it without their involvement to remove potential bias. In addition, the entire document is reviewed by the Joint Task Force, and any apparent bias is removed at that level. Finally, the practice parameter is sent for review both by invited reviewers and by anyone with an interest in the topic by posting the document on the Web sites of the ACAAI and the AAAAI.

## HOW THIS PRACTICE PARAMETER WAS DEVELOPED

### The Joint Task Force on Practice Parameters

The Joint Task Force on Practice Parameters (JTF) is a 13-member task force consisting of 6 representatives assigned by the AAAAI, 6 by the ACAAI, and 1 by the Joint Council of Allergy and Immunology. This task force oversees the development of practice parameters; selects the workgroup chair or chairs, and reviews drafts of the parameters for accuracy, practicality, clarity, and broad utility of the recommendations for clinical practice.

### The Environment Practice Parameter workgroup

The Environment Practice Parameter workgroup was commissioned by the JTF to develop practice parameters that address environmental assessment and remediation. The co-chairs (James Sublett, MD, and Kevin Kennedy, MPH) invited workgroup members who are considered experts in the field of environmental assessment and contaminant reduction to participate in the parameter development. Workgroup members have been vetted for financial conflicts of interest by the JTF, and their conflicts of interest have been listed in this document and are posted on the JTF Web site at http://www.allergyparameters.org. Where a potential conflict of interest is present, the potentially conflicted workgroup member was excluded from discussing relevant issues.

The charge to the workgroup was to use a systematic literature review in conjunction with consensus expert opinion and workgroup-identified supplementary documents to develop practice parameters that provide a comprehensive approach for identifying and managing environmental exposures and their health effects based on the current state of the science.

### Protocol for finding evidence

A search of the medical literature was performed by searching PubMed between 1960 and September 2012 for the term cockroach, resulting in 5743 references. These were further restricted to citations, with the terms *cockroach* and *allergy* resulting in 983 total references. The number of citations with the terms *cockroach* and *allergy* increased starting in 1994 and since 2000 have averaged 50 per year. All reference types were included in the results. References identified as being relevant were searched for additional references, and these also were searched for citable references. In addition, members of the workgroup were asked for references that were missed by this initial search. Although the ideal type of reference would consist of a randomized, double-blind, placebo-controlled study, the topic of this practice parameter is represented by very few such studies. Consequently, it was necessary to use observational studies, basic laboratory reports, and regulatory requirements to develop a document that addresses most of the issues included in this practice parameter.

## GLOSSARY

### Terms related to exposure

*Contaminant:* Any substance that has the potential to cause harm to a building's occupants. Cockroach contaminants include allergens, chitin, endotoxin, and other substances released from cockroaches during their lifetime.

*Facilitating factors:* Conditions that facilitate production of contaminants by a source. Examples for cockroaches include moisture, food, warmth, and shelter.

*Reservoirs:* These are contained spaces or microenvironments in which contaminants can accumulate for subsequent release into the environment. Cockroach reservoirs include mattresses, carpeting, bedding, and contaminated building materials.

### Terms related to interventions

*Abatement:* Defined as a diminution in amount, degree, or intensity. Abatement includes removing, treating, or isolating reservoirs of contaminants and could include the use of air filtration, vacuuming or removal of carpeting, use of denaturing chemicals, and removal of contaminated building materials.

*Integrated pest management:* A strategy to reduce cockroach contaminant exposure by using a combination of abatement, source reduction, and mitigation with the goal of reducing the ability of the environment to support a population of cockroaches.

*Mitigation:* The process of removing facilitating factors, either completely or partially, so that production of contaminants will no longer be facilitated. Mitigation often is the immediate first step

toward exposure reduction so that production of cockroach contamination does not continue. Once mitigation is done, restoration and remediation can commence.

*Source control:* The process of reducing or eliminating cockroaches. Once cockroaches are removed, the exposure will decrease over time as the previously released contaminants are removed from the environment.

## PREFACE

"Environmental assessment and exposure control of cockroaches: a practice parameter" is the next installment in a series of practice parameters that deal with important exposures that contribute to health problems. Future practice parameters on specific exposures are planned for fungi, dust mites, and irritants.

The health effects of cockroach exposure, as with furry animals and rodents, progresses through 3 stages: development of specific IgE (sensitization), development of clinical disease (sensitivity), and increased morbidity with ongoing exposure. These health outcomes can be measured by using 2 different types of clinical investigation. The most direct way to demonstrate a causal relationship between exposure to cockroach allergens and health outcomes is to randomly expose persons to different amounts of cockroach allergen over time in their homes and determine the likelihood of having specific IgE, disease, or worsening disease with continued cockroach exposure. Obviously, it is neither feasible nor ethical to perform this type of ideal study.

To be practical, the approach generally used in studies of cockroach-related health effects is to observe persons with different amounts of exposure to cockroach either prospectively as a cohort or as a cross-section. The prevalence of the target outcome (sensitization, disease, and morbidity) is used to determine the relationship between exposure and development of health effects. Although this does not prove causality, it does provide an estimate of the association between exposure to cockroach allergen and health as long as all other exposures are adjusted for in the statistical analysis.

Another approach to proving causality between exposure and health is to study persons who have already experienced or are at risk of experiencing health effects presumably caused by cockroach exposure in that they are sensitized, have a disease, or are experiencing morbidity because of exposure. Interventions designed to reduce cockroach allergen exposure are implemented, and measurements confirm that exposure is indeed reduced significantly. The effect of this reduced cockroach exposure on the target health outcomes can then be observed to estimate an association between the exposure and health. The advantage of this approach is that if environments are randomly assigned to receive reduced exposure, a causal relationship can be inferred regarding the health effects on occupants of those environments. The benefit of this approach is that it provides evidence for the effectiveness of the intervention and evidence that the intervention is clinically beneficial and that cockroach exposure was the likely cause of the health problem.

The evidence for causality provided by these 2 approaches (exposure being associated with disease vs reduction of exposure being associated with improvement in disease) is not the same. An environment that has low cockroach exposure might differ from an environment that had high exposure that was reduced with an intervention. The intervention might reduce other exposures, or the high-exposure environment might have other health-affecting exposures that are not removed by the intervention. For that reason, health benefits associated with an environment with intrinsically low cockroach exposure are considered separately from those that are due to a cockroach reduction intervention environment in this practice parameter.

The first type of evidence, which is mainly observational, is discussed in the health effects section of this practice parameter. Recommendations are made to keep exposure as low as possible to prevent sensitization, prevent development of disease, and reduce ongoing morbidity in sensitized persons. What we do not know is whether interventions that keep exposure low are as effective at improving health as simply living in an environment with naturally low exposure from the beginning. The recommendation could be modified to state that one should move to a low-cockroach environment rather than trying to reduce exposure in the environment in which one lives; however, that would not be practical.

On the other hand, the beneficial effect of cockroach allergen exposure reduction is discussed in the section on interventions because evidence that certain interventions are effective is integrally linked to the evidence that this improves health. Although the summary statements in this section might appear to mirror those in the health effects section, they really are distinct. These statements primarily involve reducing exposure to improve health as opposed to health effects from living in environments that have low exposure, either naturally or after an intervention, to prevent morbidity.

There are cut point values that have been proposed from numerous studies on allergens in dust. These cut points are levels above which there is an increased risk of allergy sensitization or reactions in sensitized subjects. For cockroach, indoor levels of less than 2 U/g Bla g 1 or 2 U/g Bla g 2 (which is equivalent to 0.08 μg/g Bla g 2) are associated with a lower risk of sensitization and symptoms on exposure. Although cut points are mentioned throughout this practice parameter, it should be kept in mind that these generally represent median values observed, usually in a single study. A dose-response curve for Bla g 1 exposure and sensitization did not support the use of a single value above which sensitization is inevitable but rather indicated increasing sensitization rates as exposure increased.[1]

## SUMMARY STATEMENTS

1. Exposure to cockroach allergen in homes should be minimized to reduce the risk of cockroach sensitization (StrRec, B Evidence)
2. Exposure to cockroach allergens should be minimized to reduce the risk that sensitized children will develop allergic disease. (Rec, C Evidence)
3. Cockroach allergen exposure should be minimized to reduce the risk of asthma morbidity in already sensitized subjects. (Rec, B Evidence)
4. Patients with possible cockroach allergy should be asked whether they have seen cockroaches in their homes. (Rec, C Evidence)
5. Patients with suspected atopy and likely cockroach exposure should be evaluated for sensitization to cockroach allergens by skin prick testing or measurement of specific IgE directed toward cockroach-derived allergens. (StrRec, D Evidence)
6. Factors that facilitate the growth and persistence of cockroach populations, such as food and water, paths of ingress, and microenvironments that can provide shelter, should be

mitigated to reduce the cockroach carrying capacity of the environment. (StrRec, D Evidence)
7. The extent and duration of a cockroach infestation should be monitored by using strategically placed sticky traps. (StrRec, D Evidence)
8. Pesticides should be used judiciously and ideally should be applied by a professional exterminator as part of an integrated pest management program. (Rec, C Evidence)
9. Boric acid is an effective pesticide; however, surviving cockroaches can produce more allergen after exposure. (Rec, C Evidence)
10. Measurement of cockroach allergen in dust can be considered for building occupants at increased risk of cockroach sensitization or sensitivity though routine clinical use of this information has not been sufficiently studied. (Opt, D Evidence)
11. Reservoirs of cockroach contaminants should be cleaned or removed to prevent additional exposure to occupants. (StrRec, A Evidence)
12. Integrated pest management with a combination of interventions appears to be the most effective method for preventing and eliminating cockroach infestations. (StrRec, B Evidence)
13. Integrated pest management should be used to decrease cockroach exposure to reduce asthma morbidity. (StrRec, A Evidence)
14. Immunotherapy with cockroach extracts can be considered; however, it has only been evaluated in a limited number of studies, an effective dose is not known, and it is not clear how effective the treatment is for asthma or rhinitis. (Opt, C Evidence)

## EXECUTIVE SUMMARY

Of the 4500 species of cockroach, approximately 30 are associated with human habitation, and 4 are known to be pests, including the oriental cockroach *(Blatta orientalis)*, German cockroach *(Blattella germanica)*, American cockroach *(Periplaneta americana)*, and brown-banded cockroach *(Supella longipalpa)*. Cockroaches can be found in any building that has a means of ingress, a source of water, food, adequate temperature, and shelter for their survival. Because cockroaches prefer small tight environments, they can be present without the occupant's awareness until the infestation becomes extensive.

At least 10 allergens have been isolated from the German cockroach *B germanica*, many of which exhibit extensive cross-reactivity with other cockroach genera, such as *Periplaneta*, *Blatta*, and *Supella* species. A major allergen, Bla g 1, exhibits cross-reactivity with allergens from other insects, including fruit flies and mosquitoes. Produced in the midgut, Bla g 1 is found in cockroach frass (fecal material) and has allergenic activities, as well as the ability to upregulate expression of protease-activated receptors (PARs) and enhance $T_H2$ cytokine production. Because the molecule is a polymer with various numbers of repetitions, its molecular weight is highly variable, and hence concentrations of Bla g 1 are expressed as units per gram of dust rather than micrograms per gram of dust. Another important allergen, Bla g 2, also cross-reacts with mosquito and fungal allergens. With a molecular weight of 36 kDa, Bla g 2 levels in environmental samples can be expressed in micrograms per gram of dust. The other cockroach allergens also have important properties that are described in this practice parameter. Bla g 7 (and Per a 7), which is tropomyosin, is considered to be a panallergen because it cross-reacts with numerous inhalant allergens from arthropods, such as dust mites, and foods, such as crustaceans and mollusks. In addition to allergens, cockroaches also are a source of chitin, which has proinflammatory activities and can induce cells to produce $T_H2$ cytokines.

The health effects of cockroach allergen exposure include sensitization (production of specific IgE), sensitivity (symptoms when sensitized people are exposed), and morbidity in that respiratory diseases get worse with ongoing exposure. Prevention of these health effects requires that exposure be reduced to the lowest levels achievable. A cutoff of 0.04 μg/g dust for Bla g 2 has been proposed as a threshold below which sensitization is prevented, although levels greater than 0.08 μg/g are associated with development of disease and symptoms; however, the evidence for this is based on observational studies of patients exposed to levels greater than and less than these cutoffs. The problem with these types of studies is that the length of exposure causing an increase in risk is unknown, and they do not demonstrate that reduction of cockroach exposure reduces that risk. In addition, use of a specific cutoff does not provide the shape of the dose-response curve.

Patients should be asked whether they have seen cockroaches in their homes. Because it is possible for cockroaches and their allergens to be present without the occupant's awareness, it also might help to ask patients at increased risk of cockroach exposure to place sticky traps to monitor for occult infestations and to measure Bla g 1 or Bla g 2 levels in a sample of dust obtained by patients from their vacuum cleaners. Levels of greater than 0.04 μg/g Bla g 2 indicate that cockroaches are present or at least that they have been present in the recent past. Such a finding should be used to trigger additional investigation into the cockroach status of the patient's home.

In addition, those with atopy and likely exposure should be evaluated for possible sensitization by using either percutaneous allergy tests or measurement of cockroach-specific IgE antibodies. It is not known whether use of intracutaneous tests improves the diagnostic performance of skin tests for cockroach sensitization. However, if cockroaches are present, evidence suggests that abatement measures should be undertaken regardless of whether a subject is sensitized.

Exposure assessment and reduction involve identification and removal of facilitative factors, such as means of ingress, food, water, and shelter, as well as extermination of the cockroaches themselves. Cockroach numbers can be monitored by using strategically placed sticky traps. This provides information about the number of cockroaches present, as well as the duration of the infestation, which can be determined by the number of different stages of development found in the captured cockroaches. Pesticides should be used judiciously and ideally should be applied by a professional exterminator. The effectiveness of the extermination can be monitored with sticky traps.

Once the cockroaches and facilitative factors are removed, it is necessary to remove reservoirs of cockroach allergen, or exposure of occupants will continue. Reservoir concentrations of cockroach allergen can be measured by using dust samples collected both before and after the intervention. Bla g 1 levels ideally should be reduced to less than 2 U/g and Bla g 2 levels to less than 0.08 μg/g dust to reduce the risk of occupants for symptoms and morbidity from exposure.

Abatement, or reduction of exposure that comes from reservoirs, includes several steps. These include cleaning of carpets with a high-efficiency particulate (HEPA) air vacuum cleaner or complete removal of carpets if contamination cannot be

removed by vacuuming, use of mattress covers, or ideally removal of cockroach-infested mattresses and ongoing monitoring for a recurrence of the cockroach infestation.

Integrated pest management is the combination of each of these interventions into a comprehensive program. Integrated pest management has been shown to significantly reduce cockroach exposure and to improve health in occupants for at least 1 year after the interventions had ceased, provided that ongoing monitoring is used to detect a recurrence. Integrated pest management has been used in schools in which cockroach exposure was significantly reduced as well.

There have been a few studies of cockroach immunotherapy; however, their design was not adequate to determine whether it is clinically effective and, even if it were, what the optimal dose would be. For that reason, cockroach immunotherapy is optional.

## ANNOTATIONS FOR ALGORITHM 1 (FIG E1): SCREEN FOR THE PRESENCE OF COCKROACHES

### Annotation 1. Patient with possible cockroach-related illness

Patients generally present for evaluation if they have an illness, such as rhinitis or asthma. Rhinitis and asthma are both respiratory illnesses that can be exacerbated by cockroach allergen exposure given sensitization and sensitivity. Because exposure to cockroach emanations can also trigger symptoms in nonsensitized subjects,[2] sensitization *per se* is not the only criterion for possible morbidity caused by exposure. A patient's risk for morbidity caused by cockroach exposure should therefore be evaluated by using this algorithm, regardless of sensitization status. The purpose of this first part is to determine which patients would most likely benefit from a more complete evaluation of their home environment for possible cockroach exposure. As such, this section should be considered to be a screening procedure. The 2 factors that determine whether further cockroach assessment is indicated include environment-specific factors and whether there are indications of cockroach exposure using screening criteria. The next 2 questions address each of these issues in turn.

### Annotation 2. Is there increased risk for cockroach exposure?

This question attempts to determine whether a patient is at increased risk of exposure to increased levels of cockroach allergens. Risk for cockroach exposure depends on the location of the building in which the patient lives and whether there is a history of cockroach presence in the building.

*Location*: Cockroaches tend to be found in southern latitudes because they require both warmth and moisture. They can survive in cold dry climates by occupying human residences that are artificially heated, although they are less able to travel between buildings during cold weather. Also, cockroaches are more common in multioccupant buildings. Single-family homes in colder climates have a lower risk for cockroach infestation. The risk also increases if a cockroach has been seen.

*History*: There are some basic questions that can be asked to determine the likelihood that cockroaches are present in a patient's home environment. These include the following:

- Do you know what cockroaches look like?
- Have you ever seen cockroaches in the home in which you are currently living?
- Have you observed any cockroaches in your home in the last 12 months?
- Have you observed any indications for the presence of cockroaches in your home during the last 12 months, such as dead cockroaches, frass in cupboards or around cracks, and/or gaps in the kitchen or bath cabinets?
- Have you received reports of cockroach problems in the last 12 months in the building in which you live?
- Did you bring your mattress and soft furniture from a location that had cockroach problems?

Patients who are not yet sensitized to cockroach but who are at increased risk to become sensitized should ideally be identified before the sensitization takes place and therefore deserve a greater degree of evaluation for cockroach exposure. If a patient has increased total IgE levels; if he or she is sensitized to other allergens (increased specific IgE levels or positive skin test results); if he or she has asthma, eczema, or allergic rhinitis; or if there is a strong family history of atopy, there is an increased risk of sensitization and disease development from cockroach exposure. The latter criteria are particularly important in very young children because they might not yet have evidence of atopy.

### Annotation 3. Done

If the patient does not have a significant risk for cockroach exposure, it is not necessary to perform additional procedures. However, exposure and associated risk factors can vary over time. Periodic re-evaluation of the risk for cockroach allergen exposure should occur.

### Annotation 4. Screen for exposure to cockroaches

If the patient lives where cockroaches are present or answers yes to any of the screening questions, he or she should be offered the option of surveying the home with either a simple or advanced screening method. The simple screening method for current infestations is the deployment of sticky traps in key locations in the home in areas where cockroaches are likely to nest, particularly near food and water sources in the kitchen and bathrooms. Instructions for trap placement should be offered when providing traps for monitoring for the presence of roaches. Instructions are often included on the traps themselves. If the sticky traps reveal evidence of a cockroach infestation, then the screen result is positive. In this case a more complete home assessment, followed by professional extermination, is indicated.

It is possible for the sticky trap monitor result to be negative, even when cockroaches are present. When an infestation is suspected but the sticky trap result is negative, measurement of cockroach allergen levels in dust might help to identify a covert infestation. Dust analysis is a possible screening method for current and past infestations. Cockroach allergen measurement can be done with dust from a used vacuum bag; however, dust collection by a trained technician is ideal and can help to pinpoint the main sources of exposure within a home. If a used vacuum bag from the resident's home is used, one should realize that it is the accumulation of many different locations within the home and represents a period of time that might not reflect a current infestation in that home. The 2 cockroach allergens for which standardized measurements are available are Bla g 1 and Bla g 2. Increased levels of these allergens are considered a positive screen result.

### Annotation 5. Positive cockroach screen result?

Because morbidity can occur from increased cockroach exposure regardless of sensitization, a positive response to the screening questionnaire should be followed by a more complete assessment for cockroaches. Prolonged exposure to levels of Bla g 1 of greater than 1 U/g or Bla g 2 of greater than 0.04 μg/g is associated with an increased risk of sensitization, although it is not clear how prolonged the exposure needs to be for this to happen. This is because most studies include a 1-time measurement, which is then assumed to represent prolonged exposure, when there could be substantial variability over time. If levels are greater than these cut points or if the answer to any of the brief screening questions is yes, the patient should be advised to have a home assessment to identify facilitating factors for cockroaches, determine whether cockroaches are present, and more accurately measure allergen concentrations in dust samples. The presence of cockroaches on sticky traps is a definite indicator of cockroach exposure and should be followed up with a home assessment.

### Annotation 6. Home assessment for analysis and to design integrated pest management

A home in which cockroaches have been seen or with increased cockroach allergen levels in settled dust has an increased likelihood of having a cockroach infestation. A more complete assessment by a professional service is indicated (see Annotations for algorithm 2: Environmental assessment), and the physician should recommend such an assessment be done. Suggestions for selecting such a service are provided in Appendix A.

## ANNOTATIONS FOR ALGORITHM 2 (FIG E2): ENVIRONMENTAL ASSESSMENT

### Annotation 1. Home with suspected cockroaches

Home occupant responses to the screening questions might be sufficient to indicate the presence of cockroaches. If the occupant reports deploying sticky traps and catching cockroaches, this is confirmatory evidence for the presence of cockroaches but by itself does not indicate the severity of an infestation. The number of cockroaches caught on the trap can indicate the severity of the infestation and provide some evidence of the location of the nest; however, this does not indicate the concentration of allergen in the home. If the sticky trap test results are negative, then dust measurement might provide an estimate of exposure. Specifically, Bla g 1 levels of greater than 1 U/g dust or Bla g 2 levels of greater than 0.04 μg/g indicate an increased likelihood that there are sources of cockroach allergen production. This can result from the presence of live cockroaches either currently or recently that have left a reservoir of allergen. Determination of whether cockroaches are currently living in the house ideally should be performed by a professional home assessor. Selection of a professional to perform the assessment is discussed in Appendix A.

### Annotation 2. Visual evidence of cockroaches?

Cockroaches that are visible in a home are evidence of an active infestation of live cockroaches. The presence of dead cockroaches, egg cases, exoskeletons, and/or cockroach feces, known as frass, is visual evidence of an active cockroach infestation. This increases the levels of exposure to cockroach allergen and increases the likelihood that exposure will be ongoing despite interventions that reduce reservoirs. If possible, it is helpful to identify the species of cockroach present. For example, German and brown-banded cockroaches prefer conditions more often found in kitchens, whereas American and Oriental cockroaches prefer conditions more often found in basements.

### Annotation 3. Deploy sticky traps to monitor for cockroaches

If there is no visual evidence for cockroaches, it is still possible that they are present, particularly if cockroach allergen levels are increased in settled dust. Sticky traps, which are a form of glue board, can be used to determine whether live cockroaches are present. Sticky traps should be situated in locations where cockroaches are likely to travel, such as kitchens. By trapping cockroaches over a period of time, it is possible to estimate the extent and duration of the infestation. If all cockroaches are in the same stage of development, the infestation is fairly new. If various stages are represented, the infestation is likely to have been present for a longer time, indicating that elimination might take more time. Sticky traps can also be used to monitor the success of extermination efforts and to determine whether a new infestation has started before it can become embedded in the building.

### Annotation 4. Implement integrated pest management program

If there is visual evidence of cockroaches, then it is necessary to get rid of them. Elimination of cockroaches is most effectively accomplished through a process called integrated pest management.[3] The goal of integrated pest management (per the US Environmental Protection Agency)[4] is to manage pest damage by the most economic means and with the least possible hazard to persons, property, and the environment. Integrated pest management focuses on reducing facilitative factors and reservoirs. Integrated pest management uses targeted application of pesticides with bait stations and gels to maximize the effectiveness of the pesticide and minimize the potential for exposure. Pesticide bait stations and gels should be used according to the manufacturer's instructions and ideally should be applied by a professional exterminator. There are instances when personal -protective equipment should be used by the applicator to avoid adverse health effects from pesticide exposure. Once the components of an integrated pest management program have been implemented, sticky traps should be used to confirm its success and to monitor for a recurrence that could occur, particularly if facilitating factors remain.

### Annotation 5. Cockroaches present?

If cockroaches are confirmed to be present, it is necessary to get rid of them. If they are not present, it is then desirable to identify reservoirs from which the increased cockroach allergen measurement was made.

### Annotation 6. Cockroach allergen reservoirs present?

Cockroach reservoirs can be found inside cabinets; on countertops or floors; in carpeting, upholstered furniture, mattresses, and narrow cracks between cabinets and appliances; inside drawers; inside furniture; or in other materials that become contaminated by cockroach emanations. Measurement of cockroach allergens in dust collected from reservoirs is a way to confirm the present of contaminants. If reservoirs of cockroach

allergens are present, then exposure to those cockroach allergens can persist long after the cockroaches have been eliminated. If there are no reservoirs of cockroach allergens, then additional mitigation might not be necessary because exposure should cease with the elimination of the cockroaches. It is also possible for cockroach allergen reservoirs to be present transiently, as could occur after a single episode of spilled food, with cockroaches introduced from containers that fail to become established in the new environment, or with a temporary seasonal ingress of cockroaches.

### Annotation 7. Facilitating factors present?

Facilitating factors for cockroaches include food, water, shelter, warmth, and a means of ingress. If these are present, it is necessary to remove them to reduce the carrying capacity of cockroaches and to prevent a reinfestation of cockroaches once they have been eliminated. The removal of facilitative factors is fundamental to implementing an integrated pest management program. It should eliminate cockroach infestations in ways that are more effective than their removal alone while being a more economic and sustainable long-term solution. If there are no facilitative factors, then mitigation is not necessary.

### Annotation 8. Sticky traps to monitor for cockroaches

See Annotation 3 in this environmental assessment algorithm section.

### Annotation 9. Integrated pest management mitigation: Get rid of facilitative factors

Mitigation is the process of removing facilitative factors. If these factors are removed, the environment can no longer support whatever population of cockroaches had been sustained before their removal. Cockroaches either will migrate to another location or starve as a result. This process can take a long time because cockroaches can survive for prolonged periods without food and water. If facilitative factors are not removed, the cockroaches can return after they have been eliminated from an environment. Continued monitoring for their return is still recommended.

### Annotation 10. Integrated pest management abatement: Remove or clean reservoirs

If cockroach reservoirs are identified, they should be cleaned to prevent ongoing release of allergens into the occupant's breathing space. Assuming that the cockroaches have been removed, once the reservoirs are cleaned, the occupants should experience low to undetectable levels of cockroach allergen. This reduces the risk of sensitization, disease, and morbidity.

### Annotation 11. Intervention is done

Once facilitative factors are removed, the cockroaches are exterminated, and reservoirs are cleaned, the intervention is complete. It is desirable to periodically monitor for a possible reinfestation with sticky traps, but otherwise, the occupant is no longer at increased risk of morbidity from cockroach exposure.

## INTRODUCTION

There are approximately 4500 species of cockroach, 30 of which are associated with human habitations; approximately 4 species are well known as pests.[5,6] Two species of cockroach, the German cockroach *(B germanica)* and the American cockroach *(P americana)* predominate in indoor environments. The American cockroach is about 30 mm long, whereas the German cockroach is half that size (15 mm long). Other cockroaches that are associated with human habitations include the Asian cockroach *(Blattella asahinai)* and the Oriental cockroach *(B orientalis)*. Cockroaches are among the hardiest insects on the planet, with some species being capable of survival for long periods without food. Fig E3 shows an abbreviated taxonomy of cockroaches.

Cockroaches emerge from egg cases (ootheca) as immature forms that are similar in appearance to adults. Depending on species, cockroaches typically have a 1- to 2-year lifespan, the first half of which is spent undergoing a series of instars or molts in which they shed the exoskeleton and produce a new larger one until reaching adulthood.

Cockroaches are usually not found in northern latitudes unless they can inhabit environments that are artificially warmed by human subjects. They prefer habitats that are warm and moist with adequate carbohydrate-based food sources and protection from predators. They also prefer to feel close contact with their surrounding environment and therefore are most comfortable when located in small cracks and crevices, a condition known as thigmotactic. Cockroaches are omnivorous scavengers with a taste for starch and fat. They often consume household items, such as soap and glue, as well as garbage. The nymphal stages can survive on the excretions and cast off exoskeletons of adults. Cockroaches quickly become cannibalistic when food is scarce.[7]

## MAJOR COCKROACH ALLERGENS AND CONTAMINANTS

Both the American and German cockroaches produce several potent allergens and proinflammatory contaminants. Important cockroach allergens include Bla g 1 (midgut protein), Bla g 2 (inactive aspartic proteinase), Bla g 3 (hemocyanin), Bla g 4 (calycin), Bla g 5 (glutathione-S-transferase [GST]), Bla g 6 (troponin C), Bla g 7 (tropomyosin), Bla g 8 (myosin light chain), Per a 9 (arginine kinase), and Per a 10 (trypsin protease).[8] These allergens are described in the World Health Organization/International Union of Immunological Societies Allergen Nomenclature (www.allergen.org). Structural homology between tropomyosins present among cockroaches, dust mites, and crustaceans can lead to the development of cross-reacting IgE antibodies.[9] It is important to remember that this cross-reactivity is based on IgE specificity and that there are limited data on the relationship between this type of sensitization and human disease.

### Bla g 1 and Per a 1 (midgut protein)

Bla g 1 and Per a 1 are major cross-reactive allergens from German and American cockroaches, respectively. Bla g 1, which is referred to as midgut protein, consists of several 100-amino-acid repeats. Found in cockroach frass, it is quite stable, and homologous proteins are also found in fruit flies, butterflies, and mosquitoes. Its molecular weight is variable (listed as 25-90 kDa), and in one study up to 77% of cockroach-sensitized patients produced specific IgE to this protein.[8] Although linear IgE-binding epitopes of Bla g 1 have been identified throughout its length, they are predominantly located in amino acids 1 to 111, amino acids 289 to 403, and amino acids 394 to 491.[10]

Bla g 1 is produced in the midgut and excreted as feces, otherwise known as frass. Bla g 1 production is related to food intake in adult males and females. The female's production of Bla g 1 is cyclic in relation to the gonadotrophic cycle, decreases before oviposition in relation to diminishing food intake, and remains at low levels while the female carries an egg case for 20 days. Once the embryos hatch, normal feeding resumes, with increased production of Bla g 1 in the feces. Bla g 1 protein levels are low in experimentally starved females and increase when starved females are allowed to feed. There are no apparent cycles for male production of Bla g 1.[11] Bla g 1 has been shown to be quite stable at normal room temperature and low humidity.[12]

Cloned and expressed Per a 1 (and, by analogy, Bla g 1) has no enzymatic activity but does upregulate the expression of PARs and enhances $T_H2$ cytokine (IL-4 and IL-13) production in the P815 mast cell line.[13]

## Bla g 2 (aspartic protease)

Bla g 2 has the overall structure of aspartic proteases, such as pepsin, cathepsin, renin, and chymosin. However, amino acid substitutions at the level of the active site revealed that this allergen is inactive, which was proved with functional assays.[14,15] There is 30.8% identity with mosquito lysosomal aspartic protease and several fungal allergens, as well as the γ-conglutin seed storage proteins. It is a homodimer in structure with a molecular weight of 36 kDa. One study reported that 58% of cockroach-sensitized patients had specific IgE to this protein.[8]

Conformational epitopes for 2 specific mAbs that bind to opposite sites of Bla g 2 and also interfere with IgE antibody binding have been identified by using x-ray crystallography. Mutations involving these epitopes, including prevention of glycosylation, reduced IgE binding to a variable amount in different samples, indicating that there is heterogeneity in epitope recognition among patients with cockroach allergy.[16]

## Bla g 3 and Per a 3 (hemocyanin)

Hemocyanin is a copper-containing respiratory pigment found in the hemolymph of mollusks, some gastropods, cephalopods, and arthropods. In studies with Per a 3, hemocyanin forms very stable hexamers (molecular weight, 465 kDa), with reported IgE epitopes being exposed on the surface.[17] It is considered a minor allergen of cockroaches. Its molecular weight is variable (46-79 kDa), presumably because of multiple subunits.

## Bla g 4 (calycin)

Bla g 4 is a calycin with a lipocalin structure (β-barrel) that binds fatty acids. The calycins are distantly related to the lipocalins and β-lactoglobulins, with a molecular weight of 21 kDa. In one study up to 60% of cockroach-sensitized subjects had specific IgE to this protein. It cross-reacts with dust mite group 13 fatty acid–binding proteins.[8]

rBla g 4 has been used to identify linear IgE-binding epitopes. Some IgE binding occurs at amino acid sequences 34 to 73 and 78 to 113, although the major IgE epitope of Bla g 4 is located at amino acid sequences 118 to 152 near the C-terminal.[18] Bla g 4 genetic polymorphisms have been identified among individual cockroaches, particularly in residues 38 to 45, 61 to 82, and 144 to 163. This sequence diversity might influence its allergenicity in those individual insects.[19]

## Bla g 5 (GST)

GSTs participate in detoxification of reactive electrophilic compounds. They are common in nature, being found in most organisms, including dust mites (Der f 8), cockroaches, and fungi. In one study 68% of patients sensitized to cockroach had specific IgE to GST. Its reported molecular weight is 23 kDa. GSTs are involved in biodegradative metabolism, with an N-terminal thioredoxin fold and a C-terminal α-helical domain. Again, there is evidence of high cross- reactivity among insect species (eg, with Der p 8). When IgE-binding epitopes of Bla g 5 were evaluated, recombinant proteins lacking amino acid residues 176 to 200 did not react to sera from cockroach-sensitized subjects, suggesting that this region contains the IgE-binding epitope. In addition, Bla g 5 appears to have a conformational epitope in the C-terminal region.[20]

## Bla g 6 and Per a 6 (troponin C)

Troponin C is a calcium-binding protein belonging to the EF-hand family of proteins.[21] It is involved in calcium regulation and calcium-induced muscle contraction. The EF-hand calcium-binding proteins are common allergens from plants, fish, and invertebrates and compose 63 different International Union of Immunological Societies–identified allergens. Its molecular weight is 21 kDa. Bla g 6 shows homology to the muscle protein troponin C. Approximately 14% of cockroach-sensitized subjects possessed specific IgE to troponin C. It contains 4 calcium-binding domains at amino acid residues 20 to 30, 56 to 67, 96 to 107, and 132 to 143, and its IgE reactivity is dependent on the calcium ion level.[21] The amino acid residues between 96 and 151, including the calcium-binding domains III and IV, appear to be important for IgE binding.[22]

## Bla g 7 and Per a 7 (tropomyosin)

Tropomyosins are α-helical proteins that form a coiled-coil structure containing 2 sets of 7 alternating actin-binding sites. They have been identified as inhalant allergens from arthropods, such as mites (Der f 10) and cockroaches; as food allergens, such as in crustaceans and mollusks; and in parasites. Tropomyosins are highly conserved and very stable, with a molecular weight of 31 kDa. The tropomyosins are considered panallergens. In one study specific IgE levels to nBla g 7 in 57% and to rBla g 7 in 43% of cockroach-sensitized patients were positive, as determined by using ELISA.[23]

In a study of 504 serum samples from the National Cooperative Inner-City Asthma Study (NCICAS), high exposure to *B germanica*, but not to dust mite, in the bedroom and television room corresponded with higher specific IgE levels to shrimp and cockroach. Because challenges were not performed, it was not clear whether these patients were actually allergic to the shrimp.[24]

## Bla g 8 (myosin light chain)

Myosin is a multisubunit complex made up of 2 heavy chains and 4 light chains. It is fundamentally a contractile protein found in all eukaryote cell types. This family consists of the C-terminal coiled-coil myosin heavy chain tail region. The coiled-coil is composed of the tails from 2 molecules of myosin. With a molecular weight of 21 kDa, invertebrate myosins are highly cross-reactive major allergens (Der f 11).

### Bla g 9 and Per a 9 (arginine kinase)

The arginine kinases represent a class of cross-reactive invertebrate panallergens involved in energy production. Identified as cross-reactive allergens from moths (Plo i 1), mites (Der p 20), cockroach, prawns (Lit v 2), lobster (Hom g 2), crab (Chi o 2), and mussels, arginine kinase has a molecular weight of 40 kDa. In a cross-sectional survey of *P americana* allergens, the concentrations of Per a 9 were found to be highest during the winter months and lowest in summer. In addition, exposure to this allergen correlated with disease exacerbation. Concentrations of Bla g 9 were also higher in wood-based houses than in concrete houses.[25]

### Per a 10 (serine protease)

Serine proteases (trypsin) are considered important allergens from a number of different sources, including cockroaches and mites (Der f 3, 6, and 9).[26] These proteases can activate dendritic cells and inflammatory cells, such as eosinophils, by their ability to activate PAR2. Eighty-one percent of cockroach-sensitized subjects had positive intradermal skin test results to Per a 10. With a molecular weight of 28 kDa, the serine proteases not only participate in inflammatory reactions but also are common targets of specific IgE.

### Cockroach chitin

Chitin makes up the exoskeletons of insects, crustaceans, parasites, and many fungi. It has complex and size-dependent effects on both innate and adaptive immune responses, including the accumulation in tissues of innate immune cells associated with allergy.[27,28] This includes macrophages, eosinophils, and basophils, resulting in the production of the TH2 cytokines IL-4 and IL-13. IL-13 induces epithelial cells to produce acidic mammalian chitinase (AMCase), which digests chitin. Increasing evidence has been accumulating that AMCase and other chitinases play a key role in mediating the $T_H2$ cell–driven inflammatory responses commonly associated with asthma. Although a complete discussion of chitin and chitinases is beyond the scope of this practice parameter, it is mentioned here as a likely factor as to why the clinical symptoms of cockroach allergy and perhaps other chitin-containing organisms are usually more severe and prolonged than those caused by other indoor allergens. AMCase variants, along with other factors, have been implicated in the genetics of asthma.[29]

### Frass

Cockroach frass is a generic term that refers either to cockroach feces or to a combination of feces, secretions, and body parts, depending on which group defines it (entomologists or environmental health specialists). Frass is found in areas where cockroaches hide and contains proinflammatory material that can drive the development of airway inflammation, at least in cockroach-sensitized mice.[30] One mechanism for this appears to involve the activity of serine proteases and PAR2 in modulating the innate immune response. On the other hand, frass that is protease depleted induces a decreased inflammatory response. This appears to operate through PAR2 activation.[31]

Among inner-city children, proteases from cockroaches also have been shown to activate inflammatory cells in the airways and to exacerbate asthma.[32] This inflammation can be blocked by serine protease inhibitors that interfere with activation of PAR2 and PAR3, suggesting that they might play a role in cockroach-induced inflammation.[33]

### Measurement of cockroach allergens

Assessment of cockroach allergens began with assays designed to measure Bla g 1 levels. These assays generally consisted of polyclonal antibody-based technologies by using purified allergen as a standard. Because Bla g 1 is a mixture of different molecular forms consisting of a different number of 100-amino-acid repeats with a molecular weight that varies,[34] it was not feasible to standardize the allergen in terms of mass units per gram of dust, and therefore the biologic activity of Bla g 1 was expressed in units. Many of the early studies of cockroach exposure were based on measurements of Bla g 1, and as a result, clinical thresholds of exposure were expressed as units per gram of dust. Subsequently, Bla g 2 was determined also to be an important cockroach allergen. Bla g 2 is a more homogeneous molecule than Bla g 1, and therefore its potency could be expressed both in units per gram and in micrograms per gram of dust. For that reason, the 2 allergens have been reported by using different units, although micrograms per gram is now more commonly used.

Standards that can be used in assays of allergens from settled dust samples have been developed by the US Food and Drug Administration and the World Health Organization.[35] These consist of a preparation for dust allergen measurement that contains 8 purified allergens formulated into a single multiallergen standard based on amino acid analysis.[36] The goal is to provide improved standardization of allergy diagnostics so that measurements from one investigation can be compared with measurements from others.

## HEALTH EFFECTS OF COCKROACH EXPOSURE

*B germanica* has been shown to act as a vector, transporting both pathogens and allergens. Migration of populations among and between apartment complexes is a potential mechanism for such transport. Population migration can be measured by using analysis of highly polymorphic DNA markers. In one study dispersal was more common within complexes than among them, as shown by greater genetic similarity between apartments in a single building than between separate buildings of an apartment complex. Human-mediated dispersal between buildings appears to occur infrequently. When attempts at extermination led to incomplete cockroach eradication within an apartment, recolonization occurred from genetically similar insects.[37]

A number of mechanisms have been evaluated to explain why cockroach allergen induces adverse health effects and whether there is a genetic tendency for cockroach morbidity in some subjects. For example, plasmacytoid dendritic cells cultured with $CD4^+$ T cells and exposed to crude cockroach antigen produce increased amounts of IL-13, IL-10, and TNF-$\alpha$ after 48 hours. The cells uniquely expressed the gene for CD14, particularly among subjects with the CC high-risk genotype of CD14-260C/T.[38] The underlying immune mechanism and genetic cause of cockroach allergy exposure were recently reviewed. It appears that cockroach proteases disturb airway epithelial integrity, leading to penetration of cockroach allergen. This leads to activation of dendritic cells through Toll-like receptors. In addition, mannose receptors have been shown to mediate Bla g 2 uptake by dendritic cells, leading to a $T_H2$ response. Several genes have been associated with cockroach sensitization and related phenotypes (*HLA-D*, *TSLP*, *IL12A*, and *MBL2*).[39]

## Sensitization to cockroach

**Summary Statement 1: Exposure to cockroach allergen in homes should be minimized to reduce the risk of cockroach sensitization. (StrRec, B Evidence)**

Cockroach sensitization is defined as the development of specific IgE antibodies to cockroach allergens. The best way to avoid morbidity from cockroach allergy would be to prevent sensitization. For example, cockroach allergy is less common in regions of the world that are not hospitable to cockroaches.[40] Subjects are at increased risk of becoming sensitized if they are exposed to cockroach allergen where they live, not only in their home environment but also in their community in general. For that reason, avoidance of sensitization should be possible if exposure can be reduced to less than a sensitizing level.

Persons who live in areas of urban poverty as a group have an increased prevalence of sensitization. It is estimated that 30% to 40% of children with asthma are sensitized to cockroach in the inner city, with as many as 70% to 80% sensitized in some inner cities.[41] In contrast, in one suburban population the sensitization rate was 21%. This might be due to increased exposure to cockroach allergen, as demonstrated in the multicity NCICAS conducted in the 1990s, in which bedroom concentrations of Bla g 1 were directly correlated with cockroach sensitization, as determined by using skin testing.[42] In particular, sensitization was seen in 15% of children with bedrooms that had Bla g 1 concentrations of less than the level of detection, 32% with Bla g 1 levels of 1 to 2 U/g, and 40% to 44% with levels of 4 U/g or greater.[1] A different multicenter trial conducted a few years later confirmed these previous findings, when it was found that subjects from homes with cockroach allergen exposure were twice as likely to have a positive skin test response to cockroach allergen.[43] It is important to remember that sensitization could also reflect exposure to cross-reacting antigens (see Bla g 7) and that this association does not necessarily mean that the exposure caused the sensitization.

An association between exposure and sensitization has been documented in suburban settings, as well as in inner-city areas. In a study of children with asthma 6 to 17 years of age, Bla g 1 levels of greater than 1 U/g were found in 30% of suburban or rural kitchens, and 21% were sensitized to cockroach. This study demonstrated that cockroach allergen exposure is common both in suburban and city homes and that low-level cockroach exposure is a risk factor for cockroach sensitization.[44] This same study also suggested that a threshold of 1 U/g Bla g 1 was associated with an increased likelihood of cockroach sensitization.

More recently, Bla g 2 concentrations of greater than 1 U/g (equivalent to 0.04 μg/g)[45] in settled dust also were associated with an increased risk of having cockroach-specific IgE in a cohort of 4-year-old inner-city children. A direct relationship between exposure and sensitization also was identified, with sensitization rates of 10% for children exposed to less than 0.04 μg/g, 20% for those exposed to 0.04 to 0.16 μg/g, and almost 30% for those exposed to greater than 0.16 μg/g Bla g 2. This evidence supports a dose-response relationship and not a threshold relationship between exposure and sensitization. This evidence implies that even a reduction in Bla g 2 levels from greater than 0.16 μg/g to between 0.04 and 0.16 μg/g should result in a reduction in risk of sensitization; therefore although ideally one would want to reduce the allergen level to less than 0.04 μg/g, some benefit would be expected with a smaller reduction.[46]

It does not come as a surprise that there can be disparities in cockroach allergen exposure and sensitization within the same city. Among children with the same insurance plan (a proxy for socioeconomic status), there were differences in sensitization by neighborhood. This suggests that there are building-specific factors that might be driving cockroach sensitization. What is not known is whether these children always lived in these neighborhoods or moved there.[47]

## Development of disease

**Summary Statement 2: Exposure to cockroach allergens should be minimized to reduce the risk that sensitized children will have allergic disease. (Rec, C Evidence)**

Once a person is sensitized, further cockroach allergen exposure is significantly associated with the development of recurrent asthmatic wheezing and probably with allergic rhinitis and atopic dermatitis. In a longitudinal family and birth cohort study, children living in homes with Bla g 1 or 2 levels between 0.05 and 2 U/g were 8.3 times more likely to have asthma and those with levels of greater than 2 U/g were 35.9 times more likely to have asthma than those with undetectable exposure. This suggests that exposure to cockroach allergen early in life contributes to the development of asthma in sensitized children in a dose-dependent manner.[48]

Household exposure to cockroaches also has been shown to be associated with higher rates of asthma in inner-city areas both within the United States and in other countries. In an inner-city study cockroaches were found in 77% of the apartments, 37% of the apartments had at least 1 resident with asthma, and apartments with Bla g 2 levels of greater than 8 U/g had 1.7 times greater odds of having a resident with asthma. Conversely, apartments with 1 or more asthmatic patients were more likely to have beds with high cockroach allergen levels and to have cockroaches in the kitchen.[49] It should be noted that in this study no skin testing data or specific IgE measurements were obtained, and therefore there might have been other factors involved in the result.

Exposure to cockroaches also was found to be associated with asthma among children living in 172 houses in the metropolitan area of Recife, Brazil. In this study 31.6% of children living in residences with high cockroach exposure had asthma as opposed to 11.8% in a nonexposed group.[50] This observation was further supported in another study of 61 low-income Chicago homes in which children exposed to increased concentrations of cockroach allergen in the bedroom had more asthma symptoms (scored by counting 7 distinct symptoms).[51]

Asthma is not the only disease associated with cockroach exposure. In a cohort of children followed from birth through age 3 years, a dose response was found between higher cockroach exposure and the prevalence of wheeze, rhinitis, or atopic dermatitis. In particular, the frequency of wheeze increased from less than 25% if cockroach exposure was less than 1 U/g Bla g 1 to greater than 60% if exposure was greater than 2 U/g Bla g 1. A similar correlation was found for atopic dermatitis.[52]

Exposure to cockroach allergen has also been shown to be associated with persistent childhood wheezing[53] and asthma severity.[54] On the other hand, another prospective study of adults with asthma in New York City did not find an association between sensitization to indoor allergens, including cockroach and mouse, and asthma morbidity.[55]

## Morbidity from exposure

**Summary Statement 3: Cockroach allergen exposure should be minimized to reduce the risk of asthma morbidity in sensitized subjects. (Rec, C Evidence)**

Cockroach allergens have been associated with morbidity caused by asthma, particularly in urban environments.[56,57] In particular, it has been directly linked to poorer asthma outcomes in inner-city children with asthma, including asthma-related health care use. This was also seen with cockroach exposure in the NCICAS. In that study of children from 8 inner-city areas in the United States, 36.8% were sensitized to cockroach allergen, and 50.2% were exposed to bedroom levels of cockroach allergen in dust that exceeded 8 U/g. Children who were both sensitized to cockroach allergen and exposed to high levels had more hospitalizations and unscheduled medical visits for asthma per year than those who were either not sensitized to cockroach or exposed to lower levels of cockroach allergen. They also had more days of wheezing, missed school days, nights with lost sleep, and change of daytime plans.[58] Findings from the NCICAS agreed with these results in that the combination of cockroach exposure and sensitization was associated with asthma morbidity.[41]

Cockroach exposure has been associated with an increased risk of wheeze in children of atopic adults in longitudinal studies.[59] Although there are conflicting studies,[60] this effect has been seen in both sensitized and nonsensitized children.[53] T cell–mediated allergic response to cockroach allergen correlates with exposure to increased levels at 3 months of life.[61]

In another study of asthmatic children living in New Orleans, 44% were exposed to Bla g 1 levels greater than 2 U/g, and 24% reported at least 1 hospitalization in the previous 4 months. The median Bla g 1 exposure was 6.4 U/g greater in the homes of children who were hospitalized during this time compared with those with no hospital admissions. In addition, the odds of hospitalization was 4.2 times higher in children exposed to Bla g 1 levels greater than 2 U/g independent of their sensitization status, as measured based on ImmunoCAP-specific IgE levels.[2]

In the Normative Aging Study investigators compared the relationship between home allergen cockroach exposure and decrease in $FEV_1$ in asthmatic patients and nonasthmatic control subjects. Bla g 1 and Bla g 2 levels were significantly associated with a decrease in $FEV_1$ after adjustment for age, smoking, and baseline $FEV_1$, suggesting that cockroach allergen exposure itself is a risk factor for accelerated decrease in $FEV_1$ independent of airway responsiveness.[62] One caveat is that the investigators did not adjust for housing factors that might have led to residual confounding effects.

Additional evidence for the relationship between exposure to cockroach and asthma morbidity was measured in a study of women living in Boston. Women who were sensitized and exposed to Bla g 1 or Bla g 2 levels of greater than 2 U/g over 4 years were at least 3 times more likely to have used a steroid and to have been to a hospital emergency department for asthma during this time period than those who had low cockroach exposure or who were not sensitized to cockroach.[63]

# CLINICAL EVALUATION

## Risk of sensitization

**Summary Statement 4: Patients with possible cockroach allergy should be asked whether they have seen cockroaches in their home. (Rec, C Evidence)**

Patient reports of the absence of cockroaches are relatively weak predictors of the absence of allergen because exposure can occur even when no signs of cockroaches have been reported. In a study of 499 homes in the Boston area, cockroach allergen (Bla g 1 or Bla g 2) was detected in 48% of homes with no reported signs of cockroaches in the previous 12 months. The conclusion was that home characteristics reporting is a relatively weak predictor of the absence of allergen exposures because exposure can occur even when a resident does not report signs of cockroaches.[64] On the other hand, a report of the frequency of cockroach sightings seems to be related to increasing cockroach allergen levels.[65] Therefore to assess current exposure to cockroach allergens, a good question to ask would be the following: "Have you seen cockroaches daily, weekly, monthly, or never in the recent past?" An affirmative response increases the likelihood that cockroach allergen exposure is present, whereas a negative response does not rule out such exposure.

## Evaluation for sensitization

**Summary Statement 5: Patients with suspected atopy and likely cockroach exposure should be evaluated for sensitization to cockroach allergens by means of skin prick testing or measurement of specific IgE levels directed toward cockroach-derived allergens. (StrRec, D Evidence)**

Allergen sensitization to cockroach can be detected by using *in vivo* tests, such as skin prick tests, and *in vitro* techniques that measure specific IgE levels in serum. *In vitro* tests for measurement of cockroach-specific IgE levels are available for American cockroach *(P americana), German cockroach (B germanica)*,[66] and Oriental cockroach *(B orientalis)*. Currently, there are no licensed *in vitro* tests for individual cockroach components; however, tests for specific IgE for Bla g 1, Bla g 2, Bla g 4, Bla g 5, and Bla g 7 have been developed and submitted for US Food and Drug Administration approval. Glycerinated extracts for skin prick testing and aqueous extracts for intracutaneous testing are available for the same cockroaches. These aqueous extracts also are available for provision of specific immunotherapy to cockroach, although the evidence for the efficacy of that procedure is currently under investigation (see the "Immunotherapy for cockroach allergy" section).

There is a need for standardization of cockroach extracts for allergy diagnosis. In a case-control study involving children in Brazil, skin prick tests were performed with 3 different extracts of *B germanica* and *P americana*, and specific serum IgE levels were measured for these same species. The prevalence for reactions to *B germanica* was 54.1% and that to *P americana* was 59.5%.[67] The agreement between the skin prick test and specific IgE results was reasonable for *B germanica* and weak for *P americana*, suggesting the presence of substantial differences in the potencies or constituents of the extracts.[68]

In another study of patients with rhinitis and asthma living in an urban area in Europe, 11.6% were sensitized to *P americana* and 11.1% to *B germanica*. In addition, 10.5% had detectable specific IgE levels to *P americana* and 3.5% to *B germanica*. Visual evidence of cockroach infestation was found in the homes of 46.7% of these patients.[69] In a study of 6304 patients from 25 allergy centers across China, 25.7% had positive skin prick test responses to the American cockroach, and 18.7% had positive responses to the German cockroach. Of the patients who had positive skin test results to cockroach, 88% had positive results to dust mite as well.[70] In northern Iran sensitization rates based on skin prick test responses have been reported to be 17.4% for

patients with allergic rhinitis and 12.7% for those with asthma.[71] In South Africa 38% of patients with allergic rhinitis were sensitized to *B germanica* based on ImmunoCAP results.[72]

Obviously, the diagnosis and treatment of cockroach allergy would be facilitated if there were standardized cockroach extracts of reliable potency and contents. Standardization has been attempted by using measurement of biologic potency with the ID(50)EAL method, inhibition of rabbit IgG and pooled human IgE binding to cockroach with extracts and purified allergens, and 2-site mAb assays to Bla g 1, Bla g 2 and Bla g 5.[73-76] The conclusions from these studies were that currently available commercial extracts tend to be of low and variable potency; that no single allergen is immunodominant, such that it could be used to standardize extracts; and that it is possible to improve the potency of extracts to therapeutic levels by using current technology.[76]

In addition to skin or *in vitro* tests for specific IgE, cockroach allergens can induce patch test reactions in patients with atopic dermatitis. In a study of 23 patients with atopic dermatitis and 9 control subjects, a positive atopy patch test result to cockroach was found in 10 (43%) of 23 patients with atopic dermatitis and in none of the nonatopic control subjects. In addition, the results of the cockroach patch test showed no correlation with skin prick test or specific IgE results for cockroach.[77]

## EXPOSURE ASSESSMENT AND REDUCTION

Cockroach contaminants appear to be particularly difficult to eliminate and require strict adherence to strategies designed to reduce their presence. These interventions include initial removal of facilitating factors, elimination of the cockroaches, and removal of reservoirs of cockroach-derived contaminants. In general, individual interventions are not successful at eliminating exposure to cockroach contaminants, and therefore it is necessary to use a combination of interventions depending on the specifics of the infestation. Various combinations of interventions often are referred to as integrated pest management. A list of allergen reduction techniques is provided in Table E1.[78]

### Facilitating factors

**Assessment:** Facilitating factors are conditions in the environment that facilitate or promote the production of contaminants by a source. For cockroaches, such factors include a means of ingress, as well as sources of water, food, and shelter. If any of these factors are absent, the carrying capacity of the environment will discourage immigration of cockroaches from outside and cause cockroaches already present either to die or to seek another environment. Although this is desirable for the environment being treated, it can be a problem in a multiunit building. If integrated pest management is used by 1 occupant in isolation, reinfestation by cockroaches from adjacent units could still become a problem. Ideally, integrated pest management in a multiunit building should be performed in all of the units simultaneously.

**Summary Statement 6: Factors that facilitate the growth and persistence of cockroach populations, such as food and water, paths of ingress, and microenvironments that can provide shelter, should be mitigated to reduce the cockroach carrying capacity of the environment. (StrRec, D Evidence)**

**Mitigation:** The American cockroach prefers dark moist areas and is associated with sewers, drains, boiler rooms, and basements. This species also is found outdoors in association with decaying vegetation and clutter. The German cockroach is more frequently found indoors, especially preferring food preparation and garbage areas. Problems with cockroaches often can be reduced or even eliminated by pest proofing the building and modifying its preferred habitat.

There are many ways to remove or mitigate environmental factors that support an infestation of cockroaches. These include the following:

1. Block means of ingress
   - Caulk and seal cracks and holes on the building's exterior
   - Install door sweeps and weatherproofing seals on exterior doors and garage doors
   - Screen and weatherproof windows and attic vents
   - Remove excess vegetation and prune branches that touch the building
2. Withhold sources of food and water
   - Properly store food in sealed containers
   - Maintain regular cleaning schedules
   - Regularly dispose of garbage
   - Promptly repair water leaks
   - Place stoppers in all drains and promptly wipe up spills
3. Eliminate shelter
   - Move firewood, lumber, and trash cans away from the building
   - Keep basements and crawl spaces free of clutter
   - Keep gutters clean and well maintained

### Contaminant sources

Cockroaches are the source of cockroach contaminants in the environment. For that reason, cockroach populations should be reduced and ideally eliminated. Because removal of facilitating factors might not be sufficient to eliminate an infestation, it could be necessary to remove the cockroaches as well. This can be done by judicious use of chemical insecticides or bait traps to kill live roaches and extensive cleaning to remove the dead roaches and frass. Cockroach predators are not relevant to this discussion. Significant reductions in cockroach allergen concentrations in urban homes as a result of reducing cockroach infestations through insecticide baits placed by entomologists have been reported.[79]

#### Assessment

**Summary Statement 7: The extent and duration of a cockroach infestation should be monitored by using strategically placed sticky traps. (StrRec, D Evidence)**

Before implementing interventions targeted at eliminating cockroaches, it helps to determine the extent and location of an infestation. This can be performed by using sticky traps placed in strategic locations, such as in kitchens, under sinks, near pet food, and in food cabinets. Although sticky traps can remove cockroaches, they are more useful as an indicator of the extent and duration of the infestation. If cockroaches captured on a sticky trap are at approximately the same stage of development, it is likely that the infestation is recent and that a single generation has hatched. On the other hand, captured cockroaches from a variety of stages is an indication that the infestation has been present for

many generations and that it might be more difficult to eradicate. Sticky traps should be placed periodically during the extermination process to monitor its effectiveness. Once the cockroaches are eliminated, sticky traps can be used to monitor for a possible recurrence.

### Source control

**Summary Statement 8: Pesticides should be used judiciously and ideally should be applied by a professional exterminator as part of an integrated pest management program. (Rec, C Evidence)**

**Summary Statement 9: Boric acid is an effective pesticide; however, surviving cockroaches can produce more allergen after exposure. (Rec, C Evidence)**

The cautious use of low-toxicity insecticides can be a component of integrated pest management. However, the concept of "low toxicity" is dynamic. In the 1970s, organochlorines were used widely but then banned by the US Environmental Protection Agency because of risks to human health. Different classes of pesticides have replaced the organochlorines through the years (eg, organophosphates and carbamates), and even some organophosphates were phased out or deregistered for indoor residential use by the US Environmental Protection Agency.[80] Currently used pesticides include pyrethroid sprays and gels. The popular insecticide Raid, for example, contains permethrin, tetramethrin, cypermethrin, and imiprothrin. Recent studies have shown that cockroaches can build resistance to many of these insecticides. The NCICAS used abamectin and hydramethylnon.[81] An excellent review of insecticides can be found in a review by Eggleston and Arruda.[82] In summary, low-toxicity pesticides applied in gels (or powders that are sealed in cracks or crevices) and kept out of contact with pets and children are recommended, followed by cleaning of surfaces containing any remaining cockroach bodies or frass (detritus of cockroaches).

McConnell et al[83] demonstrated that cockroach allergen levels were most effectively reduced by the combination of professional cleaning and sticky traps with insecticide. Reductions in Bla g 1 levels in cockroach-infested homes can be achieved by reducing infestations; however, the magnitude of the reduction depends on the quality of the cockroach eradication effort. When cockroach control with sticky traps performed either by professional entomologists or commercial companies was compared, homes in the entomologist group had significantly greater reductions in trap counts compared with a control and the commercial group at 12 months.[79] Although professional cleaning has been shown to be successful, one study demonstrated a difference between pest control delivered by a professional entomologist compared with commercial companies. Prolonged (12 months after intervention) reductions in cockroach allergen in homes were achieved by academic entomologists, but a lack of prolonged reduction was found in homes treated by commercial companies. In addition, reductions in Bla g 1 levels were obtained in cockroach-infested homes simply by reducing infestations and without addressing facilitating factors; however, the magnitude of allergen reduction was dependent on the thoroughness of the cockroach eradication.[79] Although this might imply that one should seek the services of an entomologist, it really points out the importance of hiring trained professionals with a detailed knowledge of cockroaches to perform cockroach extermination.

Alkyl and aryl neoalkanamides are highly effective repellents of male German cockroaches. Because of their broad spectrum of activity, longevity, and safety, these compounds, along with several other members of this family, have important applications as repellents of nuisance pests and arthropods of public health importance.[84]

The use of chemical agents, along with an intensive regimen of vacuum cleaning, is an important tool for removing material contaminated with allergenic proteins from cockroaches.[85] Professional cleaning, along with use of baited traps but without insecticide, appears to be effective in reducing cockroach allergen levels in kitchens of homes with high levels of cockroach allergen. The use of professional cleaning along with insecticides to reduce cockroach allergen levels also has been shown to be effective.[86-88] Addition of 0.5% sodium hypochlorite to denature residual allergens did not seem to improve allergen reduction.[89] Also, there was no difference in either Bla g 1 or Bla g 2 concentrations between cockroaches that ingested hydramethylnon gel and those in control colonies. The application of boric acid, which is a common pesticide, although killing many cockroaches appears paradoxically to increase the production of Bla g 2 by any surviving cockroaches.[90]

Successful allergen reduction was also demonstrated in cockroach-infested indoor environments by using routine extermination and vacuuming.[91] A reduction in the number of cockroaches and in total allergen levels in bedding dust can be achieved by caretakers of asthmatic children after a single home educational intervention by peer educators.[92]

Another study of integrated pest management compared hydramethylnon gel baits with conventional spraying for controlling German cockroaches in 2 residential buildings in Yasuj, Iran. The integrated pest management included educational programs using pamphlets, posters, and lectures; vacuuming; and application of hydramethylnon gel baits or cypermethrin on baseboard and cracks and crevices. Cockroach population densities were monitored with sticky traps. This integrated pest management approach reduced the rate of insecticide application and completely eliminated the cockroaches by week 4 from all of the treated units as opposed to the control approach that did not eliminate the cockroaches. Although it was highly effective, this integrated pest management approach was significantly more expensive than the conventional method.[93]

## Reservoirs

### Assessment

**Summary Statement 10: Measurement of cockroach allergen in dust might be considered for building occupants who are at increased risk of cockroach sensitization or sensitivity, although routine clinical use of this information has not been sufficiently studied. (Opt, D Evidence)**

Once the ongoing production of cockroach contaminants has been stopped by eliminating the cockroaches, reservoirs are important targets for intervention because they can release allergens into the environment long after the sources are gone. Reservoirs of cockroach allergens include carpeting, upholstered furniture, mattresses, cockroach fecal droppings known as frass, and dead cockroach bodies.[94,95] It might help to measure cockroach allergen concentrations in settled dust to determine whether reservoirs contain clinically significant amounts of cockroach allergens. The process for collecting dust and for

identifying laboratories to do the analysis was described in the rodent practice parameter.[96]

Currently, assays are available for measurement of Bla g 1 and Bla g 2 levels in dust, and there is evidence defining clinically relevant effects of exposure. The question is whether allergen measurement in dust would be helpful in the clinical setting for patients with suspected cockroach exposure. There is no consensus on this issue nor is there precedence for recommending dust analysis for cockroach exposure. Given the lack of prospective studies using dust analysis to guide clinical practice, we believe that routine use of cockroach allergen measurements is premature, although there are situations in which it might be helpful, such as identifying preintervention and postintervention levels to determine whether an intervention has been effective.

Air sampling of dust particles for cockroach allergen requires a higher level of training and at this time is not recommended in clinical practice. Although several researchers have shown that cockroach allergen can be found in airborne dust, the method of collection has varied with regard to sampling conditions (quiescent vs artificial disturbance), sampling duration (short vs long term), and type of sampling (intranasal impactors vs volumetric sampling pump).[97-100] Most of the mass of airborne cockroach allergen appears to be associated with larger airborne particles (>10 μm), but a substantial fraction of particulates can penetrate the thoracic regions and deeper (<10 μm).[65,99] Therefore airborne cockroach allergen can migrate throughout a home not only through tracking in reservoirs (eg, frass) from one room to another but also through air currents.[100]

## Abatement

**Summary Statement 11: Reservoirs of cockroach contaminants should be cleaned or removed to prevent additional exposure to occupants. (StrRec, A Evidence)**

The process of removing reservoirs is referred to as abatement. Early attempts at extermination alone to control cockroach allergen exposure were ineffective for improving asthma and allergy symptoms. A study of cockroach extermination in inner-city homes found that the cockroaches could be eliminated but the allergen persisted in the face of routine cleaning practices.[81] Recent results from comprehensive cleaning environmental control coupled with mold remediation, home fix-up, and education has been shown to be successful in several reports.[86]

Reservoirs of cockroach allergen can be anywhere that cockroaches are seen. Appearance of cockroaches has been significantly associated with higher cockroach allergen loading and concentration. Other factors related to reservoirs can contribute to high allergen levels. For example, carpeted homes in Cincinnati had significantly higher cockroach allergen concentrations than noncarpeted homes.[101] On the other hand, a meta-analysis of allergen studies showed that carpet was protective against high Bla g 1 and Bla g 2 levels in bedroom dust.[102] The rationale given was that carpeting can reduce tracking of cockroach allergen into bedrooms from the main reservoirs, such as kitchens. Daily vacuuming of carpets has been shown to reduce exposure.[95]

Data from the National Survey of Lead and Allergens in Housing was used to characterize the prevalence of cockroach allergen exposure in a nationally representative sample of US homes. Cockroach allergen (Bla g 1) concentrations exceed 2.0 U/g, a level previously associated with allergic sensitization, in 11% of US living room floors and 13% of kitchen floors and exceed 8.0 U/g, a level previously associated with asthma morbidity, in 3% of living room floors and 10% of kitchen floors.[103]

## Integrated pest management

**Summary Statement 12: Integrated pest management with a combination of interventions appears to be the most effective method for preventing and eliminating cockroach infestations. (StrRec, B Evidence)**

Although mitigation (removal of facilitating factors) is clearly important, clinical trials of this intervention generally have not been done in part because such trials tend to be performed in homes that are infested already. In addition, it has been difficult to separate the relative efficacy of source control (getting rid of the cockroaches) and abatement (getting rid of the reservoirs) because most trials of cockroach control use multiple interventions simultaneously, including removal of cockroaches and cleaning of residual cockroach allergens.

One trial that compared cockroach removal alone without cleaning with no intervention showed that Bla g 1 levels decreased by up to 93% in the kitchen and by 78% in the bedroom of study homes. The value of this approach is uncertain, however, because the cockroach allergens persisted at greater than clinically relevant morbidity thresholds after treatment.[104]

Another 11-week study with groups that received cockroach removal and professional cleaning, cleaning alone, and no intervention at 1 and 7 weeks found that cockroach counts decreased by 90% in homes with cockroach removal but not in control homes. Homes that had cockroach control with cleaning and homes with cleaning alone had similar reductions in Bla g 2 levels, leading the authors to conclude that cleaning was as effective as the combined intervention.[83] This result was reiterated in another study that found significant cockroach and allergen reductions in a 6-month intervention that combined integrated cockroach control, resident education, and professional cleaning in homes located in Raleigh, North Carolina.[86]

The investigators found that pest control alone was able to reduce environmental allergens to less than the proposed exposure thresholds with or without professional cleaning.[87] This result appears to be paradoxical and might be explained by the fact that specific strategies could reveal high efficacy in controlled investigations but lower effectiveness in "real-world" populations. Apparently, the specific tactics used to eliminate cockroaches significantly influence the effectiveness of the control and the amount of environmental allergen reduction.

Several studies have demonstrated the greater effectiveness of integrated pest management compared with routine chemical interventions in apartment buildings and the benefit of cockroach allergen reduction using integrated pest management.[105] Integrated pest management typically includes education of staff and residents, monthly monitoring, imposition of physical barriers to cockroach entry, and nonchemical (laying sticky traps) and chemical treatment based on monitoring results. Several reports of reductions on the order of 99% in dust-borne Bla g 1 have been reported.

When coupled with tailored environmental intervention, overall exposure reduction, including cockroach reduction, resulted in reduced asthma-associated morbidity.[106]

Arbes et al[87] investigated multiple interventions, including occupant education, insecticide bait, and professional cleaning for 6 months, for the abatement of cockroach allergen in

low-income urban homes. Vacuumed dust and multiple swab samples were collected at 0, 1, 2, 4, and 6 months in intervention homes and at 0 and 6 months in control homes. Room maps containing cockroach and allergen data were used to guide and monitor the interventions. Substantial reductions in cockroach allergen levels were achieved. Allergen levels were reduced to less than 2 U/g (sensitization threshold) in beds and to less than 8 U/g (asthma morbidity threshold) in other parts of the home.

Recently, physiologic regulation and developmental expression of cockroach-produced allergens have been investigated. In turn, this information has been used to guide current cockroach control strategies. Although successful removal of cockroach allergens from the infested environment has been difficult to accomplish with remedial sanitation, large-scale reductions in cockroach allergen levels to less than clinically relevant thresholds have recently been realized through suppression of cockroach populations.[107]

The use of HEPA filters was used in addition to extermination to reduce airborne particles; however, there was little evidence that cockroach allergens themselves were removed by these filters. Instead, the filters were used to eliminate other allergens and pollutants that could have served as confounding variables in the studies. As a result, this combination of home-based education, cockroach extermination, and HEPA filters reduced cockroach allergen levels by 51%.[108] A different study demonstrated that this combination was successful at reducing cockroach allergen for up to 1 year after the monitored intervention trial.[106]

Compared with control subjects, apartments receiving a single integrated pest management visit had fewer cockroaches at both 3 and 6 months. In addition, integrated pest management was associated with lower cockroach allergen concentrations in kitchens and beds. A single integrated pest management visit was more effective than the regular application of pesticides alone in managing pests and their consequences.[109]

**Summary Statement 13: Integrated pest management should be used to decrease cockroach exposure to reduce asthma morbidity. (StrRec, A Evidence)**

The ultimate importance of allergen reduction is to improve health outcomes. In recent years, there have been more studies examining the efficacy of insect and rodent pest removal to not only decrease allergen levels but also improve asthma symptoms. This provides the beneficial link between environmental intervention and improved health outcomes. Researchers from the NCICAS were the first to demonstrate that environmental interventions reduced asthma symptoms. They demonstrated that 1 year of controlled intervention tactics (professional cleaning, bait traps, insecticides, and HEPA filters) was able to reduce cockroach allergen levels and that these improvements were significantly correlated with decreased wheeze, decreased nighttime asthma symptoms, and fewer missed school days. These clinical improvements persisted for 1 year after the monitored environmental intervention had ceased.[106] In a similar study, Eggleston et al[108] used environmental interventions to reduce cockroach allergen levels and, subsequently, reduce daytime asthma symptoms.

There are relatively few studies focusing on the long-term outcomes or side effects of pest allergen reduction. There is concern about the long-term efficacy of integrated interventions. Morgan et al[106] demonstrated reduced allergen exposure and improved asthma symptoms for 1 year after interventions. In contrast to this, an earlier study from the NCICAS showed that the decrease in cockroach allergen levels was evident 6 months after interventions but that levels had returned to baseline 12 months after interventions.[88] As noted previously, Sever et al[79] found a significant reduction in cockroach allergen levels 12 months after interventions performed by professional entomologists but no reduction at 12 months after intervention by a commercial pest removal company. This demonstrates that continuous efforts (professionally or family directed) to eliminate these allergens might be necessary for sustained cockroach allergen reduction. Similar long-term studies are needed on the reduction of rodent allergen levels.

Integrated pest management in schools has been evaluated as well. In one study 2 school districts used conventional pest control and 1 district used integrated pest management to control pests. Cockroach counts and Bla g 1 concentrations were significantly lower in integrated pest management–treated schools. Not surprisingly, the number of cockroaches and levels of Bla g 1 were higher in food service areas than in classrooms and offices.[110]

## IMMUNOTHERAPY FOR COCKROACH ALLERGY

**Summary statement 14: Immunotherapy with cockroach extracts can be considered; however, it has only been evaluated in a limited number of studies, an effective dose is not known, and it is not clear how effective the treatment is for asthma or rhinitis. (Opt, C Evidence)**

Immunotherapy with cockroach extracts has been evaluated in a limited number of studies. In one controlled study, 28 subjects with asthma and cockroach sensitivity treated for up to 5 years, the active treatment group, experienced a significant improvement in symptom scores and reduced medication use relative to the control group.[111]

In another double-blind, placebo-controlled study immunotherapy with *P americana* extract was administered for 1 year in 50 patients with asthma, rhinitis, or both. The active treatment group had a significant improvement in clinical parameters compared with baseline values and with the placebo group. In addition, specific IgE levels decreased and $IgG_4$ levels increased after 1 year, confirming that the clinical improvement after cockroach immunotherapy is associated with corresponding immunologic changes. Unfortunately, the amount of cockroach allergen in the extract used in this study could not be determined.[112]

### REFERENCES

1. Eggleston PA, Rosenstreich D, Lynn H, Gergen P, Baker D, Kattan M, et al. Relationship of indoor allergen exposure to skin test sensitivity in inner-city children with asthma. J Allergy Clin Immunol 1998;102:563-70, (IIb).
2. Rabito FA, Carlson J, Holt EW, Iqbal S, James MA. Cockroach exposure independent of sensitization status and association with hospitalizations for asthma in inner-city children. Ann Allergy Asthma Immunol 2011;106:103-9, (III).
3. HUD's guidance on integrated pest management. Available at: http://www.nchh.org/Portals/0/HUD%20Guidance%20on%20IPM.pdf. Accessed July 20, 2013, (IV).
4. Integrated pest management (IPM) principles. US Environmental Protection Agency. Available at: http://www.epa.gov/opp00001/factsheets/ipm.htm. Accessed July 20, 2013.
5. Schal C, Hamilton RL. Integrated suppression of synanthropic cockroaches. Annu Rev Entomol 1990;35:521-51, (III).
6. Valles SM, Koehler PG, Brenner RJ. Comparative insecticide susceptibility and detoxification enzyme activities among pestiferous blattodea. Comp Biochem Physiol C Pharmacol Toxicol Endocrinol 1999;124:227-32, (III).

7. Jones S. American cockroach Available at: http://ohioline.osu.edu/hyg-fact/2000/pdf/2096.pdf. Accessed July 20, 2013.
8. Arruda LK, Vailes LD, Ferriani VP, Santos AB, Pomes A, Chapman MD. Cockroach allergens and asthma. J Allergy Clin Immunol 2001;107:419-28, (NR).
9. Santos AB, Chapman MD, Aalberse RC, Vailes LD, Ferriani VP, Oliver C, et al. Cockroach allergens and asthma in Brazil: identification of tropomyosin as a major allergen with potential cross-reactivity with mite and shrimp allergens. J Allergy Clin Immunol 1999;104:329-37, (III).
10. Yi MH, Jeong KY, Kim CR, Yong TS. IgE-binding reactivity of peptide fragments of Bla g 1.02, a major German cockroach allergen. Asian Pac J Allergy Immunol 2009;27:121-9, (LB).
11. Gore JC, Schal C. Expression, production and excretion of Bla g 1, a major human allergen, in relation to food intake in the German cockroach, *Blattella germanica*. Med Vet Entomol 2005;19:127-34, (LB).
12. Erban T, Stejskal V, Aulicky R, Krizkova-Kudlikova I, Nesvorna M, Hubert J. The influence of environmental temperature and humidity on temporal decomposition of cockroach allergens Bla g 1 and Bla g 2 in feces. J Med Entomol 2010; 47:1062-70, (LB).
13. He S, Zhang Z, Zhang H, Wei J, Yang L, Yang H, et al. Analysis of properties and proinflammatory functions of cockroach allergens Per a 1.01s. Scand J Immunol 2011;74:288-95, (LB).
14. Gustchina A, Li M, Wunschmann S, Chapman MD, Pomes A, Wlodawer A. Crystal structure of cockroach allergen Bla g 2, an unusual zinc binding aspartic protease with a novel mode of self-inhibition. J Mol Biol 2005;348: 433-44, (LB).
15. Wunschmann S, Gustchina A, Chapman MD, Pomes A. Cockroach allergen Bla g 2: an unusual aspartic proteinase. J Allergy Clin Immunol 2005;116: 140-5, (LB).
16. Glesner J, Wunschmann S, Li M, Gustchina A, Wlodawer A, Himly M, et al. Mechanisms of allergen-antibody interaction of cockroach allergen Bla g 2 with monoclonal antibodies that inhibit IgE antibody binding. PLoS One 2011; 6:e22223, (LB).
17. Mindykowski B, Jaenicke E, Tenzer S, Cirak S, Schweikardt T, Schild H, et al. Cockroach allergens Per a 3 are oligomers. Dev Comp Immunol 2010;34: 722-33, (LB).
18. Shin KH, Jeong KY, Hong CS, Yong TS. IgE binding reactivity of peptide fragments of Bla g 4, a major German cockroach allergen. Korean J Parasitol 2009;47:31-6, (LB).
19. Jeong KY, Yi MH, Jeong KJ, Lee H, Hong CS, Yong TS. Sequence diversity of the Bla g 4 cockroach allergen, homologous to lipocalins, from *Blattella germanica*. Int Arch Allergy Immunol 2009;148:339-45, (LB).
20. Jeong KJ, Jeong KY, Kim CR, Yong TS. IgE-binding epitope analysis of Bla g 5, the German cockroach allergen. Protein Pept Lett 2010;17:573-7, (LB).
21. Hindley J, Wunschmann S, Satinover SM, Woodfolk JA, Chew FT, Chapman MD, et al. Bla g 6: a troponin C allergen from *Blattella germanica* with IgE binding calcium dependence. J Allergy Clin Immunol 2006;117:1389-95, (LB).
22. Un S, Jeong KY, Yi MH, Kim CR, Yong TS. IgE binding epitopes of Bla g 6 from German cockroach. Protein Pept Lett 2010;17:1170-6, (III).
23. Sookrung N, Indrawattana N, Tungtrongchitr A, Bunnag C, Tantilipikorn P, Kwangsri S, et al. Allergenicity of native/recombinant tropomyosin, per a 7, of American cockroach (CR), *Periplaneta americana*, among CR allergic Thais. Asian Pac J Allergy Immunol 2009;27:9-17, (III).
24. Wang J, Calatroni A, Visness CM, Sampson HA. Correlation of specific IgE to shrimp with cockroach and dust mite exposure and sensitization in an inner-city population. J Allergy Clin Immunol 2011;128:834-7, (III).
25. Tungtrongchitr A, Sookrung N, Indrawattana N, Sae-Lim J, Puduang S, Phonrat B, et al. Seasonal levels of the major American cockroach allergen per a 9 (arginine kinase) in Bangkok and their relevance for disease severity. Asian Pac J Allergy Immunol 2009;27:1-7, (III).
26. Sudha VT, Arora N, Gaur SN, Pasha S, Singh BP. Identification of a serine protease as a major allergen (Per a 10) of *Periplaneta americana*. Allergy 2008;63:768-76, (LB).
27. Elias JA, Homer RJ, Hamid Q, Lee CG. Chitinases and chitinase-like proteins in T(H)2 inflammation and asthma. J Allergy Clin Immunol 2005;116:497-500, (IIb).
28. Reese TA, Liang HE, Tager AM, Luster AD, Van Rooijen N, Voehringer D, et al. Chitin induces accumulation in tissue of innate immune cells associated with allergy. Nature 2007;447:92-6, (LB).
29. Lee CG, Da Silva CA, Lee JY, Hartl D, Elias JA. Chitin regulation of immune responses: an old molecule with new roles. Curr Opin Immunol 2008;20:684-9, (LB).
30. Page K, Zhou P, Ledford JR, Day SB, Lutfi R, Dienger K, et al. Early immunological response to German cockroach frass exposure induces a Th2/Th17 environment. J Innate Immun 2011;3:167-79, (III).
31. Day SB, Zhou P, Ledford JR, Page K. German cockroach frass proteases modulate the innate immune response via activation of protease-activated receptor-2. J Innate Immun 2010;2:495-504, (III).
32. Wada K, Matsuwaki Y, Moriyama H, Kita H. Cockroach induces inflammatory responses through protease-dependent pathways. Int Arch Allergy Immunol 2011;155(Suppl. 1):135-41, (III).
33. Lee MF, Wang NM, Liu SW, Lin SJ, Chen YH. Induction of interleukin 8 by American cockroach allergens from human airway epithelial cells via extracellular signal regulatory kinase and jun N-terminal kinase but not p38 mitogen-activated protein kinase. Ann Allergy Asthma Immunol 2010;105: 234-40, (LB).
34. Pomes A, Melen E, Vailes LD, Retief JD, Arruda LK, Chapman MD. Novel allergen structures with tandem amino acid repeats derived from German and American cockroach. J Biol Chem 1998;273:30801-7, (LB).
35. Filep S, Tsay A, Vailes LD, Gadermaier G, Ferreira F, Matsui E, et al. Specific allergen concentration of WHO and FDA reference preparations measured using a multiple allergen standard. J Allergy Clin Immunol 2012;129:1408-10, (LB).
36. Filep S, Tsay A, Vailes L, Gadermaier G, Ferreira F, Matsui E, et al. A multi-allergen standard for the calibration of immunoassays: CREATE principles applied to eight purified allergens. Allergy 2012;67:235-41, (LB).
37. Crissman JR, Booth W, Santangelo RG, Mukha DV, Vargo EL, Schal C. Population genetic structure of the German cockroach (Blattodea: Blattellidae) in apartment buildings. J Med Entomol 2010;47:553-64, (III).
38. Gao P, Grigoryev DN, Rafaels NM, Mu D, Wright JM, Cheadle C, et al. CD14, a key candidate gene associated with a specific immune response to cockroach. Clin Exp Allergy 2010;40:1353-64, (III).
39. Gao P. Sensitization to cockroach allergen: immune regulation and genetic determinants. Clin Dev Immunol 2012;2012:563760, (LB).
40. Lodrup Carlsen KC, Carlsen KH, Buchmann MS, Wikstrom J, Mehl R. Cockroach sensitivity in Norway: a previously unidentified problem? Allergy 2002; 57:529-33, (III).
41. Gruchalla RS, Pongracic J, Plaut M, Evans R 3rd, Visness CM, Walter M, et al. Inner City Asthma Study: relationships among sensitivity, allergen exposure, and asthma morbidity. J Allergy Clin Immunol 2005;115:478-85, (III).
42. Bush RK, Wood RA, Eggleston PA. Laboratory animal allergy. J Allergy Clin Immunol 1998;102:99-112, (IV).
43. Huss K, Adkinson NF Jr, Eggleston PA, Dawson C, Van Natta ML, Hamilton RG. House dust mite and cockroach exposure are strong risk factors for positive allergy skin test responses in the Childhood Asthma Management Program. J Allergy Clin Immunol 2001;107:48-54, (IIb).
44. Matsui EC, Wood RA, Rand C, Kanchanaraksa S, Swartz L, Curtin-Brosnan J, et al. Cockroach allergen exposure and sensitization in suburban middle-class children with asthma. J Allergy Clin Immunol 2003;112:87-92, (III).
45. Arruda LK, Vailes LD, Mann BJ, Shannon J, Fox JW, Vedvick TS, et al. Molecular cloning of a major cockroach *(Blattella germanica)* allergen, Bla g 2. Sequence homology to the aspartic proteases. J Biol Chem 1995;270: 19563-8, (LB).
46. Chew GL, Perzanowski MS, Canfield SM, Goldstein IF, Mellins RB, Hoepner LA, et al. Cockroach allergen levels and associations with cockroach-specific IgE. J Allergy Clin Immunol 2008;121:240-5, (IIb).
47. Olmedo O, Goldstein IF, Acosta L, Divjan A, Rundle AG, Chew GL, et al. Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in New York City. J Allergy Clin Immunol 2011;128: 284-92.e7, (III).
48. Litonjua AA, Carey VJ, Burge HA, Weiss ST, Gold DR. Exposure to cockroach allergen in the home is associated with incident doctor-diagnosed asthma and recurrent wheezing. J Allergy Clin Immunol 2001;107:41-7, (III).
49. Chew GL, Carlton EJ, Kass D, Hernandez M, Clarke B, Tiven J, et al. Determinants of cockroach and mouse exposure and associations with asthma in families and elderly individuals living in New York City public housing. Ann Allergy Asthma Immunol 2006;97:502-13, (III).
50. Sarinho E, Schor D, Veloso MA, Rizzo JA. There are more asthmatics in homes with high cockroach infestation. Braz J Med Biol Res 2004;37:503-10, (III).
51. Turyk M, Curtis L, Scheff P, Contraras A, Coover L, Hernandez E, et al. Environmental allergens and asthma morbidity in low-income children. J Asthma 2006; 43:453-7, (III).
52. Donohue KM, Al-alem U, Perzanowski MS, Chew GL, Johnson A, Divjan A, et al. Anti-cockroach and anti-mouse IgE are associated with early wheeze and atopy in an inner-city birth cohort. J Allergy Clin Immunol 2008;122:914-20, (IIb).
53. Silva JM, Camara AA, Tobias KR, Macedo IS, Cardoso MR, Arruda E, et al. A prospective study of wheezing in young children: the independent effects of cockroach exposure, breast-feeding and allergic sensitization. Pediatr Allergy Immunol 2005;16:393-401, (III).

54. Ramsey CD, Celedon JC, Sredl DL, Weiss ST, Cloutier MM. Predictors of disease severity in children with asthma in Hartford, Connecticut. Pediatr Pulmonol 2005;39:268-75, (III).
55. Wisnivesky JP, Sampson H, Berns S, Kattan M, Halm EA. Lack of association between indoor allergen sensitization and asthma morbidity in inner-city adults. J Allergy Clin Immunol 2007;120:113-20, (IIb).
56. Amr S, Bollinger ME, Myers M, Hamilton RG, Weiss SR, Rossman M, et al. Environmental allergens and asthma in urban elementary schools. Ann Allergy Asthma Immunol 2003;90:34-40, (III).
57. Crain EF, Walter M, O'Connor GT, Mitchell H, Gruchalla RS, Kattan M, et al. Home and allergic characteristics of children with asthma in seven U.S. urban communities and design of an environmental intervention: the Inner-City Asthma Study. Environ Health Perspect 2002;110:939-45, (IIb).
58. Rosenstreich DL, Eggleston P, Kattan M, Baker D, Slavin RG, Gergen P, et al. The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. N Engl J Med 1997;336:1356-63, (Ib).
59. Litonjua AA, Milton DK, Celedon JC, Ryan L, Weiss ST, Gold DR. A longitudinal analysis of wheezing in young children: the independent effects of early life exposure to house dust endotoxin, allergens, and pets. J Allergy Clin Immunol 2002;110:736-42, (IIa).
60. Tepas EC, Litonjua AA, Celedon JC, Sredl D, Gold DR. Sensitization to aeroallergens and airway hyperresponsiveness at 7 years of age. Chest 2006;129:1500-8, (III).
61. Finn PW, Boudreau JO, He H, Wang Y, Chapman MD, Vincent C, et al. Children at risk for asthma: home allergen levels, lymphocyte proliferation, and wheeze. J Allergy Clin Immunol 2000;105:933-42, (III).
62. Weiss ST, O'Connor GT, DeMolles D, Platts-Mills T, Sparrow D. Indoor allergens and longitudinal FEV1 decline in older adults: the Normative Aging Study. J Allergy Clin Immunol 1998;101:720-5, (III).
63. Lewis SA, Weiss ST, Platts-Mills TA, Burge H, Gold DR. The role of indoor allergen sensitization and exposure in causing morbidity in women with asthma. Am J Respir Crit Care Med 2002;165:961-6, (IIb).
64. Chew GL, Burge HA, Dockery DW, Muilenberg ML, Weiss ST, Gold DR. Limitations of a home characteristics questionnaire as a predictor of indoor allergen levels. Am J Respir Crit Care Med 1998;157:1536-41, (IIb).
65. Peters JL, Levy JI, Rogers CA, Burge HA, Spengler JD. Determinants of allergen concentrations in apartments of asthmatic children living in public housing. J Urban Health 2007;84:185-97, (III).
66. Steinman H. Cockroach, German. Thermo Scientific; 2011. Available at: http://www.phadia.com/en/Allergen-information/ImmunoCAP-Allergens/Insects/Allergens/Cockroach-German/. Accessed June 24, 2012.
67. Londres MI, Sarinho FW, Miranda PJ, Sole D, Sarinho E. Allergy to cockroaches: challenges in diagnosis. Clin Lab 2011;57:969-74, (IV).
68. Lopes M, Miranda P, Sarinho E. Use of the skin prick test and specific immunoglobulin E for the diagnosis of cockroach allergy. J Pediatr (Rio J) 2006;82:204-9, (IIb).
69. Sastre J, Ibanez MD, Lombardero M, Laso MT, Lehrer S. Allergy to cockroaches in patients with asthma and rhinitis in an urban area (Madrid). Allergy 1996;51:582-6, (III).
70. Sun BQ, Lai XX, Gjesing B, Spangfort MD, Zhong NS. Prevalence of sensitivity to cockroach allergens and IgE cross-reactivity between cockroach and house dust mite allergens in Chinese patients with allergic rhinitis and asthma. Chin Med J (Engl) 2010;123:3540-4, (III).
71. Ghaffari J, Khademloo M, Saffar MJ, Rafiei A, Masiha F. Hypersensitivity to house dust mite and cockroach is the most common allergy in north of iran. Iran J Immunol 2010;7:234-9, (III).
72. Seedat RY, Claassen J, Claassen AJ, Joubert G. Mite and cockroach sensitisation in patients with allergic rhinitis in the Free State. South Afr Med J 2010;100:160-3, (III).
73. Turkeltaub PC. Biological standardization. Arb Paul Ehrlich Inst Bundesamt Sera Impfstoffe Frankf A M 1997;91:145-56, (IV).
74. James R, Mitchell H, Gergen PJ, Eggleston PA, Slater JE. Analyzing of ID50EAL data for the standardization of German cockroach allergen extracts in the U.S. Arb Paul Ehrlich Inst Bundesamt Sera Impfstoffe Frankf A M 2006;95:117-27, 155. (IIb).
75. Slater JE, James R, Pongracic JA, Liu AH, Sarpong S, Sampson HA, et al. Biological potency of German cockroach allergen extracts determined in an inner city population. Clin Exp Allergy 2007;37:1033-9, (IIb).
76. Nowak-Wegrzyn AH, Bencharitiwong R, Schwarz J, David G, Eggleston P, Gergen PJ, et al. Mediator release assay for assessment of biological potency of German cockroach allergen extracts. J Allergy Clin Immunol 2009;123:949-55.e1, (LB).
77. Michel S, Yawalkar N, Schnyder B, Fischer B, Helbling A. Eczematous skin reaction to atopy patch testing with cockroach in patients with atopic dermatitis. J Investig Allergol Clin Immunol 2009;19:173-9, (IIb).
78. Sheehan WJ, Rangsithienchai PA, Wood RA, Rivard D, Chinratanapisit S, Perzanowski MS, et al. Pest and allergen exposure and abatement in inner-city asthma: a work group report of the American Academy of Allergy, Asthma & Immunology Indoor Allergy/Air Pollution Committee. J Allergy Clin Immunol 2010;125:575-81, (Ia).
79. Sever ML, Arbes SJ Jr, Gore JC, Santangelo RG, Vaughn B, Mitchell H, et al. Cockroach allergen reduction by cockroach control alone in low-income urban homes: a randomized control trial. J Allergy Clin Immunol 2007;120:849-55, (Ib).
80. Pesticide Reregistration Status. US Environmental Protection Agency; 2012. Available at: http://www.epa.gov/oppsrrd1/reregistration/status.htm. Accessed June 24, 2012.
81. Eggleston PA, Wood RA, Rand C, Nixon WJ, Chen PH, Lukk P. Removal of cockroach allergen from inner-city homes. J Allergy Clin Immunol 1999;104:842-6, (Ib).
82. Eggleston PA, Arruda LK. Ecology and elimination of cockroaches and allergens in the home. J Allergy Clin Immunol 2001;107(suppl):S422-9.
83. McConnell R, Jones C, Milam J, Gonzalez P, Berhane K, Clement L, et al. Cockroach counts and house dust allergen concentrations after professional cockroach control and cleaning. Ann Allergy Asthma Immunol 2003;91:546-52, (Ib).
84. Steltenkamp RJ, Hamilton RL, Cooper RA, Schal C. Alkyl and aryl neoalkanamides: highly effective insect repellents. J Med Entomol 1992;29:141-9, (IIb).
85. Liccardi G, Cazzola M, D'Amato M, D'Amato G. Pets and cockroaches: two increasing causes of respiratory allergy in indoor environments. Characteristics of airways sensitization and prevention strategies. Respir Med 2000;94:1109-18, (IIb).
86. Arbes SJ Jr, Sever M, Archer J, Long EH, Gore JC, Schal C, et al. Abatement of cockroach allergen (Bla g 1) in low-income, urban housing: a randomized controlled trial. J Allergy Clin Immunol 2003;112:339-45, (Ib).
87. Arbes SJ Jr, Sever M, Mehta J, Gore JC, Schal C, Vaughn B, et al. Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: month 12 continuation results. J Allergy Clin Immunol 2004;113:109-14, (III).
88. Gergen PJ, Mortimer KM, Eggleston PA, Rosenstreich D, Mitchell H, Ownby D, et al. Results of the National Cooperative Inner-City Asthma Study (NCICAS) environmental intervention to reduce cockroach allergen exposure in inner-city homes. J Allergy Clin Immunol 1999;103:501-6, (III).
89. Wood RA, Eggleston PA, Rand C, Nixon WJ, Kanchanaraksa S. Cockroach allergen abatement with extermination and sodium hypochlorite cleaning in inner-city homes. Ann Allergy Asthma Immunol 2001;87:60-4, (IIa).
90. Zhang YC, Perzanowski MS, Chew GL. Sub-lethal exposure of cockroaches to boric acid pesticide contributes to increased Bla g 2 excretion. Allergy 2005;60:965-8, (IIb).
91. Sarpong SB, Wood RA, Eggleston PA. Short-term effects of extermination and cleaning on cockroach allergen Bla g 2 in settled dust. Ann Allergy Asthma Immunol 1996;76:257-60, (IIb).
92. McConnell R, Milam J, Richardson J, Galvan J, Jones C, Thorne PS, et al. Educational intervention to control cockroach allergen exposure in the homes of hispanic children in Los Angeles: results of the La Casa study. Clin Exp Allergy 2005;35:426-33, (Ib).
93. Shahraki GH, Hafidzi MN, Khadri MS, Rafinejad J, Ibrahim YB. Cost-effectiveness of integrated pest management compared with insecticidal spraying against the German cockroach in apartment buildings. Neotropical Entomol 2011;40:607-12, (IIb).
94. Leung TF, Wong YS, Chan IH, Yung E, Sy HY, Lam CW, et al. Domestic exposure to aeroallergens in Hong Kong families with asthmatic children. Pediatr Pulmonol 2011;46:632-9, (III).
95. Wu FF, Wu MW, Pierse N, Crane J, Siebers R. Daily vacuuming of mattresses significantly reduces house dust mite allergens, bacterial endotoxin, and fungal beta-glucan. J Asthma 2012;49:139-43, (III).
96. Phipatanakul W, Matsui E, Portnoy J, Williams PB, Barnes C, Kennedy K, et al. Environmental assessment and exposure reduction of rodents: a practice parameter. Ann Allergy Asthma Immunol 2012;109:375-87, (Ia).
97. Goldstein IF, Reed CE, Swanson MC, Jacobson JS. Aeroallergens in New York inner-city apartments of asthmatics. Experientia Suppl 1987;51:133-8, (III).
98. De Lucca SD, Taylor DJ, O'Meara TJ, Jones AS, Tovey ER. Measurement and characterization of cockroach allergens detected during normal domestic activity. J Allergy Clin Immunol 1999;104:672-80, (IIb).
99. de Blay F, Sanchez J, Hedelin G, Perez-Infante A, Verot A, Chapman M, et al. Dust and airborne exposure to allergens derived from cockroach *(Blattella germanica)* in low-cost public housing in Strasbourg (France). J Allergy Clin Immunol 1997;99:107-12, (III).
100. Esposito WA, Chew GL, Correa JC, Chillrud SN, Miller RL, Kinney PL. Quantitative measurement of airborne cockroach allergen in New York City apartments. Indoor Air 2011;21:512-20, (IIb).
101. Cho SH, Reponen T, Bernstein DI, Olds R, Levin L, Liu X, et al. The effect of home characteristics on dust antigen concentrations and loads in homes. Sci Total Environ 2006;371:31-43, (III).

102. Wilson J, Dixon SL, Breysse P, Jacobs D, Adamkiewicz G, Chew GL, et al. Housing and allergens: a pooled analysis of nine US studies. Environ Res 2010;110:189-98, (IIa).
103. Cohn RD, Arbes SJ Jr, Jaramillo R, Reid LH, Zeldin DC. National prevalence and exposure risk for cockroach allergen in U.S. households. Environ Health Perspect 2006;114:522-6, (III).
104. Williams LW, Reinfried P, Brenner RJ. Cockroach extermination does not rapidly reduce allergen in settled dust. J Allergy Clin Immunol 1999;104:702-3.
105. Wang C, Bennett GW. Cost and effectiveness of community-wide integrated pest management for German cockroach, cockroach allergen, and insecticide use reduction in low-income housing. J Econ Entomol 2009;102:1614-23, (IIb).
106. Morgan WJ, Crain EF, Gruchalla RS, O'Connor GT, Kattan M, Evans R 3rd, et al. Results of a home-based environmental intervention among urban children with asthma. N Engl J Med 2004;351:1068-80, (IIa).
107. Gore JC, Schal C. Cockroach allergen biology and mitigation in the indoor environment. Annu Rev Entomol 2007;52:439-63, (NR).
108. Eggleston PA, Butz A, Rand C, Curtin-Brosnan J, Kanchanaraksa S, Swartz L, et al. Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. Ann Allergy Asthma Immunol 2005;95:518-24, (Ib).
109. Kass D, McKelvey W, Carlton E, Hernandez M, Chew G, Nagle S, et al. Effectiveness of an integrated pest management intervention in controlling cockroaches, mice, and allergens in New York City public housing. Environ Health Perspect 2009;117:1219-25, (IIa).
110. Nalyanya G, Gore JC, Linker HM, Schal C. German cockroach allergen levels in North Carolina schools: comparison of integrated pest management and conventional cockroach control. J Med Entomol 2009;46:420-7, (IIb).
111. Kang BC, Johnson J, Morgan C, Chang JL. The role of immunotherapy in cockroach asthma. J Asthma 1988;25:205-18, (IIb).
112. Srivastava D, Gaur SN, Arora N, Singh BP. Clinico-immunological changes post-immunotherapy with Periplaneta americana. Eur J Clin Invest 2011;41:879-88, (III).

## APPENDIX A: A SHORT GUIDE TO WORKING WITH INTEGRATED PEST MANAGEMENT PROFESSIONALS

### Pest control and management companies should be licensed

Most state or provincial governments issue licenses for pest control and pesticide application. A current operator's license indicates they have passed an examination and that their training is up to date. The government department or agency issuing the license can provide information about its pesticide certification and training programs and whether periodic recertification is required. Company employees should be bonded.

When qualifying an integrated pest management professional, ask for the following:

- their qualifications, including training, experience, and references, and
- a written description or scope of services.

### Determine whether the company has a good track record

- Is the company affiliated with a professional pest control association? Professional associations keep members informed of new developments in pest control methods, safety, training, research, and regulations. Members agree to honor a code of ethics.
- Ask friends and neighbors whether they have dealt with the company.
- If you are concerned, call your state or local pesticide regulatory agency and find out whether they have received complaints about the company.
- Does the company guarantee its work? You should be skeptical about a company that does not guarantee its work.
- The guarantee might become invalid if you make structural alterations to your home without updating the pest control company.

All companies should inspect your premises and outline a recommended and comprehensive program, including the pests to be controlled, the extent of the problem, and how to determine whether additional treatment is needed. Several expert committees have found that cockroach control through integrated pest management is effective in reducing asthma symptoms. The company and the application technician should be knowledgeable about integrated pest management. Information should be provided that includes the specific pesticide being applied and a description of the application techniques. Ask for a copy of the label or associated booklet to verify that any chemical used has a federal registration number and that the application is consistent with the intended use, as stated on the label. This will also provide basic information, including known adverse reactions after the application.

The integrated pest management service technician should be conversant in a variety of integrated pest management strategies and should discuss these strategies with the client. They should provide instructions to reduce pesticide exposures to residents, such as vacating the home, emptying the cupboards, and placing any bait out of reach of children and pets. They should be able to clearly discuss steps to take to minimize pest problems in the future. If possible, clients should be present during visits such that during the initial inspection, the technician can explain the steps he or she proposes to take and review these when the work is completed.

### Integrated pest management service contractors

There are 3 programs that credential pest management firms on professionalism and integrated pest management services. They are GreenShield Certified, GreenPro, and EcoWise Certified (California only).

Use these 3 questions as a guide to determine whether you are receiving integrated pest management services:

1. Does your contractor routinely monitor for pests so that problems can be avoided?
2. Are baits and traps used instead of pesticide sprays and ONLY when pests are present?
3. Does the integrated pest management service technician provide suggestions to prevent future pest problems?

## APPENDIX B: A QUICK GUIDE TO GOOD ENVIRONMENTAL ASSESSMENT REPORTS

*Assessment report:* A summary of the investigation that shows the information the assessor gathered and is dependent on the quality of their assessment procedures. It also provides an indication of their thoroughness. Assessment values are often dependant on how forthcoming the client was and whether they are willing to let someone explore every part of their house.

Environmental assessment reports should include all or most of the following:

*Scope of work:* Indicates the purpose and objectives of the assessment. It should also describe what testing was used and why to develop any recommendations.

*Report limitations*: Indicates how and why the data gathered are limited in their use and that any recommendations are based on data gathered on the day of assessment.

*Assessment summary:* There should be a summary of the visual assessment: what was observed, what was evaluated, and the results of the visual assessment.

*Assessment results:* This should be a discussion of any quantitative measurements taken and samples collected and tested. It should include both the results and an interpretation of the results.

*Recommendations for environmental management:* There should be a discussion of recommendations based on the results of the visual assessment and the environmental measurement. These recommendations should include specific actions that can be taken to try to resolve any potential environmental concerns identified.

*Results of testing:* This can be the most confusing part of the report. How results are presented is essential to the comprehension of both you and the patient. It is important for you to have an understanding of the following: units of measurement, accuracy of instruments and methods, and how to interpret results. Common units of measurements you might find in the report include ppm, ppb, μg/g, U/g, ng/g, mg/L, and mg/kg. For particle counting, units might include μm, nm, cts, and $\mu g/m^3$.

*Limit of detection:* All test results should indicate the detection limit for each test performed. This is the lowest reproducible value for a device or procedure that has a stated probability of being able to identify an analyte and report it at a value greater than zero.

*Instrument detection limit (IDL):* Specific to an instrument or detector

*Method detection limit (MDL):* Adjusted detection limit based on the method used to analyze the sample.

Does the laboratory used matter? Yes! Look for test results from accredited laboratories. Laboratory accreditation might include ISO9001, AIHA-Accredited, ELAP, CLIA, NAB, US Environmental Protection Agency, and AOAC. Ask for the Laboratory Statement of Qualifications and a reference list.

## REFERENCES

Environmental Protection Agency. Citizen's guide to pest control and pesticide safety: using chemical pest controls. Available at: http://www.epa.gov/oppfead1/Publications/Cit_Guide/. Accessed July 20, 2013.

Cockroach control manual. University of Nebraska, Lincoln. Nebraska. Available at: http://lancaster.unl.edu/pest/roach/Cockroach%20Manual.pdf. Accessed July 20, 2013.

National Pest Information Center. Oregon State University, Corvallis, Oregon. Available at: http://npic.orst.edu/pest/ipm.html. Accessed July 20, 2013.

Stop pests in housing. Northeastern IPM Center, Cornell University, Ithaca, NY. Available at: http://www.stoppests.org/what-is-ipm/. Accessed July 20, 2013.

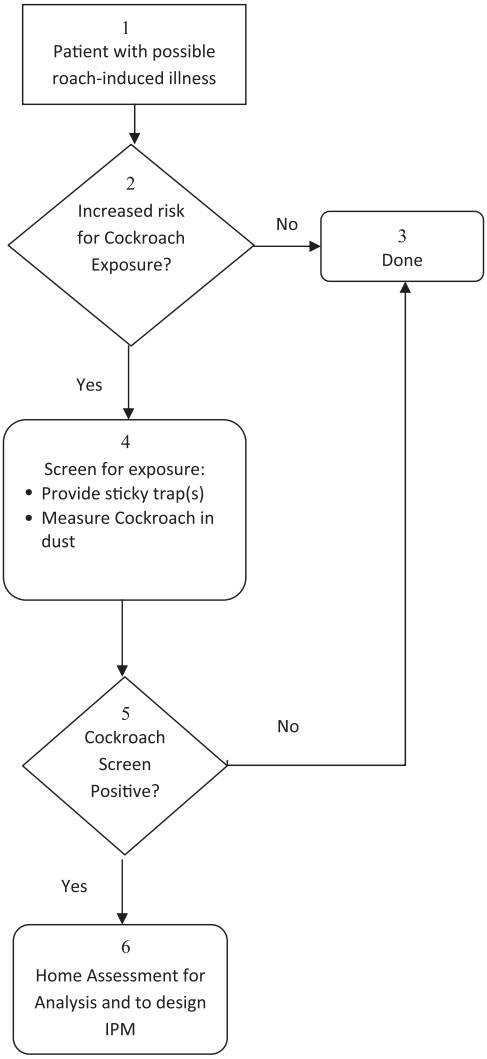


**FIG E1.** Algorithm for screening for the presence of cockroaches. This is an iterative process. Exposure and associated risk factors can vary over time.

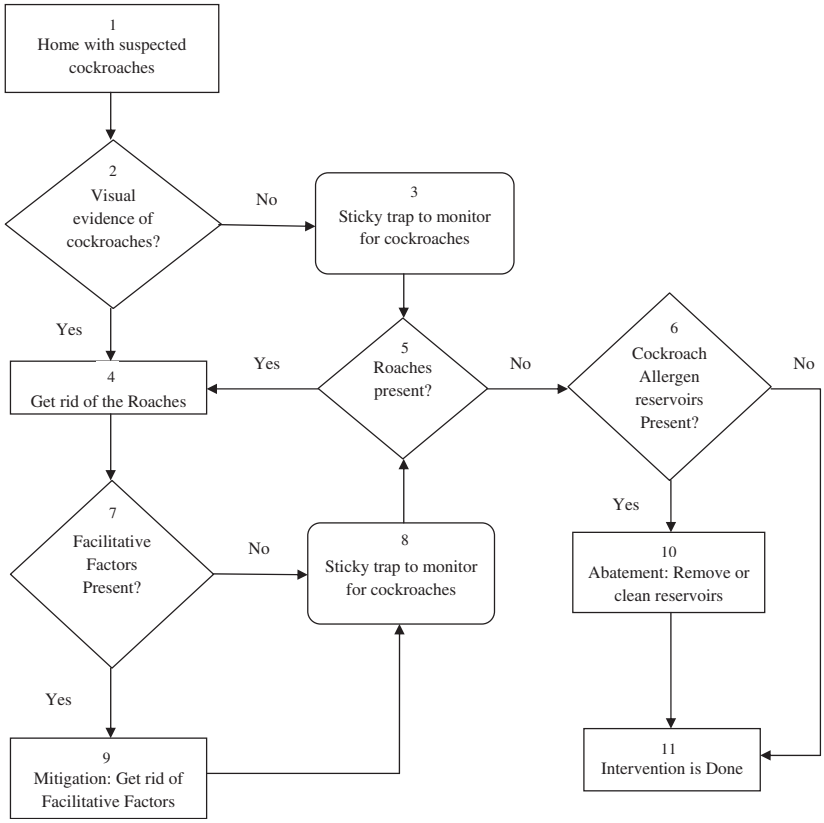


**FIG E2.** Environmental assessment algorithm. This is an iterative process. Exposure and associated risk factors can vary over time.

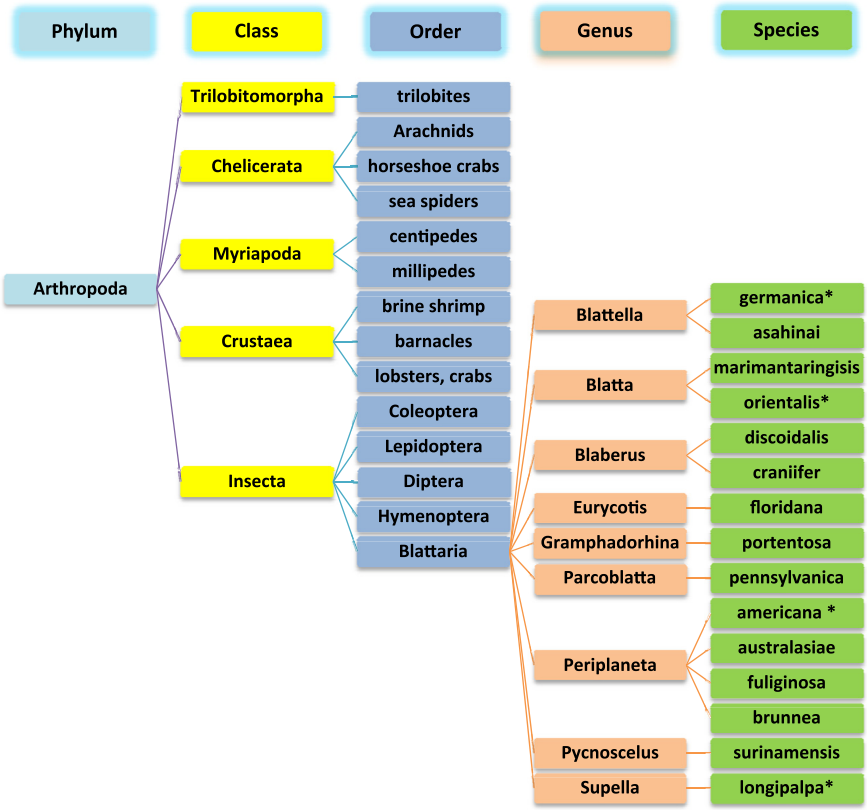


**FIG E3.** Taxonomy of cockroaches. *Significant indoor allergens.

**TABLE E1.** Techniques for cockroach allergen reduction

| |
|---|
| Block means of ingress |
| • Caulk and seal cracks and holes on the building's exterior |
| • Install door sweeps and weatherproofing seals on exterior doors and garage doors |
| • Screen and weatherproof windows and attic vents |
| • Remove excess vegetation and prune branches that touch the building |
| Withhold sources of food and water |
| • Properly store food in sealed containers |
| • Maintain regular cleaning schedules |
| • Regularly dispose of garbage |
| • Promptly repair water leaks |
| • Place stoppers in all drains and promptly wipe up spills |
| Eliminate shelter |
| • Move firewood, lumber, and trash cans away from the building |
| • Keep basements and crawl spaces free of clutter |
| • Keep gutters clean and well maintained |
| Eliminate contaminant sources |
| • Use sticky traps to monitor and trap cockroaches |
| • Judiciously use insecticides |
| Reservoirs |
| • Use HEPA vacuuming to remove cockroach contaminants |
| • Use mattress covers |
| • Remove contaminated materials |
| Public policy |
| • Legal housing codes (development and enforcement) |
| • City housing and environmental commissions |
| • Neighborhood housing coalitions |

Adapted in part from Sheehan et al.[78]