U.S. Department of Housing and Urban Development

Healthy Homes Issues: Pesticides in the Home – Use, Hazards, and Integrated Pest Management

HEALTHY HOMES INITIATIVE (HHI) BACKGROUND INFORMATION
Version 3
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Healthy Homes Issues: Pesticides -- Use, Hazards, and Integrated Pest Management

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Preface

In 1998, Congress appropriated funds and directed the U.S. Department of Housing and Urban Development (HUD) to "develop and implement a program of research and demonstration projects that would address multiple housing-related problems affecting the health of children." In response, HUD solicited the advice of experts in several disciplines and developed a preliminary plan for the Healthy Homes Initiative (HHI). The primary goal of the HHI is to protect children from housing conditions that are responsible for multiple diseases and injuries. As part of this initiative, HUD has prepared a series of papers to provide background information to their current HHI grantees, as well as other programs considering adopting a healthy homes approach. This background paper focuses on pesticides and provides a brief overview of the current status of knowledge on:

- The extent and nature of pesticide uses and hazards in the home;
- Assessment methods for pesticide hazards in the home;
- Mitigation methods for pesticide hazards in the home, including preventive measures such as integrated pest management (IPM); and
- Research needs regarding residential pesticide hazards and IPM in the home.

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Table of Contents

List of Tables

Executive Summary

Broadly defined, pesticides are substances or mixtures of substances used to control pests such as insects, rodents, weeds, fungi, or bacteria. The use of pesticides is widespread in the United States, particularly in agricultural settings, though use in home and garden applications is on the rise. Pesticides are generally classified by their target pest group and function, as well as by their formulation and chemical class. Use patterns for residential and agricultural insecticides have evolved over the last 50 years, during which time three major classes of compounds — the organochlorines, the organophosphates, and the pyrethroids — have been used.

The prevalence of pesticide use has raised significant concern over the potential health effects associated with both acute and chronic exposure to these compounds. Children, in particular, may be especially vulnerable to the toxicants present in many commercial pest control products. Based on evidence of or potential for serious and persistent toxic effects, the primary compounds used in the pesticide market have undergone a dramatic shift in recent years, with the elimination of some substances from commercial use and the development of alternative strategies for controlling pests in and around the home.

Multiple hazards are associated with pesticide use in the home. Low-dose, chronic exposure may negatively impact the nervous system, though long-term effects are still not thoroughly understood. Cases of poisoning resulting from accidental acute exposure to pesticides have been well documented in children. Some research has suggested a possible link between pesticide exposure and neurodevelopmental effects, as well as potential asthma exacerbation. These risks may be amplified in low-income urban neighborhoods, where substandard housing conditions increase the chances of pest infestation and, consequently, pesticide usage. Efforts are underway to assess the degree of residential pesticide use in the U.S. and effects of exposure, particularly upon children and pregnant women. Methods of quantifying pesticide use include home surveys and questionnaires, human biological sampling, and sampling of environmental media within the home.

Because of the potential health effects of pesticide exposure, it is preferable to minimize pesticide use in residential situations. Techniques to mitigate pesticide hazards include the following:

- Public education to prevent improper pesticide use;
- Decontamination following inappropriate use of pest control substances; and
- Adoption of an integrated pest management (IPM) approach to pest control, which minimizes the use of chemical pesticides.

Case studies on the use of IPM in schools and residential settings provide examples of promising results from the use of IPM in lieu of “traditional” pest control methods. Additional studies are needed to better characterize the risks of exposure to pest control products and to evaluate the effects of intervention strategies, such as those used in integrated pest management, on health outcomes associated with pest infestation and pesticide use.

Pesticides in the Home:
Use, Hazards, and Integrated Pest Management

1.0 OVERVIEW OF PESTICIDE USE IN THE HOME

Today, there are a wide variety of tools available for pest control in residential environments, including the use of chemical pesticides as well as various non-chemical techniques. Broadly defined, a pesticide is any agent used to suppress pests such as insects, rodents, weeds, fungi, or bacteria. Though often misunderstood to refer only to insecticides, which target insect pests, the term pesticide also applies to herbicides (plants), fungicides (fungi), rodenticides (rodents), acaricides (mites), and various other substances used to control pests. Many common household products are also considered pesticides, such as kitchen disinfectants and products that eliminate mold and mildew (Olkowski et al., 1991; EPA, 2002a). In addition to being classified by their target pest group and function, pesticides are often described according to their formulation and chemical class. Some of the major chemical classes of pesticides are shown in Table 1 below.

Table 1. Selected Major Chemical Classes of Pesticides

Pesticides Classified by Chemical Category	
Category	**Examples**
Organochlorines*	Aldrin, chlordane, DDT
Organophosphates	chlorpyrifos (Dursban), diazinon, acephate (Orthene), malathion
Carbamates	carbaryl (Sevin), propoxur (Baygon)
Synthetic pyrethroids	permethrin, resmethrin, cypermethrin, cyfluthrin
Inorganic	boric acid, chlorates, cryolite, diatomaceous earth, silica aerogel, chromated copper arsenate (CCA)
Organic (botanical)	garlic, limonene, neem, nicotine, pyrethrum, rotenone, ryania, sabadilla
Organic (microbial)	*Bacillus thuringiensis, B. popillae, Cephalasporium, lecanii, Morrenia odorata, Nosema locustae*
Miscellaneous	Horticultural oils, insect growth regulators, insecticidal soaps, insect pheromones

Source: Olkowski et al., 1991. Table 6.3
*Aldrin, chlordane, and DDT are no longer available in the U.S.
Note: The names in parentheses are trade names that have become so common that the chemical or generic name is less known.

Given the toxicity of pesticides and their application in the home, the sheer volume of their use is cause for concern. Approximately 2.2 billion pounds of pesticide active ingredients are used each year, or eight pounds for each man, woman and child in the U.S. (EPA, 1997; Natural Resources Defense Council, 1997). The U.S. Environmental Protection Agency (EPA) uses information from a variety of annual surveys to publish estimates on the production and use of pesticides in the United States. The most recent report (EPA, 2004) includes data on 2000-

2001 market estimates. Table 2 presents the most common active ingredients in home and garden pesticides in 2001. The inventory generally indicates that most pesticides are used in agriculture, with home and garden use accounting for less than ten percent of the total. The latest market estimate compilations from EPA are presented online, as available, at http://www.epa.gov/oppbead1/pestsales/.

Table 2. Most Commonly Used Pesticide Active Ingredients in Home and Garden[1] Market, 2001 (Ranked by Range in Millions of Pounds of Active Ingredient)

2001 Rank	Active Ingredient	Type	Million pounds active ingredient	Chemical class
1	2,4-D	Herbicide	8 - 11	Chlorinated phenoxy compound
2	Glyphosate	Herbicide	5 - 8	Plant hormone-type
3	Pendimethalin	Herbicide	3 - 6	Dinitroaniline
4	Diazinon[2]	Insecticide	4 - 6	Organophosphate
5	MCPP	Herbicide	4 - 6	Hormone-type phenoxy
6	Carbaryl	Insecticide	2 - 4	Carbamate
7	Dicamba	Herbicide	2 - 4	Benzoic acid type
8	Malathion	Insecticide	2 - 4	Organophosphate
9	DCPA	Herbicide	1 - 3	Phthalate
10	Benefin	Herbicide	1 - 3	Dinitrotoluidine

Note: Includes applications to homes and gardens by professional applicators and excludes pesticides used for agriculture. Does not include moth controls: Paradiclorobenzene (30 - 35 million pounds per year) and naphthalene (2 - 4 million pounds per year). Also does not include insect repellent N,N-diethyl-meta-toluamide (5 - 7 millions pounds per year). Source: EPA proprietary data (EPA, 2004).
[1] Garden herbicides would not be expected to have as much impact on home exposure as the insecticides used inside the house.
[2] As of December 31, 2004, diazinon is no longer produced or sold in the United States.

The data also demonstrate that home and garden pesticide use has been increasing since 1995, reversing the trend of the last two decades. Herbicides used to kill lawn weeds are used more than other pesticides; seven of the 10 most commonly used pesticides around the home are weedkillers, and approximately 71 million pounds of herbicide active ingredients were used on lawns in 2001 (EPA, 2004).

Some research has been conducted on the intrusion of lawn chemicals into the home via track-in or spray drift (Nishioka et al., 1997). In general, however, insecticides used in the home would be expected to represent most of the exposure. Exposure may also occur outside the residence, such as at school or the work place.

Of particular concern is children's exposure to pesticides because of research that indicates they are more vulnerable to the effects of many toxicants. Children also generally receive higher exposures to pesticides (i.e., per kilogram of body weight) through food and as a result of their behavior (e.g., play and mouthing behavior) (EPA, 2000a; EPA, 2000b; Natural Resources Defense Council, 1997; Olden and Guthrie, 2000). Congress recognized the importance of protecting children when it unanimously passed the Food Quality Protection Act (FQPA) in 1996. The law represents a major breakthrough, amending both major pesticide laws to establish a more consistent, protective regulatory scheme, grounded in sound science. It mandates a single, health-based standard for all pesticides in all foods; provides special protections for infants and children; expedites approval of safer pesticides; creates incentives for the development and maintenance of effective crop protection tools for American farmers; and requires periodic re-evaluation of pesticide registrations and tolerances to ensure that the scientific data supporting pesticide registrations will remain up to date in the future (EPA, 2003a).

In recent years, the primary compounds used in the pesticide market have undergone a dramatic shift. Use patterns for residential and agricultural insecticides have evolved over the last 50 years, during which time three major classes of compounds — the organochlorines, the organophosphates, and the pyrethroids — have been used. The following discussion and the accompanying role in current human exposure patterns will be based on two representative compounds of each class: DDT (dichlorodiphenyltrichloroethane) and chlordane for the organochlorine class, diazinon and chlorpyrifos for the organophosphate class, and permethrin and cypermethrin for the pyrethroid class.

The insecticidal properties of DDT were discovered in 1939, and its greatest use in the U.S. occurred in the 1940s and 1950s; its use was phased out in the 1960s, and all crop application uses were canceled in 1972 (EPA, 2002b). From 1948 to 1978, chlordane was used in the United States as a pesticide on agricultural crops, lawns, and gardens and as a fumigating agent. In 1978, the EPA canceled the use of chlordane on food crops and phased out other above-ground uses for the next five years. From 1983 to 1988, the only approved use of chlordane was to control termites in homes. The pesticide was applied underground around the foundation of homes. Indoor residential use appears to have been limited. In 1988, all approved uses of chlordane in the United States were terminated; however, manufacture for export continued until 1997 (EPA, 2005c).

The insecticidal properties of organophosphates were discovered in 1932; however, they did not achieve widespread use for agricultural and residential pest control until lower cost organochlorines were banned. While the organophosphates are less persistent in the environment, they are more acutely toxic to humans than organochlorines.

During the latter half of 1990s, it was estimated that two to four million pounds each of diazinon and chlorpyrifos (on the basis of active ingredients) were used annually by homeowners in the U.S. home and garden market (Aspelin and Grobe, 1999). Prior to their ban for indoor home use, EPA estimated that approximately 75% of U.S. diazinon and 50% of U.S. chlorpyrifos was used for residential pest control (EPA, 2000c; EPA, 2001). In 2000, EPA obtained agreements with manufacturers of diazinon and chlorpyrifos to begin phasing out these chemicals from formulations used for indoor pest control (and diazinon from lawn and garden applications). The sale of diazinon for all home lawn and garden use ended on December 31, 2004; however, the phase out for chlorpyrifos is expected to be completed in 2006. These agreements were in response to developmental toxicity studies that found chlorpyrifos, and by implication, possibly the entire class of organophosphate pesticides, more toxic to infants, children, and pregnant or nursing women than was previously understood (Avakian, 2001).

This ban on indoor products containing organophosphates led to the rapid introduction of pyrethroids for indoor pest control. The market is quite diverse with up to 10 different pyrethroids being used in common products. These insecticides are widely viewed as "less toxic," although this assumption is based on the earliest pyrethrins that were botanicals derived from chrysanthemum flowers and had the advantage of low mammalian toxicity and very short environmental half-lives (Pesticide Profiles, 1997). The search for more potent and longer-lived products led to the introduction of synthetic pyrethroids that were formulated to increase toxicity, increase resistance to degradation (either hydrolysis or enzymatic), decrease water solubility (Pesticide Profiles, 1997; Elliot, 1977; Itaya et al., 1977), and, by extension, enhance solubility in the human membranes, including those important to neurological function (Marei et al., 1982; Staatz et al., 1982).

The introduction or use of any semi-volatile chemical (such as these insecticides) in the home results in a residue being deposited in sorptive reservoirs of the home — dust, fabric, and furnishings (Cohen Hubal et al., 2000). These chemical residues, if persistent, will continually cycle through the indoor reservoirs either by virtue of volatilization and reabsorption, or as a result of reservoirs being disturbed by activities such as cleaning or active play. For these reasons, dermal, inhalation and non-dietary ingestion exposures to organochlorine and organophosphate insecticides can continue to occur on a chronic basis. However, except in cases of gross misapplications, these chronic exposure levels will be overshadowed by the dietary ingestion of residue levels in foods. For the organochlorines, the dietary ingestion levels are driven by bioaccumulation in meat, fish, milk, and other high fat foods. For the organophosphates, the dietary ingestion levels are driven by those fruit, vegetable and grain products where agricultural uses are still permissible (EPA, 2003b).

In contrast to the phased-out organochlorines and organophosphates, currently used pyrethroids may dominate indoor residential pesticide exposures in the future. Pyrethroid pesticides are also being used to a greater extent in the agricultural arena, so that dietary exposures to these pesticides are expected to increase as well. In addition to the pesticidal active ingredient, adjuvants such as piperonyl butoxide, which is used to enhance the "knock-down" effect of pyrethroids, and inert ingredients, such as solvents, may cause health problems for sensitive individuals such as children, older adults, and people with chronic illnesses (Watson et al., 2003).

Due to concern over the health hazards associated with pesticide use in homes, alternative pest control methods have become more widespread. For example, integrated pest management is a less-toxic strategy that employs knowledge of a pest's feeding, travel, and nesting habits, rather than implementing indiscriminate chemical extermination methods such as perimeter sprays or pesticide "bombs." Home pest control businesses that practice IPM will first employ non-chemical controls, such as sanitation, physical exclusion, or trapping, before turning to chemical pesticides (Consumer Reports, 1997). Typical IPM treatment plans include sanitation and maintenance, structural repairs, physical controls, spot application of pesticides when needed, and long-term monitoring (Siddiqi, 2001) (see Section 3.3 for more details on IPM).

2.0 HAZARDS ASSOCIATED WITH PESTICIDE USE IN THE HOME

2.1 Nature and Extent of Pesticide Hazards in the Home

Pesticides are used in agriculture and in homes, schools, parks, and commercial buildings. EPA estimates that in 2000, the number of households using insecticides and herbicides totaled 59 million (about 56%) and 41 million (about 39%), respectively (EPA, 2004). Seventy-four percent of American households used some type of pesticide in 2000 (EPA, 2004). The use, misuse, and/or misapplication of insecticides in the residential environment can lead to acute, sub-acute or chronic exposures. In addition, illegal pesticides – such as insecticidal chalk, "Tres Pasitos," and naphthalene mothballs that are not registered and approved by the EPA, - can pose significant health risks (EPA, 2005a). Children are more susceptible than adults with respect to the potential adverse health outcomes that can result from pesticide exposures (EPA, 2000a; EPA, 2000b; Natural Resources Defense Council, 1997; Olden and Guthrie, 2000; Wilson et al., 2003).

Past studies have shown that the presence of certain physical housing characteristics can lead to an increased risk of pesticide use, which in turn can contribute to or even increase the exposure to pesticides and lead to detrimental health outcomes. Housing characteristics that are associated with increased risk of pest infestation and the subsequent risk of pesticide exposures include aspects of housing condition, such as a degraded foundation and building envelope which allow pest migration into the home, multifamily or conjoined housing in which infestation in one unit allows migration of pests to the adjoining units, and poor ventilation which does not allow the pesticide residue to dissipate after an application (Health Canada, 2001; Alliance for Healthy Homes, 2003). In addition, pets may also introduce pests, such as fleas, into the home from the outdoor environment if they are not properly screened and treated (Ohio State University Extension, 2003).

A correlation between pesticides typically used within a geographic region and type of pesticide found in the home has also been noted (Colt et al., 2004). For example, in one study, residents living in southern California reported using pesticides mostly for crawling insects, fleas/ticks, and termites and therefore had high levels of insecticides found in their homes; however, residents in Iowa reported using pesticides mainly for lawn/garden weeds and therefore had higher levels of herbicides in their homes (Colt et al., 2004). Age of the housing unit is also an important factor. Offenberg et al. (2004) found that older homes, built between 1945 and 1959 were more likely to contain higher levels of chlordane than homes built during a later time period.

Studies conducted in the last 10 years have documented the presence of numerous different pesticides in indoor air, in carpet dust, and on settled dust of surfaces in homes (Rudel et al., 2003). Concentration or surface loading levels for individual pesticides span up to five orders of magnitude (Gordon et al., 1999; Nishioka et al., 1999; Roinestad et al., 1993; Simcox et al., 1995; Whitmore et al., 1994).

2.2 Health Impacts and Toxicity

Most pesticides found in indoor air and household dust are present at levels that, on a compound by compound basis, do not appear to constitute an immediate health risk. However, there are several major unknowns in the determination of potential health outcomes. First, the health impacts and outcomes from chronic pesticide exposures are unknown at this time (EPA, 2000b; Weiss, 2000). Animal data and *in-vitro* work suggest that chronic pesticide exposures might be tied to learning and behavioral problems, such as attention deficit hyperactivity disorder (ADHD) and other neuropsychological deficits (Chanda et al., 1996; Rice et al., 2000). These possible effects can, and will, be ascertained only from epidemiologic data where both exposure and outcome are monitored, with control for the many other potential neurotoxic covariates and confounders of the residential environment and food (e.g., lead, mercury, PCBs) (Jacobson and Jacobson, 1996). In addition, difficulty in ascertaining the precise timing of exposure makes it difficult to determine specific health outcomes. Short-term exposures, during vulnerable windows of opportunity (such as periods of rapid prenatal development), may have the greatest impact on children's health (Arbuckle et al., 2001; Selevan et al., 2000).

Another complicating factor is that within each pesticide formulation there are active and inert ingredients. Active ingredients are defined as those that prevent, destroy, repel or mitigate a pest, whereas inert ingredients have no direct effect on pests (EPA, 2002a). Inert ingredients are not defined based toxicity or risk to human health (EPA, 2005b). Many health-based studies and risk assessments have tended to focus solely on active ingredients, which may comprise a small percentage of the total formulation (Grossman, 1995). However, inert ingredients may pose an additional health risk or possibly contribute to the health effects associated with the active ingredients (EPA, 2005b; Watson et al., 2003).

Also, there are generally multiple pesticides present in environmental media (e.g., dust, air) in and around the home. These include previously banned organochlorine insecticides (e.g., chlordane, DDT), currently scrutinized organophosphate insecticides (e.g., chlorpyrifos) and newer, replacement pyrethroid insecticides. The cumulative effects of exposures to several different pesticides are not well known. However, given the toxicity of all insecticides toward some component of the nervous system (both central and peripheral nervous systems), it is believed that children are a vulnerable, at-risk population because complete development of the nervous system does not occur until late in childhood (Hall et al., 1997).

Organophosphate Toxicity Studies. Extensive mammalian studies of organophosphate toxicity, in general, and chlorpyrifos toxicity, in particular, have suggested that neurotoxic effects can be expected from low dose/chronic exposures. In addition to inhibiting nerve transmission, organophosphates also interfere in the acquisition and development of new brain cells and inhibit DNA synthesis (Whitney et al., 1995; Dam et al., 1998; Li and Casida, 1998). These functions are critical to proper neurological development, especially with respect to cognitive functions (Rice and Barone, 2000; Weiss, 2000).

Pyrethroid Toxicity Studies. Even though research in the area of pyrethroid insecticides is only beginning, there is existing evidence on pyrethroid toxicity and the associated modes of action and metabolism that point toward the possibility of an association between pyrethroid compounds and adverse health outcomes. Evidence in support of this link follows.

Based on their chemical structure, synthetic pyrethroids are divided into two major classes (Type I which lack a cyano moiety and Type II which contain a cyano moiety). Laboratory studies on the oral toxicities of Type I and II pyrethroids in rats, together with data on the toxicities of diazinon and chlorpyrifos, indicate that many pyrethroids approach the toxicities of the organophosphates (Kamrin, 1997; Miyamoto, 1976; Elliott, 1977; Worthing, 1983). The active ingredient(s) of major insecticide products for in-home use may be either Type I or Type II pyrethroids, and many high volume products (e.g., Raid with 23% of the market share, Hot Shot with 16% of the market share) contain Type II pyrethroids (Market Share Reporter, 2001). Many current products for outdoor use are convenient-to-use aerosols and sprays that can easily be used indoors (against label directions), and these products contain both organophosphates and pyrethroids.

Research has indicated that the primary site of action for these insecticides is the central nervous system, rather than peripheral (Staatz et al., 1982). In a study of a high level exposure to permethrin, certain groups of rats showed significantly lower retention capacity, decreases in coordination and balance, and higher incidence of conflict behavior (Sherman, 1979). Finally, important studies have also demonstrated critical issues for neonatal exposures to pyrethroids. Cantalamessa (1993) found two pyrethroids, permethrin and cypermethrin, to be more toxic to the neonate compared with the adult rat. Sheets (2000) identified no difference between neonate and adult susceptibility for exposure to Type I pyrethroids but a three-fold difference for exposures to Type II pyrethroids. Sheets attributes this increased susceptibility in neonates to a limited detoxification capacity for Type II compounds, as well possibly the ability of Type II compounds to accumulate in biological tissues. Since initial pyrethroid exposures may occur early in life, when metabolic systems have limited capacity and exposures may have life-long implications, it is important to understand the frequency and magnitude of early childhood exposures, the routes by which these exposures occur, and the outcomes of such exposures.

Acute and Sub-Acute Exposures. The most obvious adverse health outcome for children is poisoning from an accidental acute exposure. Cases of acute poisoning are generally due to direct contact with a product via inadvertent ingestion, dermal contact, and/or inhalation. In 2002, the American Association of Poison Control Centers documented 727,036 cases of nonpharmaceutical pediatric (<6 years of age) poisonings in the United States (Watson et al., 2003). Ninety-two percent of all of the exposures reported in 2002 occurred in the home. Of the total nonpharmaceutical pediatric poisoning cases, 7% (50,415) were attributable to pesticide exposures. Of the 7%, approximately 15,000 cases (30%) were attributed to rodenticide exposure. These numbers are likely an underestimate of the true number of cases each year due to the fact that the symptoms of mild insecticide poisoning and the "flu" or other common ailments are often very similar. The symptoms of insecticide poisoning include headache, fatigue, dizziness, shortness of breath, and loss of appetite with nausea, vomiting, stomach cramps, and diarrhea (University of Nebraska Cooperative Extension, 1997). For very young children, the increased salivation, crankiness and loss of appetite due to mild pesticide poisoning may be dismissed as "teething." Organizations such as the American Academy of Pediatrics have developed resource materials (e.g., *Handbook of Pediatric Environmental Health*) to help raise awareness among pediatricians and clinicians about the symptoms of pesticides and other environmental toxicants (Etzel and Balk, 1999).

The majority of sub-acute poisoning cases (i.e., "mild poisoning" cases with flu-like symptoms) occur after indoor use of insecticides, such as in homes or schools, and appear to be primarily due to either misapplication or a failure to fully ventilate the rooms after application. In studies examining such scenarios, levels of the insecticide chlorpyrifos were measured indoors on the day of application and the following day, and these data were combined with assumptions about exposure to estimate a dose for comparison with the NOEL (No Observable Effect Level; 30 µg/kg/day for chlorpyrifos) and the recently defined chronic exposure MRL (Minimum Risk Level; 1 µg/kg/d for chlorpyrifos) reported by the Agency for Toxic Substances and Disease Registry (ATSDR) (Fenske et al., 1990; Krieger et al., 2000; ATSDR, 2000). Both studies found that the NOEL and chronic exposure MRL were in some instances exceeded in the short term.

There has also been speculation in the scientific community about a potential association between pesticide exposure and neurodevelopmental effects (Mendola et al., 2002), as well as potential asthma exacerbation (Quarles, 1999). The acute health outcomes for farmers and farm workers routinely exposed to organophosphates have been studied, and symptoms such as headache, dizziness and sleepiness appear to be associated with exposure, as well as some loss of peripheral nerve function (Eskanazi et al., 1999). Contaminants such as odor-producing agents in organophosphate pesticides have been linked to asthma in adults; these agents are thought to be low-molecular weight mercaptans and sulphides (Quarles, 1999; O'Malley, 1997).

Pesticides are of particular concern in low-income, inner-city neighborhoods, where conditions favor pest infestation (Berkowitz et al., 2003). In an ongoing study being conducted by Columbia University on the effects of indoor air pollutants on pregnant women and their newborns in minority communities within the New York City area, strong associations were observed between dilapidated housing and pesticide exposures. Results suggested widespread use of pesticides in these areas, with 85% of the women reporting the use of pest control techniques during pregnancy, and at least four pesticides detected in the personal air samples of all women who consented to monitoring during their third trimester (Whyatt et al., 2002). The project also reported a high degree of correlation between maternal pesticide levels and levels found in cord blood samples, indicating that exposures are easily transferred between mother and fetus (Whyatt et al., 2003). Most recently, the study found highly significant associations between birth weight and length and blood cord levels of chlorpyrifos and diazinon (Whyatt et al, 2004). Among newborns born after the EPA regulatory actions to phase out residential use of these insecticides in 2000-2001, exposure levels were substantially lower, and significant increases in infant birth weights were observed (Whyatt et al., 2004). In another study of prenatal exposure to common urban pollutants, maternal chlorpyrifos exposure was associated with reduced birth weight and length among African Americans newborns, as assessed by personal monitoring, biomarkers, questionnaire data, and medical records (Perera et al., 2003).

Persistence in Homes and Chronic Exposures. Even with full implementation of pesticide use precautions, residues can remain in a home for years after use, and chronic exposures may occur (Whitmore et al., 1994). Factors for environmental degradation and dispersion (e.g., sunlight, wind, rain and microbes) are not readily available for completely dissipating indoor pesticide levels. This persistence in the indoor environment is further exacerbated by the presence of household materials such as carpets, upholstered furniture, and draperies. These act as sorbents or reservoirs resulting in subsequent slow release of the pesticides over time (Cohen Hubal et al., 2000). For example, prior to their cancellation, organochlorine termiticides (particularly chlordane) were used to treat many homes, soils, and building structures. Particularly during demolition or other disturbances, these reservoirs have the potential to be significant sources. Research shows that indoor air and house dust in structures previously treated with these persistent organochlorines can have residual pesticide levels as much as 10-100 times higher than in outdoor air and surface soil (Lewis et al., 1988; Whitmore et al., 1994; EPA, 2000d; Wilson et al., 2003).

Studies on chronic health outcomes in children are very limited. At the initiation of several major studies funded by the National Institute of Environmental Health Sciences (NIEHS) and EPA on health outcomes for very young children exposed to diazinon and chlorpyrifos, the EPA reached an agreement with manufacturers to remove these products. Thus, children's exposures have been significantly reduced throughout the course of these critical studies. One study (Guillette et al., 1998), though, did document significant differences in stamina, gross and fine eye-hand coordination, 30 minute memory, and the ability to draw a person among two identical populations of children – one essentially unexposed to pesticides, and the other exposed to insecticides indoors in the home on a daily basis. The pesticides used by the families were not documented, but they are presumed to have been organophosphates.

2.3 Methods Used To Assess Pesticide Hazards In The Home

The following section provides the reader with an overview of the range of assessment techniques that are available, from both a research and programmatic perspective. The level of rigor for assessing hazards in a research setting surpasses that which is needed for programmatic or public health use. From a housing or public health perspective, a home assessment is generally constrained by the need for cost effective methods that are sufficient to allow for the identification of targeted substances at levels of concern. Low cost residential assessment methods typically employed from a programmatic perspective include inventory surveys of pesticides and resident questionnaires; however, there are disadvantages to both approaches. More rigorous research studies utilize human biological sampling data, as well as samples taken from environmental media, to assess pesticide levels in the home. Each of these approaches is described below.

Home Surveys and Questionnaires. From a public health program perspective, simple, non-invasive methods to assess potential pesticide exposures in the home include inventory surveys of pesticides stored throughout a home and garage and recall questionnaires about pesticide use and frequency of application (Adgate et al., 2000). These methods are lower in cost than conventional sampling and chemical analyses and point to the general prevalence of pesticides use in and around the home, and thus the potential for an exposure event to occur. However, the inventory approach will miss a product that has been used completely and no container remains for counting. Surveys are also often flawed because personal recall of pesticide use has low validity generally, and recall of specific product use is quite poor (Gordon et al., 1999). Some of this is due to the very nature of insecticide use indoors – products are readily available in convenient-to-use containers, and use is sporadic and rapid. In addition, individual activity factors, for the applicator, the child, other family members, and even pets, can have dramatic impacts on exposure. The role of personal activity factors has only recently been identified and quantified in one study, so that specific questions to capture these factors are only now beginning to appear in questionnaires and surveys (Nishioka et al., 1999). An individual's attitude and perception of risk related to pesticide use can also influence information obtained in questionnaires and potentially result in underreporting, especially when questions used to obtain information are limited in scope (Nieuwenhuijsen et al., 2005).

Very limited information is available on how well pesticide exposure information obtained from questionnaires corresponds with data collected from environmental samples taken in the home. Sexton et al. (2003) found that telephone screening and questionnaires were inadequate predictors of households exposed to higher levels of target pesticides, possibly due to incongruity between the general questions asked on the survey and the far more specific pesticide measurements taken in sample homes. However, Colt et al. (2004) found information gathered from the use of detailed questionnaires that included visual aids and focused on the types of pests treated, who applied the pesticide, how often the pesticide was applied, and longer time frames of interest, correlated well with the types of pesticides found in vacuum bag samples. In addition, authors suggest that detailed questionnaires can be useful in capturing pesticides used in the home prior to the installation of carpets. Therefore, when used in conjunction with environmental sampling, questionnaires can provide additional useful information that may not otherwise be captured.

In the event of acute or sub-acute poisonings, the causative event or product can usually be inferred by parents or caregivers via area surveillance. Because "mild poisonings" (e.g., with flu-like symptoms) often occur when a pesticide misapplication is made in the home or school, sudden onset of conditions for multiple individuals can be used as an indication of possible sub-acute exposure. At these times, a lingering odor from the pesticide can also be used as an indicator that further ventilation of the rooms and cleaning of surfaces must be performed immediately to reduce the levels of toxic residues (Markowitz, 1992).

Human Biological Sampling Data. The Centers for Disease Control and Prevention's National Center for Health Statistics conducts a nationwide National Health and Nutrition Examination Survey (NHANES) of randomly selected individuals and measures the levels of environmental contaminants in blood and urine samples (NHANES, 2003; CDC, 2003 and 2005). Statistics on the levels of various contaminants, including organophosphates, organochlorines, herbicides, and various other pesticides, are reported by gender, age and race/ethnicity. For several pesticides, which are rapidly metabolized and excreted in urine, contaminant levels are estimated from analysis for a pesticide's metabolite. Information from this national survey could be used in contrast or comparison with the data from poison control centers. Selected results from NHANES 1999-2000 and NHANES 2001-2002 are presented in Table 3 below. Whether the levels of the pesticides and metabolites reported in this table are a cause for health concern is not known; more research is needed (CDC, 2003 and 2005). However, the NHANES data do provide reference ranges (levels of chemicals in blood and urine that were found in the general population) to aid physicians and health researchers in determining if a person or group of people have an unusual level of exposure.

Table 3. Average concentrations[1] of Selected Pesticides Found in Clinical Specimens[2], NHANES 1999-2000 and 2001-2002

Pesticide of concern	Analyte[3]	1999-2000 Average Concentration	1999-2000 Limit of Detection	2001-2002 Average Concentration	2001-2002 Limit of Detection
Urinary metabolites					
	dimethylthiophosphate	1.82 ug/l	0.18 ug/l	*	0.4 ug/l
Organophosphates	diethylphosphate	1.03 ug/l	0.2 ug/l	*	0.2 ug/l
	diethylthiophosphate	*	0.09 ug/l	0.457 ug/l	0.1 ug/l
Chlorpyrifos	trichloro-2-pyridinol	1.77 ug/l	0.4ug/l	1.76 ug/l	0.4 ug/l
Organochlorines	2,4,6-trichlorophenol	2.85 ug/l	1 ug/l	*	1.3 ug/l
Para-dichlorbenzene	2,5-dichlorophenol	6.01 ug/l	0.1 ug/l	*	0.1 ug/l
o-phenyl phenol	o-phenylphenol	0.494 ug/l	0.3 ug/l	*	0.3ug/l
Pyrethroids	3-phenoxybenzoic acid	No information		0.321 ug/l	0.1 ug/l
Serum samples					
DDT	p,p'-DDE	260 ng/g lipid	18.6 ng/g lipid	295 ng/g lipid	8.3 ng/g lipid
Lindane	beta-hexachlorocyclohexane	9.68 ng/g lipid	9.36 ng/g lipid	*	6.76 ng/g lipid
Chlordane	trans-nonachlor	18.3 ng/g lipid	14.5 ng/g lipid	17.0 ng/g lipid	10.5 ng/g lipid
	oxychlordane	*	14.5 ng/g lipid	11.4 ng/g lipid	10.5 ng/g lipid

* Proportion of samples below the limit of detection was too high to calculate average concentrations.
[1] Urinary metabolites represent geometric mean of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000 and 2001-2002. Serum sample represent geometric mean of serum concentrations (in nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000 and 2001-2002. [Source: CDC, 2003 and 2005]
[2]Chemical specimens reflect total exposure to pesticides and do not indicate what proportion comes from home exposures
[3] Exposure to some analytes could result from exposure to non-pesticide substances (e.g., o-phenyl phenol is a common analyte from exposure to disinfectants like Lysol).
[4] Additional research is needed to determine whether the average concentrations of pesticides detected in NHANES biological samples are at levels of concern.

The National Children's Study is a planned longitudinal study of over 100,000 children designed to examine the effects of the environment on health and development of children. One aim of the study is to investigate if pre- and post-natal exposure to non-persistent pesticides increases the risk of poor performance on neurobehavioral tests. To address this issue, levels of pesticides will be characterized using questionnaires, biological markers, and environmental sampling data (Bradman and Whyatt, 2005). Although data is not yet available, results from this study will also provide important pesticide exposure information to which other data can be compared.

Based on results such as those discussed above and the sustained market for insecticides, it is reasonable to expect that pyrethroid metabolites will be found with increasing frequency in the future. Similarly, the occurrence of pyrethroid insecticides in indoor air and house dust is expected to supplant that of the organophosphates (Gordon et al., 1999), especially given that the major suppliers of pyrethroids to the residential market produce "fogger" formulations, which (in organophosphate studies) are associated with the highest indoor air levels of pesticide active ingredient (Fenske et al., 1990).

Sampling and Analysis of Environmental Media. From a research perspective, sampling to assess exposure can be accomplished in one of several different ways. First, microenvironmental sampling for pesticide residues in air and settled dust, and on surfaces, can be combined with child activity profiles, such as respiration rates and time spent indoors, to estimate the exposure via a specific exposure pathway (Zartarian et al., 2000). Alternatively, personal samples, such as hand wipes and videotape records of child hand-to-mouth activity, can be used to estimate exposures (Reed et al., 1999). Finally, the measurement of a biomarker of exposure, such as the excreted pesticide metabolite in urine or pesticide concentration in blood, can be used to assess the potential internal dose (Krieger et al., 2000; MacIntosh et al., 1999). Each method has strengths and limitations (Zartarian et al., 2000; Bradman and Whyatt, 2005). At this time, two of the most useful samples for assessing a child's potential residential pesticide exposure are the bulk house dust and the child's hand wipe. The former indicates "what's there" and the latter indicates "how much" the child comes in contact with when interacting with this environment.

Sampling of dust reservoirs is usually achieved using a suction/vacuum device, wipe sampling, or a dislodgeable residue sampling device. A frequently used vacuum device for collection of floor dust for pesticide analysis is the High Volume Surface Sampler (HVS3) or HVS4 (Cascade Stack Sampling Systems, Inc.; Nishioka et al., 1996). The use of this device has been formalized as ASTM method D5438-93. Wipe sampling has typically been accomplished with Johnson and Johnson SOF-WICK gauze dressing sponges moistened with isopropanol, water, or a "sweat simulant" (Nishioka et al., 1999). Dislodgeable residue sampling can be accomplished with research devices such as the Polyurethane Foam (PUF) Roller, CDFA Roller, Dow Drag Sled or the EL Press Sampler (Nishioka et al., 1996; Ross et al., 1991; Edwards and Lioy, 1999).

Since all of these techniques are most appropriate for use in a research setting as opposed to routine housing assessments, they have not been subject to the same extensive intercomparison studies that were used to select and certify techniques for lead sampling. There are also drawbacks to these techniques. The HVS3 vacuum, which is based on an upright Royal vacuum cleaner, is relatively expensive (~$3000), large, and awkward to use for routine sampling in multiple locations (the HSV4 vacuum sampler is smaller and more portable than the HSV3 sampler). The dislodgeable residue samplers are research tools and, as such, are not available commercially. Several of them are somewhat cumbersome to use and are not amenable to collection of residues on surfaces other than floors.

In general, when samples are collected in homes, the primary collection sites include floor areas where children typically play (e.g., family room, bedroom, kitchen), and wipes of surfaces that children frequently contact (e.g., tables, counters). Vacuum dust collection of floors typically covers a 1-2 m^2 area of these rooms; wipe sampling typically covers a smaller area (e.g., 30 cm x 30 cm (1 ft^2)).

Chemical analyses for pesticides in environmental media and biomarker samples involve extraction, cleanup, and GC/MS analysis. While the overall process is relatively labor-intensive, the protocols and methods can be adapted so that multiple residues, even as many as 25-50 analytes, can be analyzed in the same sample extract (Chuang et al., 1999).

2.4 Methods Used To Mitigate Pesticide Hazards In The Home

While pesticide application methods, such as crack and crevice application, can limit children's exposure to pesticides used in the homes (Hore et al., 2005), from a preventive standpoint, it is preferable to minimize home pesticide use. Therefore, outreach to the public on alternatives to traditional pesticide use is a first step in reducing pesticide exposure in the home. However, in some cases pesticide use may be necessary, or pre-existing pesticide contamination may also be present. In cases where pesticide exposure hazards are discovered through a home assessment, actions to mitigate those hazards are necessary.

Prevention. In many cases, the prevention of improper pesticide use and application, as well as the minimization of overall pesticide use, are the most cost-effective method for mitigating pesticide exposures in the home. These preventive methods may be achieved best through public education programs and adequate product labeling (e.g., descriptive product instructions that are written in type large enough to be easily read). Public education programs should include, for example, information on the importance of following use and application labeling, sufficient room ventilation after product use, proper protective clothing and cleanup following product application, license checks for commercial applicators, and non-pesticide alternatives.

- *Proper use.* Consumer education can focus on using the least toxic approach, using pesticides only when necessary, and following the application rates provided on the label. Many homeowners over-apply, for example assuming that the "more the better," or desiring to empty the container to eliminate concerns over long-term storage, stability, and potential child contact.
- *Modification of the living environment.* Consumer education should focus on modifying the living environment to make it less attractive to pests.
    - *Eliminate food sources and manage garbage.* By preventing access to food, keeping food properly stored, frequently cleaning counters, floors, and dishes, and securing trash, residents can reduce pest infestation.
    - *Eliminate home access points.* The use of caulking, sealants, weather stripping, screens, and the installation of floor drains can help prevent pests from entering the home.
    - *Eliminate water sources.* By controlling leaking pipes, toilets, faucets, standing water, and excessive humidity, homeowners can reduce the attraction of pests who seek out and thrive in damp environments.

- *Selective use of pesticides.* The need to use insecticides on a whole-room or whole-house basis to treat flea infestations may be reduced by using products directly on pets, such as insecticide impregnated pet collars. Several control technologies have emerged recently that involve spotting a solution to the back of a pet cat or dog once per month to effectively eliminate fleas and ticks. Use of low impact insecticides such as insect growth regulator bait instead of spray or dust are increasing in popularity.
- *Proper ventilation.* For products used indoors, the instructions for proper ventilation after application are important. This includes direct ventilation with a fan of those treated closets and enclosed areas that are not reached by general air streams from open windows and doors.
- *Treatment of applicator clothing and shoes.* For pesticides used outdoors, or with a heavy indoor application, the applicator should either place/leave shoes outdoors or wash them off (as in rubber boots) before wearing them indoors. Use of coveralls and/or removal of contaminated clothing outdoors, with immediate laundering, can prevent some of the contamination and dispersion within the home that comes from this source.
- *Assessment of contract applicators*. Homeowners and renters can check with commercial applicators, or building supervisors for rental property, to verify that the applicator is licensed (ask to see the license), and that the applicator is applying an approved and registered pesticide for that situation/location. (For pesticide related questions, homeowners and renters can contact the National Pesticide Information Center at 1-800-858-7378.)

Post-Contamination Clean-Up. While preventive measures are preferable, *post facto* decontamination procedures must be included in any public health program responding to the misuse of pesticides indoors. In the case of overuse of an approved pesticide, continued and aggressive use of ventilation, combined with repeated detergent-based cleaning of toys, countertop, table, and dish surfaces, can reduce residue levels that children may contact. This work needs to be instigated at the earliest possible time before pesticide residues have time to migrate into carpet backing and pads, where they are no longer amenable to removal by cleaning (Fortune et al., 2000).

If early interventions do not occur, removal of carpets may be necessary. The efficacy of steam cleaning for removal has not been investigated; however, steam cleaning may have only minimal utility since the majority of pesticide residues in floors reside in the carpet backing and pad compartments, and not in the dust per se, that are not effectively reached by cleaning (Fortune et al., 2000). As the pesticides slowly volatilize from this reservoir, they equilibrate with the settling dust. Frequent vacuuming or steam cleaning may be sufficient to remove superficial residues but probably will not remove the larger source. Carpets should be removed from closets and enclosed areas that cannot be readily ventilated. Some consideration may be given to periodically replacing carpets and pads of high traffic areas or removing them from high use areas. Carpets should be discouraged in kitchens, as insecticides are frequently used in this room.

3.0 INTEGRATED PEST MANAGEMENT (IPM)

3.1 Overview of Integrated Pest Management in the Home

Growing concern over the health hazards associated with pesticide use in homes has also led many municipalities, school districts, and public policy officials to seek ways to minimize pesticide use. IPM has received recognition internationally as a beneficial approach to pest control, due to the fact that this approach encourages reducing overall pesticide use (i.e., applying only as needed), using the least toxic product if a pesticide is needed, and confining the area of pesticide application (e.g., with targeted gels, baits, and powders), in conjunction with other non-pesticide methods, such as habitat modification, to control pests (Campbell et al., 1999; CMHC, 1998). In addition to reducing the probability of human pesticide exposures, IPM has been credited with greater sustainability in keeping pest populations down (in contrast to extermination-only methods, which typically need to be repeated), and with reducing pesticide release into the environment (New York State Integrated Pest Management Program, 2001). IPM also helps to combat the problem of insecticide resistance, which has been documented in cockroaches across many classes of commonly used insecticides (Wu et al., 1998).

An important part of the IPM process is education of residents. A recent study in an urban community found IPM to be a cost-effective and successful method of controlling cockroach infestation when community residents are involved at every stage of the project and provided with hands on training and education (Brenner et al., 2003). Similarly, another study conducted in older, urban dwellings found that IPM (incorporated as part of a multi-hazard, multi-strategy approach to home remediation of hazards) was more effective in reducing allergen levels in homes if residents were trained compared to using IPM in homes where residents received no training (Klitzman et al., 2005).

3.2 General Guidelines for IPM in Homes

Because IPM is a process, the specific management strategies used are defined by a particular situation. For example, an IPM plan may include use of mechanical and physical controls, such as structural repairs, preventive maintenance, or pest trapping, as well as targeted application of pesticides. IPM also generally requires the active involvement of residents (Siddiqi, 2001). The following general framework can be applied with modifications to most specific situations. In general, IPM programs consider the following key elements (sources: San Francisco, New York State, and Northeast IPM Programs):

Identification, Monitoring & Recordkeeping. To attain the benefits of an IPM program, information must be gathered, integrated into a body of knowledge, and used to determine the appropriate IPM program. The pest and/or the problem (including the type of pests and how many), or potential pest problem, must be correctly identified and observed at regular intervals throughout the implementation process. Records are kept on what is seen, decisions made, actions taken, and results.

Tolerance Levels. When a pest problem is identified, a decision is made on whether these pests should be controlled. Considerations when determining if action is necessary may include: whether the benefits derived from control justify the costs and risks incurred, when (if not currently) the pest problem is likely to become serious enough to require some action, and tolerance levels (e.g., a certain number of pests may be tolerable).

Least-Toxic Treatments. In an IPM program, the object of treatment is to suppress pest populations to an acceptable level, but not necessarily to eradicate them. Control strategies that are easy to carry out effectively, long-lasting, and least disruptive to the environment are selected.

Pest Control Options/Treatment Strategies. If action is called for, actions with minimum adverse effects are preferred. Examples of different control methods commonly used in IPM programs include:

- *Behavioral methods.* Many behavioral practices can reduce pests by making their environment less favorable. For example, sanitation is one of the most important steps in pest management. Proper disposal of garbage, clearing up clutter in offices and basements, eliminating water sources (e.g., leaking pipes), and removing weeds in gardens all contribute to removing food and shelter for pests.
- *Mechanical or physical methods.* Mechanical controls are direct measures that either kill the pest or make the environment unsuitable for their entry, dispersal, or survival. For example, traps can be used to catch a variety of pests, including cockroaches, ants, and mice. Several practices physically keep insect pests from places where they're not wanted by eliminating home access points. Barriers, such as window screens and caulking/sealing cracks, will help exclude many health and nuisance pests from buildings.
- *Biological methods.* Virtually all species, including all types of pests, have natural enemies. The most common ones are predators and parasites. For example, predators, such as ladybugs and lacewings, feed on aphids, caterpillars, and beetle larvae. Parasitoids such as mini-wasps and flies are important in the fight against aphids, scale insects, and whiteflies. The use of natural enemies to combat pests is generally restricted to lawn and garden areas.
- *Chemical methods.* Least-toxic chemical herbicides, insecticides, fungicides, or rodenticides are preferred for controlling pests. Chemical pesticides that are selective (i.e., target specific pests) are preferred. During treatment, instructions are followed carefully and appropriate protective equipment and clothing is worn, if necessary. Chemical pesticides are used only when other methods and techniques have failed to manage the pest, and they are used for spot treatments rather than for broadcast applications.

For example, the New York State IPM Program recommends five specific preventive management strategies for residents who want to implement IPM in their homes.

- Keep the home clean by wiping up spills, not leaving food exposed for long periods of time, and removing clutter.
- Prevent access to pests by storing all dry food, pet food, and birdseed in tightly covered containers.
- Remove open, uncovered enticements such as sweet and greasy foods from the home.
- Control the amount of moisture that may be in the home by fixing leaks and encouraging ventilation, because insects often seek wet spots.
- Erect blockades, such as caulking, door sweeps, netting, and screens to exclude pests (The New York State IPM Program - fact sheet).

These strategies, as well as others, are incorporated into an EPA booklet entitled "Safe Control - Cockroaches and Rodents. Using IPM in Your Neighborhood." While several resources exist, this is one example of an educational tool that can be useful to residents and is available in a several different languages. (To obtain copies of this booklet call the EPA, Office of Pesticides Program at 703-305-5017.)

Implementation. If a control is justified, care is taken to implement it properly and at the right time. For instance, many insecticides are more effectively applied when the pest is at a susceptible stage in its life-cycle.

Evaluation/Re-evaluation. After the treatment action has been taken, inspections are made, and the short term and long-term effectiveness of the treatment strategy are assessed. If preventive methods attempted by the owner or occupant prove ineffective, professional help may be required. Market research indicates that although many companies in the pest control industry advertise IPM as the preferred form of pest management, pesticide-usage data suggests that the transition from traditional methods may be incomplete (Consumer Reports, 1997). Therefore, it is recommended that consumers are careful in identifying an IPM contractor. Contractors can obtain voluntary certification in IPM through organizations such as the IPM Institute of North America, Inc., a nonprofit institute that operates training and certification programs for IPM professionals (The IPM Institute of North America, Inc., 2003). Questions to be asked before committing to a pest control contract may include: Are employees trained or certified in IPM, or supervised by a manager with IPM certification? Will the work include an inspection of the home? Does the company use least-toxic chemical pesticides only as a last resort? In general, IPM requires more active participation by residents and homeowners than more traditional treatments (Consumer Reports, 1997).

3.3 <u>IPM Control Methods for Specific Pests</u>

3.3.1 Cockroaches

In addition to being a common household nuisance pest, cockroaches have also been identified as an important indoor allergen source related to the exacerbation of asthma, particularly in any area where substandard housing permits cockroach infestation (Katial, 2003; DeVera et al., 2003; Arruda et al., 2001). Although there are 70 cockroach species that occur in the U.S., only five species are commonly found in residential settings: the German cockroach (*Blatella* *germanica*), the American cockroach (*Periplaneta americana*), the Oriental cockroach (*Blatta orientalis*), the smoky brown cockroach (*Periplaneta fuliginosa*), and the brown-banded cockroach (*Supella longipalpus*) (Eggleston and Arruda, 2001). The widespread use of chemicals to control cockroach populations has led to insecticide resistance in some species, particularly the German cockroach. Resistance in the German cockroach has been documented extensively for organophosphates, carbamates, and more recently, pyrethroids. Repeated exposure to these compounds has allowed the German cockroach to develop behavioral, physiological, and metabolic defenses that allow populations to thrive even after extensive insecticide application (Wu et al., 1998). In addition, more recent evidence indicates that certain strains of the German cockroach have developed an aversion to the food ingredients (sucrose, fructose, glucose, and maltose) used in gel baits (Wang et al., 2004). The resistance behavior is very stable and can be maintained in many generations (Wang et al., 2006). The development of behavioral and physiological resistance to gel baits in cockroaches further emphasizes the need for adoption of IPM strategies.

An IPM program for cockroaches may consist of both physical and chemical control measures. These include reduction or elimination of food, water, and shelter resources (such as use of good sanitation practices and plugging major holes around plumbing, sealing cracks and crevices to prevent entry and limit hiding places), in combination with careful placement of the least toxic baits and insecticides necessary (Katial, 2003; CMHC, 1998; Ogg et al., 1994). Following initial intervention, IPM approaches emphasize continued monitoring of cockroaches in the same areas to assess the success of the control program and whether additional intervention is necessary (Ogg et al., 1994). The humidity in a home may be another important factor in cockroach infestations for some species, such as the German and American cockroaches which tend to aggregate in warm, humid crevices such as those around water heaters, laundries, bathrooms, appliances, and plumbing fixtures, and the Oriental cockroach which prefers damp areas such as basements, plumbing, and sewers (Eggleston and Arruda, 2001).

Demonstrating the importance of home repair and maintenance in mitigating cockroach populations, Rauh et al. (2002) investigated levels of cockroach allergens (Bla g 2) in a sample of low-income households with young children in northern Manhattan in New York City (40% were receiving public assistance) to determine whether the distribution of allergens is a function of housing deterioration. Results showed significant positive associations between housing deterioration and cockroach allergen levels (measured in dust) in kitchens. These findings demonstrate that indoor household cockroach allergen levels are related to the degree of household disrepair, suggesting that social-structural aspects of housing may be appropriate targets for public health interventions designed to reduce allergen exposure (Rauh et al., 2002).

Insecticides, including inorganic compounds (e.g., boric acid), pyrethrins, avermectins/abamectin (e.g., Raid®, Combat®), and newer compounds (e.g., fipronil, hydramethylnon, imidacloprid, and sulfluramid) are often used in the home to kill cockroaches (Katial, 2003; Vaughan and Platts-Mills, 2000; Eggleston and Arruda, 2001). Boric acid and a less processed form (disodium octoborate tetrahydrate) may be appropriate for persons who are chemically sensitive (Katial, 2003; Vaughan and Platts-Mills, 2000). Studies reviewed by Eggleston

(2000) indicated that pesticides such as these can be effective in reducing cockroach populations by as much as 90% for as long as three months. Although these pesticides may be applied in almost any form, cockroach gel baits are available and can be applied to cracks and other critical areas in a manner that will reduce potential exposures to pets and children (Eggleston and Arruda, 2001). Gel baits may also be preferred because they have a longer duration of effectiveness and because the insecticides can be carried back to areas of heavy infestation (Kopanic and Schal, 1999; Durier and Rivault, 2000; Buczkowski and Schal, 2001; Buczkowski and Kopanic, 2001). Bait traps have also been developed that limit access to the pesticide (Eggleston and Arruda, 2001) but may require frequent replacement to provide long-term benefit (Katial, 2003; Ogg and Gold, 1993).

There is evidence that the use of cockroach allergen abatement strategies that combine extermination and cleaning can temporarily reduce exposure. A recent study reported that a decline in the levels of cockroach allergen and dust mite allergens in bedrooms of asthmatic children was significantly associated with a decrease in asthma complications (Morgan et al., 2004). Suggested reasons for the lack of effectiveness in cockroach allergen level reduction by cockroach abatement strategies that have been observed in some studies include: the presence of residual cockroach allergens (due to carcasses remaining in areas that are not easily accessible or lack of thorough cleaning following extermination) and re-infestation problems (especially in multi-family dwellings). For example, in a study of thirteen homes in inner-city Baltimore, Maryland, Eggleston et al. (1999) found that although cockroach extermination was feasible, standard housecleaning procedures were only partially effective in removing residual cockroach allergen over eight months (Gergen et al., 1999; Eggleston, 2000). However, Arbes et al. (2003) recently observed substantial reductions in cockroach allergen levels in low-income, urban housing through a combination of occupant education, use of insecticide bait, and professional cleaning. Although levels in some areas (e.g., the kitchen) remained above estimated asthma exacerbation thresholds (8 U/g), cockroach allergen levels (Bla g1) in areas highly relevant for exposure (e.g., the most heavily contaminated areas in the bedding and bedroom) were significantly reduced to below the asthma sensitization threshold (2 U/g). In a follow-up study of homes that participated in this six-month intervention, Arbes et al. (2004) found that reductions in cockroach allergen concentrations could be maintained through 12 months with the continued application of insecticide bait alone.

The Center for Medical, Agricultural, and Veterinary Entomology in Gainesville, Florida, conducts research on innovative strategies for removing cockroaches and the effectiveness of these strategies at removing cockroach allergens. For example, “Pesticide Reduction Through Precision Targeting” is one project conducted by the Center to evaluate reduced-pesticide-use technologies. As part of this project, researchers have demonstrated that using a computerized precision targeting system to determine the distribution and location of cockroaches reduces the amount of pesticides needed by allowing pest control operators to treat only pest-infested areas (Weaver, 1998).

Another innovative strategy for managing cockroach infestations is to use heat combined with boric acid to control cockroaches. At the U.S. Army Fort Knox food service facilities, heat was used against resistant roaches. Heaters were used in the facilities to draw cockroaches from their harborage, forcing them to congregate in cooler areas. When congregations were observed, they were vacuumed up immediately. Once cockroaches were no longer observed in large numbers, a residual adulticide was applied. Although the thermal control treatments used at Fort Knox required considerable planning and high initial capital investment, the project led to a long-term reduction of difficult-to-control, insecticide-resistant cockroach populations (Zeichner et al., 1998). The use of a portable heat gun to flush roaches in combination with a vacuum to capture them has been successfully used to achieve significant reductions in cockroach populations as part of an IPM strategy (Greenberg, 2004).

3.3.2 Rodents

As well as damaging food, clothing, and other items around the home, mice have been associated with the transmission of a number of important human diseases. In addition, like cockroaches, rodents (mice) have also been associated with asthma exacerbation. Recent research supports a significant association between exposure to mouse urine (*Mus musculus*) allergen (Mus m 1) and asthma sensitization, particularly in inner city, multiple family dwellings (Phipatanakul et al., 2000b). Housing conditions, such as the presence of holes in ceilings or walls, have been associated with increased mouse allergen levels in the home, and mouse allergen has been observed to be prevalent among inner-city apartments (Chew et al., 2003). In addition, high levels of mouse allergen in homes have been found where home occupants reported never seeing mice (Chew et al., 2003).

Because high mouse allergen levels have been associated with cockroach infestation (Phipatanakul et al., 2000a), and because both types of pests have similar environmental requirements (e.g., a means of access to the home, food, water), IPM approaches discussed above for cockroaches may also be effective for controlling rodent populations (Frantz et al., 1999). In general, the literature recommends “mouse-proofing” a house as one would weather-proof it. Specific recommendations include blocking small holes where mice may enter, storing food in tight-fitting containers, and trapping mice that may have already entered the house. Trapping is `preferred over bait poison because it is less hazardous to people and pets and it provides physical evidence for the effectiveness of control methods. Only when mouse-proofing and trapping have failed to solve the problem are poison baits recommended, and at that point careful choice of a specific rodenticide is recommended (Olkowski and Olkowski, 1990).

3.3.3 Other Pests

There are other household pests that may cause residents to use excessive pesticides in an effort to get rid of them. Some pest-specific IPM tips, from the New York State IPM Program, include:

- Bats: Inspect the exterior of the building for openings larger than ¼” in height and seal them; light your attic; and offer a “bat house” away from areas of human activity.
- Carpenter Ants: Fix the problem that is causing moist wood and replace the damaged wood. Also, baits specifically for carpenter ants are available.

- Fleas: Vacuum regularly and place contents outdoors in the trash and treat the animal, preferably by a veterinarian.
- Mosquitoes: Prevent water from accumulating; replace bird bath water every few days; and keep window and door screens tight and in place until winter.
- Spiders: Scoop them into a container and release them outside or use a fly swatter. Most spiders are beneficial for killing other insects.

The use of vacuum cleaners may also be useful for quick removal of incidental pests and rodent droppings, flying insects, beetles, sowbugs, pill bugs, crickets, spiders, and anything else that can be caught. An ordinary vacuum may be used, but if the machine is used almost entirely for catching pests, a HEPA-filtered vacuum is preferred. Moths and cockroaches have allergenic particles and compounds that escape through an ordinary filter. HEPA vacuuming can also be used to remove accumulated rodent droppings and dead insects. Re-inspection will determine if rodents are still present. See the San Francisco Department of the Environment Pesticide Program web site for more information (www.sfgov.org/sfenvironment/aboutus/toxics/ipm/).

3.4 IPM Programs and Effectiveness

There are many programs currently in place to evaluate and promote the human health benefits of IPM. Examples of some of the more visible programs can be found in Appendix B.

IPM is increasingly being mandated in public sector buildings. While not extensive, some studies have been conducted to evaluate its cost-effectiveness compared to baseline pest control methods. Wang and Bennett (2006) conducted a study comparing IPM strategies to the application of insecticide bait alone in public housing buildings. Although costs associated with IPM were initially higher than costs for the bait treatment (mostly as a result of the high costs associated with the vacuuming treatment), after twenty-nine weeks costs were similar between the two interventions. However, buildings that received IPM had significantly lower levels of cockroach infestations compared to buildings, which received bait alone. Therefore, it is suggested that IPM may be a more cost-effective strategy to decrease cockroaches long-term (Wang and Bennett, 2006). Costs associated with IPM have also been compared to “traditional” monthly crack and crevice treatment in public housing buildings (Miller and Meek, 2004). Although IPM costs were higher ($1.50 more per unit per year than the traditional treatment), IPM treated units had significant reductions in cockroach populations while the traditional treatment had little effect.

A study evaluated the U.S. General Services Administration’s (GSA) Structural IPM Program to demonstrate whether IPM is an improvement over traditional methods. The evaluations were based on both client satisfaction and pesticide reduction. The authors found that since its implementation in 1989, the IPM program successfully decreased both the quantities of insecticide applied indoors and the number of requests for pest control services by building occupants, and they concluded that IPM can successfully reduce pest populations as part of a large-scale program for public buildings (Greene and Breisch, 2002).

Preliminary research has indicated that IPM techniques can be effective for cockroach control (Frantz, et al., 1999; Campbell et al., 1999). Results of a study which assessed the effectiveness of a pilot IPM program in controlling cockroaches in an apartment complex, without pesticide sprays, showed that education can influence building residents to accept and comply with an IPM program, and that the program can be effective in controlling cockroaches (Campbell et al., 1999). Also, tests on the effectiveness of a bait (containing 2.15% imidacloprid) to control German cockroach populations found that when applied at 15-45g per kitchen, the bait significantly reduced cockroach trappings over a 4-week period (Appel and Tanley, 2000).

Smith et al. (1993, 1995, & 1997) have published some of the most extensive IPM effectiveness studies on smoky brown cockroaches (Appel and Smith, 2002). They have researched treatments for reducing smoky brown cockroaches around homes in Alabama, in both urban and rural areas. They have found that by targeting management tactics where cockroaches hide and forage, use of insecticide can be decreased and control can be maintained for longer periods of time than by employing a standard perimeter spray (Smith et al., 1993, 1995). Specifically, they have developed a comprehensive IPM system that includes sanitation, landscape management, and targeted application of insecticidal baits and sprays, and they found that the IPM system reduced cockroach abundance faster and longer than the conventional spray while using up to 80% less of the active ingredient (Appel and Smith, 2002). The authors have concluded that IPM treatment is an effective, safe, and economical way to manage cockroaches (Smith et al., 1997).

A recent study in East Harlem, New York City (Brenner et al., 2003) tested the effectiveness of IPM in household cockroach infestations. Two groups were studied; an intervention group that received individually tailored IPM education and support, including advice from pest control experts and home treatment by a professional exterminator using least-toxic pesticide gels and baits, and a control group that received only an injury prevention intervention. Evaluations were performed to assess the cockroach levels, and it was found that the proportion of intervention households with cockroaches declined significantly after 6 months (from 80.5% to 39%) whereas the control group levels were essentially unchanged (from 78.1% to 81.3%). The costs of the individually tailored IPM program were equal to or lower than traditional, chemical-based pest control methods, demonstrating that an individually tailored IPM program can be successful and cost-effective in an urban community (Brenner et al., 2003).

In Los Angeles, California, a randomized trial (McConnell et al., 2005) assessed an educational intervention to control cockroach allergen levels in the homes of Hispanic children. Caretakers were randomly assigned to an in-home intervention or comparison group. In the intervention group, peer educators trained caretakers in IPM strategies including reducing harborage and food access, applying boric acid, and proper cleaning to reduce allergen levels. Caretakers were also given supplies, such as materials for blocking pest entryways and allergen impermeable mattress and pillow covers. Four months after the training session, caretakers reported an increase in the use of recommended practices and the number of cockroaches in homes receiving the intervention was 60% lower than the number found in control homes. Allergen concentrations found in kitchen dust were also lower in homes receiving the intervention.

In Baltimore, Maryland, research has also been conducted on the effectiveness of IPM intervention projects that target rodent populations. A Rodent Control Committee, created by Mayor Schmoke in 1992, implemented a number of programs to combat the increasing Norway rat problem. The programs focused on rodent management through IPM practices, public education, increased community clean-up, and intensified baiting, which required cooperation between local authorities, residents, and pest control operators. The direct intervention was initially successful (up to 90% of rat burrows in target communities were eliminated), but attempts to modify behavior of residents through community outreach and education were generally unsuccessful, and follow-up surveys showed that reinfestation was common (achieving pre-intervention levels within 6 months in neighborhoods where environmental factors favored rat populations) (Lambropoulos et al., 1999).

Results from a more recent study found that IPM was effective in decreasing mouse allergen levels in inner-city mouse-infested homes in Boston (Phipataknakul et al., 2004). Over a five-month period mouse allergen levels significantly decreased in homes that received IPM interventions compared to control homes. IPM strategies included filling holes and cracks with copper mesh and sealant, using vacuums with HEPA filters, cleaning surfaces with mild detergents, trapping, applying low-toxicity pesticides in wall cavities and educating families. Allergen levels in the kitchen and bedroom decreased significantly in homes receiving IPM (78.8% and 77.3%, respectively); whereas levels in control homes increased (319% in the kitchen and 358% in the bedroom). Although this study was also designed to investigate if lung function or asthma symptoms improved with a decline in mouse allergen levels, no significant clinical differences were observed, possibly due to the small sample size (Phipataknakul et al., 2004).

4.0 RESEARCH NEEDS AND INFORMATION GAPS

The most significant data gap related to pesticide use in the home is the effect of chronic pesticide exposure on the neurodevelopmental competency of children (EPA, 2000b; Goldman and Koduru, 2000). Although the National Children's Study may provide more insight into this area and animal studies suggest that there may be effects, specific outcomes are difficult to ascertain. There are not only numerous different pesticides with the same mode of action, but also other pesticides with related or unrelated modes of action, and other completely different compounds which also act on the nervous system, thus creating an enormous effort for cumulative risk assessment (EPA, 2000b; Natural Resources Defense Council, 1997).

The scientific community also lacks standardized sample collection methods for pesticides in house dust. Sampling tools that have been used for lead exposure assessment may not be useful for pesticide sampling due to the higher vapor pressure of pesticides relative to lead. The rapid airflow over dust on a filter, or continual resuspension in less efficient sampling devices, may lead to pesticide losses during sampling. Tools have been used on an *ad hoc* basis without intercomparisons of methods, and thus comparability between findings of several large studies cannot be determined as yet (Cohen Hubal et al., 2000; Gordon, et al., 1999; Lioy, et al., 2000).

Despite the many microenvironmental measurements that have been collected in recent studies, no model yet exists to predict exposure from pesticide surface loadings.

Finally, studies have not been conducted to ascertain the indoor levels of pesticides in rental properties where pesticides are applied on a routine basis as a preventive maintenance measure. Lower SES populations may be at higher risk of exposure because of these use patterns.

Possible areas of consideration for future research include:

Health and Exposure Issues

- Information on the potential combined or synergistic effects of pesticides that have and do not have a common mechanism of action.
- The effect of chronic pesticide exposure on the neurodevelopmental competency of children.
- Additional data on the role of cockroach and rodent allergen exposure in asthma sensitization and exacerbation, particularly in socially disadvantaged populations.
- Information on the relationship between indoor exposure to pesticides and sensitization and exacerbation of asthma.
- Information on factors that affect pests, including research on how risk factors vary by location, or by housing or population characteristics.

Methodological Issues Related to Assessment

- Standardized sample collection methods for house dust to be analyzed for pesticides from floors and surfaces.
- Relation of environmental samples/pesticide surface loadings (vacuum dust, etc.) to actual exposure (e.g., information on exposure pathways and activity patterns of children).

Methodological Issues Related to Mitigation and IPM

- Research on the relative effectiveness and cost-benefit analysis of different pest control intervention strategies (e.g., traditional insecticide use versus IPM) with regards to pest populations, undesirable pesticide exposures, and asthma/allergen control.
- Research on effective methods of clean up after use of insecticides.
- Information on the prevalence of use of IPM methods in homes.
- Research on the most effective methods for educating home occupants about alternative pest control/IPM techniques.
- Long-term assessment of the methods and effectiveness of IPM strategies, as employed in different housing environments, in reducing: pest infestation, pesticide residues/exposure, and the levels of pest-related allergens.

References

Adgate, J.L., Barr, D.B., Clayton, C.A., Eberly, L.E., Freeman, N.C.G., Lioy, P.J., Needham, L.L., Pellizzari, E.D., Quackenboss, J.J., Roy, A., and K. Sexton. 2001. Measurement of children's exposure to pesticides: Analysis of urinary metabolite levels in a probability-based sample. Environmental Health Perspectives. 109(6): 583-590.

Adgate, J.L., Kukowski, A., Stroebel, C., Shubat, P.J., Morrell, S., Quackenboss, J.J., Whitmore, R.W., and K. Sexton. 2000. Pesticide storage and use patterns in Minnesota households with children. Journal of Exposure Analysis and Environmental Epidemiology. 10: 159-167.

Alliance for Healthy Homes. 2003. Pesticides. Available online at: http://www.afhh.org/hhe/hhe_pesticides.htm.

American Association of Poison Control Centers. 1999. Toxic Exposure Surveillance System. Available online at: www.aapcc.org/poison1.htm.

Appel, A.G. and L.M. Smith. 2002. Biology and management of the smoky brown cockroach. Annual Review of Entomology. 47: 33-55.

Appel, A.G. and M.J. Tanley. 2000. Laboratory and field performance of an imidacloprid gel bait against German cockroaches (Dictyoptera; Blattellidae). Journal of Economic Entomology. 93: 112-118.

Arbes, S.J., Sever, M., Archer, J., Long, E.H., Gore, J.C., Schal, C., Walter, M., Neubler, B., Vaughn, B., Mitchell, H., Liu, E., Collette, N., Adler, P., Sandel, M., and D.C. Zeldin. 2003. Abatement of cockroach allergen (Bla g 1) in low-income, urban housing: A randomized controlled trial. Journal of Allergy and Clinical Immunology. 112(2): 339-345.

Arbes, S.J., Sever, M.; Mehta, J., Gore, J.C., Schal, C., Vaughn, B., Mitchell, H., and D.C. Zeldin. 2004. Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: Month 12 continuation results. Journal of Allergy and Clinical Immunology. 113(1): 109-14.

Arbuckle, T.E., Lin, Z., and L.S. Merry. 2001. An exploratory analyses of the effect of pesticide exposure on the risk of spontaneous abortion in an Ontario Farm Population. Environmental Health Perspectives. 109(8): 851-857.

Arruda, K.L., Vailes, L.D., Ferriani, V.P., Santos, A.B., Pomes, A., and M.D. Chapman. 2001. Cockroach allergens and asthma. Journal of Allergy and Clinical Immunology. 107(3): 419-427.

Aspelin, A.L. and A.H. Grobe. 1999. Pesticides industry sales and usage: 1996 & 1997 market estimates. USEPA (OPPTS). Report No. 733-R-99-001.

ATSDR. 2000. Minimal Risk Levels (MRLs) for Hazardous Substances. Agency for Toxic Substances and Disease Control. Available online at: http://www.atsdr.cdc.gov/mrls.html

Avakian, M.D. 2001. EPA/NIEHS Superfund basic Research Program Research Brief 80: Mechanisms of Chlorpyrifos Developmental Neurotoxicity. Available online at: http://www-apps.niehs.nih.gov/sbrp/rb/rbs.cfm?Resbrfnum=80&view=.

Berkowitz, G.S., Obel, J., Deych, E., Lapinski, R., Godbold, J., Liu, Z., Landrigan, P.J., and M.S. Wolff. 2003. Exposure to indoor pesticides during pregnancy in a multiethnic, urban cohort. Environmental Health Perspectives. 111: 79–84.

Bradman, A. and R.M. Whyatt. 2005. Characterizing exposures to nonpersistent pesticides during pregnancy and early childhood in the National Children's Study: A review of monitoring and measurement methodologies. Environmental Health Perspectives. 113(8): 1092-1099.

Brenner, B.L., Markowitz, S., Rivera, M., Romero, H., Weeks, M., Sanchez, E., Deych, E., Garg, A., Godbold, J., Wolff, M.S., Landrigan, P.J., and G. Berkowitz. 2003. Integrated pest management in an urban community: a successful partnership for prevention. Environmental Health Perspectives. 111(13): 1649-53.

Buczkowski, G. and C. Schal. 2001. Emetophagy: Fipronil-induced regurgitation of bait and its dissemination from German cockroach adults to nymphs. Pesticide Biochemistry and Physiology. 71(3): 147-155.

Buczkowski, G., Kopanic, R.J., and C. Schal. 2001. Transfer of ingested pesticides among cockroaches: Effects of active ingredient, bait formulation, and assay procedures. Journal of Economic Entomology. 94(5): 1229-1236.

Campbell, M.E., Dwyer, J.J., Goettler, F., Ruf, F., and M. Bittiglio. 1999. A program to reduce pesticide spraying in the indoor environment: Evaluation of the 'Roach Coach' project. Canadian Journal of Public Health. 90(4): 277-281.

Cantalamessa, F. 1993. Acute toxicity of two pyrethroids, permethrin and cypermethrin, in neonatal and adult rats. Archives of Toxicology. 67: 510-513.

CDC. 2003. Second National Report on Human Exposure to Environmental Chemicals. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Environmental Health. Pub. No. 02-0716. January 2003, Revised March 2003. Available online at: http://www.cdc.gov/exposurereport/.

CDC. 2005. Third National Report on Human Exposure to Environmental Chemicals. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Environmental Health. Pub. No. 05-0570. July 2005. Available online at: http://www.cdc.gov/exposurereport/.

Chanda, S.M. and C.N. Pope. 1996. Neurochemical and neurobehavioral effects of repeated gestational exposure to chlorpyrifos in maternal and developing rats. Pharmacology Biochemistry and Behavior. 53: 771-776.

Chew, G.L., Perzanowski, M.S., Miller, R.L., Correa, J.C., Hoepner, L.A., Jusino, C.M., Becker, M.G., and P.L. Kinney. 2003. Distribution and determinants of mouse allergen exposure in low-income New York City apartments. Environmental Health Perspectives. 111: 1348–1351.

Chuang, J.C., Lyu, C.W., Chou, Y-L, Callahan, P.J., Nishioka, M., Andrews, K., Pollard, M.A., Brackney, L., Hines, C., Davis, D.B., and R.G. Menton. 1999. Evaluation and Application of Methods for Estimating Children's Exposure to Persistent Organic Pollutants in Multiple Media. EPA/600/R-98/164 a, b, and c (Volume I, II, and III).

CMHC. 1998. Farewell To Cockroaches: Getting Rid of Cockroaches the Least-Toxic Way. Canada Mortgage and Housing Corporation. Canada. Available online at: http://www.cmhc-schl.gc.ca/cmhc.html.

Cohen Hubal, E.A., Sheldon, L.S., Burke, J.M., McCurdy, T.R., Berry, M.R., Rigas, M.L., Zartarian, V.G., and N.C.G. Freeman. 2000. Children's exposure assessment: A review of factors influencing children's exposure, and the data available to characterize and assess that exposure. Environmental Health Perspectives. 108: 475-486.

Colt, J.S., Lubin, J., Camann, D., Davis, S., Cerhan, J., Severson, R. K., Cozen, W., and P. Hartge. 2004. Comparison of pesticide levels in carpet dust and self-reported pest treatment practices in four U.S. sites. Journal of Exposure Analysis and Environmental Epidemiology. 14: 74-83.

Consumer Reports. 1997. Safer Ways to Banish Bugs. 62: 48-51.

Dam, K., Seidler, F.J., and T.A. Slotkin. 1998. Developmental neurotoxicity of chlorpyrifos: delayed targeting of DNA synthesis after repeated administration. Developmental Brain Research. 108: 39-45.

De Vera, M.J., Drapkin, S., and J.N. Moy. 2003. Association of recurrent wheezing with sensitivity to cockroach allergen in inner-city children. Annals of Allergy, Asthma, and Immunology. 91(5): 455-459.

Durier, V. and C. Rivault. 2000. Secondary transmission of toxic baits in German cockroach (Dictyoptera: Blattellidae). Journal of Economic Entomology. 93 (2). 434-440.

Edwards, R.D. and P.J. Lioy. 1999. The EL Sampler: A press sampler for the quantitative estimation of dermal exposure to pesticides in housedust. Journal of Exp Analysis and Environmental Epidemiology. 9: 521-529.

Eggleston, P.A. 2000. Environmental causes of asthma in inner city children. Clinical Reviews of Allergy & Immunology. 18(3): 311-324.

Eggleston, P.A. and L.K. Arruda. 2001. Ecology and elimination of cockroaches and allergens in the home. Journal of Allergy and Clinical Immunology (Supplement). 107(3, part 2): 422.

Eggleston, P.A., Wood, R.A., Rand, C., Nixon, W.J., Chen, P.H., and P. Lukk. 1999. Removal of cockroach allergen from inner city homes. Journal of Allergy Clinical Immunology. 104: 842-846.

Elliott, M. 1977. Synthetic Pyrethroids. In "Synthetic Pyrethroids" ACS Symposium Series 42, ACS, Washington, DC. 1-28.

EPA, 2005a. Illegal Pesticide Products. U.S. Environmental Protection Agency. Available online at: http://www.epa.gov/pesticides/health/illegalproducts/#products.

EPA, 2005b. Inert (other) Ingredients in Pesticide Products. U.S. Environmental Agency. Available online at: http://www.epa.gov/opprd001/inerts/.

EPA, 2005c. Persistent Organic Pollutants (POPs). (Persistent Bioaccumulative and Toxic (PBT) Chemical Program). U.S. Environmental Protection Agency. Available online at: http://www.epa.gov/oppfead1/international/pops.htm.

EPA, 2004. Pesticide Industry Sales and Usage: 2000 and 2001 Market Estimates. U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, Office of Pesticide Programs, Biological and Economic Analysis Division. May 2004. Available online at: http://www.epa.gov/oppbead1/pestsales/index.htm.

EPA, 2003a. The Food Quality Protection Act (FQPA) Background. U.S. Environmental Protection Agency. Available online at: http://www.epa.gov/oppfead1/fqpa/backgrnd.htm#implementation.

EPA, 2003b. Types of Pesticides. U.S. Environmental Protection Agency. Available online at: http://www.epa.gov/pesticides/about/types.htm.

EPA, 2002a. What is a Pesticide? U.S. Environmental Protection Agency, Office of Pesticide Programs. Available online at: http://www.epa.gov/pesticides/about/.

EPA, 2002b. DDT Regulatory History: A Brief Survey (to 1975). Available online at: http://www.epa.gov/history/topics/ddt/02.htm. Excerpt from *DDT, A Review of Scientific and*

Economic Aspects of the Decision To Ban Its Use as a Pesticide, prepared for the Committee on Appropriations of the U.S. House of Representatives by EPA, July 1975. U.S. Environmental Protection Agency. EPA-540/1-75-022.

EPA. 2001. Diazinon Revised Risk Assessment and Agreement with Registrants. Washington DC: U.S. Environmental Protection Agency.

EPA. 2000a. Developmental and Neurological Problems. U.S. Environmental Protection Agency, Office of Children's Health Protection. Available online at: http://www.epa.gov/children/toxics.htm.

EPA. 2000b. Strategy for Research on Environmental Risks to Children. U.S. Environmental Protection Agency. EPA/600/R-00/068.

EPA. 2000c. Chlorpyrifos Revised Risk Assessment and Agreement with Registrants. Washington, DC: U.S. Environmental Protection Agency.

EPA. 2000d. Analysis of Aged In-home Carpets to Determine the Distribution of Pesticide Residues and their Potential Availability for Human Exposure. U.S. Environmental Protection Agency, National Exposure Research Laboratory, May 2000. EPA/600/R-00/030.

EPA. 1997. Pesticide Industry Sales and Usage: 1994 and 1995 Market Estimates. U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, Office of Pesticide Programs, Biological and Economic Analysis Division. August 1997. Available online at: http://www.epa.gov/oppbead1/pestsales/.

Eskenazi B., Bradman A., and R. Castorina. 1999. Exposures of children to organophosphate pesticides and their potential adverse health effects. Environmental Health Perspectives. 107 (Suppl 3): 409-19.

Etzel R.A. and S.J. Balk, eds. (1999). Handbook of Pediatric Environmental Health (The Green Book). Elk Grove Village IL: American Academy of Pediatrics.

Fenske, R.A., Black, K.G., Elkner, K.P., Lee, C.L., Menther, M.M., and R. Soto. 1990. Potential exposure and health risks of infants following indoor residential pesticide applications. American Journal of Public Health. 80: 689-693.

Fortune, C.R., Blanchard, F.T., and W.D. Ellenson. 2000. Analysis of aged in-home carpeting to determine the distribution of pesticide residues between dust, carpet and pad components. EPA/600/R-00/030.

Frantz, S.C., Gronning, E.K., and R.L. Chaput. 1999. Designing Integrated Pest Management for the Sustained Reduction of Cockroach and Rodent Populations for Asthma Prevention in Low-Income Urban Residences. National Environmental Health Association's 63rd Annual Educational Conference & Exhibition, Nashville, TN, July 6-9, 1999.

Gergen, P.J., Mortimer, K.M., Eggleston, P.A., Rosenstreich, D., Mitchell, H., Ownby, D., Kattan, M., Baker, D., Wright, E.C., Slavin, R. and F. Malveaux. 1999. Results of the National Cooperative Inner-City Asthma Study (NCICAS) environmental intervention to reduce cockroach allergen exposure in inner-city homes. Journal of Allergy and Clinical Immunology. 103(3): 501-506.

Goldman, L.R., and S. Koduru. 2000. Chemicals in the Environment and Developmental Toxicity to Children: A Public Health and Policy Perspective. Environmental Health Perspectives. 108 (Suppl 3): 443-448.

Gordon, S.M., Callahan, P.J., Nishioka, M.G., Brinkman, M.C., O'Rourke, M.K., Lebowitz, M.D., and D.J. Moschandreas. 1999. Residential environmental measurements in the National Human Exposure Assessment Survey (NHEXAS) pilot study in Arizona: Preliminary results for pesticides and VOCs. Journal of Exposure Analysis and Environ Epidemiology. 9: 456-470.

Greenberg, S. 2004. Cockroach Allergen Reduction Using Precision-Targeted IPM and the Lead Dust Cleaning Protocol. Final Report. Environmental Health Watch. HUD Cooperative Agreement #OHLHH0069-99. Available on-line at: www.ehw.org/Asthma/ASTH_RoachFinalRpt.pdf.

Greene, A. and N. Breisch. 2002. Measuring integrated pest management programs for public buildings. Journal of Economic Entomology. 95(1): 1-13.

Grossman, J. 1995. What's hiding under the sink: Dangers of household pesticides. Environmental Health Perspectives. 115(2): 550-555.

Guillette, E.A., Meza, M.M., Aquilar, M.G., Soto, A.D., and I.E. Garcia. 1998. An anthropological approach to the evaluation of preschool children exposed to pesticides in Mexico. Environmental Health Perspectives. 106(6): 347-53.

Hall, S.K., Chakraborty, J., and R.J. Ruch (eds). (1997). Chemical Exposure and Toxic Responses. Boca Raton: Lewis Publishers.

Health Canada. 2001. Tips to rid your house of insects and rodents. Available online at: http://www.hc-sc.gc.ca/pmra-arla/english/pdf/pnotes/hhpests-e.pdf.

Hill, R.H., Head, S.L., Baker, S., Gregg, M., Shealy, D.B., Bailey, S.L., et al. 1995. Pesticide residues in urine of adults living in the United States: reference range concentrations. Environmental Research. 71: 99-108.

Hom, A. 1999. The urban IPM challenge: San Francisco and beyond. The IPM Practitioner: Monitoring the Field of Pest Management. 21(3): 1-8.

The IPM Institute of North America, Inc. 2003. IPM in the Marketplace, Vol. 3, Issue No. 4. Available online at: http://www.ipminstitute.org/newsletter_v3i4.htm#IPMStar.

Itaya, N., Matsuo, T., Ohno, N., Mizutani, T., Fujita, F., and H. Yoshioka. 1977. Recent Progress in Syntheses of the New and Most Potent Pyrethroids. In “Synthetic Pyrethroids” ACS Symposium Series 42, ACS, Washington, D.C., pp. 45-54.

Jacobson, J.L., and S.W. Jacobson. 1996. Intellectual Impairment in Children Exposed to Polychlorinated Biphenyls in Utero. The New England Journal of Medicine. 335: 783-789.

Kamrin, M.A. (ed.). (1997). Pesticide Profiles: Toxicity, Environmental Impact, and Fate (pp 15-44). Boca Raton: Lewis Publishers.

Katial, R.K. 2003. Cockroach allergy. Immunology and Allergy Clinics of North America. 23: 483-499.

Klitzman, S., Caravanos, J., Belanoff, C., and L. Rothenberg. 2005. A multihazard, multistrategy approach to home remediation: Results of a pilot study. Environmental Research. 99(3): 294-306.

Kopanic, R.J. and C. Schal. 1999. Coprophagy facilitates horizontal transmission of bait among cockroaches (Dictyoptera: Blattellidae). Environmental Entomology. 28 (3): 431-438.

Krieger, R.I., Bernard, C.E., Dinoff, T.M., Fell, L., Osimitz, T.G., Ross, J.H., and T. Thongsinthusak. 2000. Biomonitoring and whole body cotton dosimetry to estimate potential human dermal exposure to semivolatile chemicals. Journal of Exposure Analysis and Environmental Epidemiology. 10: 50-57.

Lambropoulos, A.S., Fine, J.B., Perbeck, A., Torres, D., Glass, G.E., McHugh, P., and E.A. Dorsey. 1999. Rodent control in urban areas: An interdisciplinary approach. Journal of Environmental Health. 61(6): 12-16.

Lewis, R.G., Bond, A.E., Johnson, D.E., and J.P. Hsu. 1988. Measurement of atmospheric concentrations of common household pesticides: a pilot study. Environmental Monitoring Assessment. 10: 59-73.

Li, W.W., and J.E. Casida. 1998. Organophosphorous neuropathy target esterases inhibitors selectively block outgrowth of neurite-like and cell processes in cultured cells. Toxicology Letters. 98: 139-146.

Lioy, P.J., Edwards, R.D., Freeman, N., Gurunathan, S., Pellizzari, E., Adgate, J.L., Quackenboss, J., and K. Sexton. 2000. House dust levels of selected insecticides and an herbicide measured by the EL and LWW samplers and comparisons to hand rinses and urine metabolites. Journal of Exposure Analysis and Environmental Epidemiology. 10: 327-340.

MacIntosh, D.L., Needham, L.L., Hammerstrom, K.A., and P.B. Ryan. 1999. A longitudinal investigation of selected pesticide metabolites in urine. Journal of Exposure Analysis and Environmental Epidemiology. 9: 494-501.

Marei, A.E.M., Ruzo, L.O., and J.E. Casida. 1982. Analysis and persistence of permethrin, cypermethrin, deltamethrin and fenvalerate in the fat and brains of treated rats. Journal of Agricultural and Food Chemistry. 30: 558-562.

Market Share Reporter. (2001). Indoor Pest Control Market-1998 (p. 163). Farmington Hilles, MI: Thomson Gale.

Markowitz, S.B. 1992. Poisoning of an urban family due to misapplication of household organophosphate and carbamate pesticides. Clinical Toxicology. 30: 295-303.

McConnell, R., Milam, J., Richardson, J., Galvan, J., Jones, C., Thorne, P.S., and K. Berhane. 2005. Educational intervention to control cockroach allergen exposure in the homes of Hispanic children in Los Angeles: results of the La Casa study. Clinical and Experimental Allergy. 35: 426-433.

Mendola, P., Selevan, S., Gutter, S., and D. Rice. 2002. Environmental factors associated with a spectrum of neurodevelopmental deficits. Mental Retardation and Developmental Disabilities Research Reviews. 8: 188-197.

Miller, D.M. and F. Meek. 2004. Cost and efficacy comparison of integrated pest management practices with monthly spray insecticide applications for German cockroach (Dictyoptera: Blattellidae) control in public housing. Journal of Economic Entomology. 97(3): 559-569.

Morgan, W.J., Crain, E.F., Gruchalla, R.S., O'Connor, G.T., Kattan, M., Evans III, R., Stout, J., Malindzak, G., Smartt, E., Plaut, M., Walter, M., Vaughn, B., and H. Mitchell. 2004. Results of a home-based environmental intervention among urban children with asthma. New England Journal of Medicine. 351(11) 1068- 1080.

Miyamoto, J. 1976. Degradation, metabolism and toxicity of synthetic pyrethroids. Environmental Health Perspectives. 14: 15-28.

Murphy, R.S., Kutz, F.W., and S.C. Strassman. 1983. Selected pesticide residues or metabolites in blood or urine specimens from a general population survey. Environmental Health Perspectives. 48: 81-86.

Natural Resources Defense Council. 1997. Our Children at Risk: The Five Worst Environmental Threats to Their Health. Available online at: www.nrdc.org/health/kids/ocar/ocarinx.asp.

New York State Integrated Pest Management Program. 2001. IPM for Homes (brochure from Cornell Cooperative Extension). Available online at: http://www.nysipm.cornell.edu/publications/homesbro/homes.pdf.

New York State Integrated Pest Management Program. http://www.nysipm.cornell.edu/.

NHANES. 2003. National Health and Nutrition Examination Survey. Centers for Disease Control and Prevention, National Center for Health Statistics. Available online at: http://www.cdc.gov/nchs/nhanes.htm.

Nieuwenhuijsen, M.J., Grey, C.N.B., Golding, J., and the ALSPAC Group. 2005. Exposure misclassification of household pesticides and risk perception and behaviour. Annals of Occupational Hygiene. (Accepted June 20, 2005).

Nishioka, M.G., Burkholder, H.M., Brinkman, M.C., Gordon, S.M., and R.G. Lewis. 1996. Measuring transport of lawn-applied herbicide acids from turf to home: Correlation of dislodgeable residues with carpet dust and carpet surface residues. Environmental Science and Technology. 30: 3313-3320.

Nishioka, M.G., H.M., Brinkman, M.C., and S.M. Gordon. 1997. Simulation of track-in of lawn-applied pesticides from turf to home: Comparison of dislodgeable turf residues with carpet dust and carpet surface residues. Report No. EPA/600/SR-97/108. Research Triangle Park: U.S. Environmental Protection Agency, National Exposure Research Laboratory, October, 1997.

Nishioka, M.G., Burkholder, H.M., Brinkman, M.C., and R.G. Lewis. 1999. Distribution of 2,4-D in floor dust throughout homes following homeowner and commercial lawn applications: Quantitative effects of children, pets, and shoes. Environmental Science and Technology. 33: 1359-1365.

Northeast Integrated Pest Management Home Page. http://northeastipm.org/index.html.

Ogg, B., Ferraro, D., and C.L. Ogg. 1994. Cockroach Control Manual. University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Lancaster County Cooperative Extension Office. Lincoln, NE. Available online at: http://pested.unl.edu/cockcom.htm.

Ogg, C.L. and R.E. Gold. 1993. Inclusion of insecticidal bait stations in a German cockroach (Orthoptera Blattellidae) control program. Journal of Economic Entomology. 86(1): 61-65.

Ohio State University Extension. 2003. Pet Pest Management: Bulletin 586, (by William F. Lyon). Available online at: http://ohioline.osu.edu/b586/b586_1.html.

Olden, K and J. Guthrie. 2000. Editorial perspective: Children’s health - a mixed review. Environmental Health Perspectives. 108: A250-251.

Olkowski, H. and W. Olkowski. 1990. Management of the house mouse – A cute little menace. Common Sense Pest Control Quarterly. 6(4): 7-15.

Olkowski, W., Daar, S., and H. Olkowski. 1991. Common Sense Pest Control: Least Toxic Solutions for your Home, Garden, Pets, and Community. The Tauton Press.

O'Malley, M. 1997. Clinical evaluation of pesticide exposure and poisonings. The Lancet. 349: 1161-1166.

Offenberg, J.H., Naumova, Y.Y., Turpin, B.J., Eisenreich, S.J., Morandi, M.T., Stock, T., Colome, S.D, Winer, A.M., Spektor, D.M., Zhang, J., and C.P. Weisel. 2004. Chlordanes in the indoor and outdoor air of three U.S. cities. Environmental Science and Technology. 38: 2760-2768.

Perera, F.P., Rauh, V., Tsai, W-Y., Kinney, P., Camann, D., Barr, D., Bernert, T., Garfinkel, R., Tu, Y-H., Diaz, D., Dietrich, J., and R.M. Whyatt. 2003. Effects of transplacental exposure to environmental pollutants on birth outcomes in a multiethnic population. Environmental Health Perspectives. 111(2): 201-205.

Persky, V., Coover, L., Hernandez, E., Contreras, A., Slezak, J., Piorkowski, J., Curtis, L., Turyk, M., Ramakrishnan, V., and P. Scheff. 1999. Chicago Community-Based Asthma Intervention Trial (Statistical Data Included). Chest. 116(4): 216S.

Pesticide Profiles. 1997. Ed. Kamrin MA. Pesticide profiles: toxicity, environmental impact, and fate. Boca Raton: Lewis Publishers, pp 15-44.

Phipatanakul, W., Eggleston, P.A., Wright, E.C., Wood, R.A., and National Cooperative Inner-City Asthma Study. 2000a. Mouse allergen. I. The prevalence of mouse allergen in inner-city homes. The National Cooperative Inner-City Asthma Study. Journal of Allergy and Clinical Immunology. 106(6): 1070-4.

Phipatanakul, W., Eggleston, P.A., Wright, E.C., Wood, R.A., and National Cooperative Inner-City Asthma Study. 2000b. Mouse allergen. II. The relationship of mouse allergen exposure to mouse sensitization and asthma morbidity in inner-city children with asthma. Journal of Allergy and Clinical Immunology. 106(6): 1075-1080.

Phipatanakul, W., Cronin, B., Wood, R.A., Eggleston, P.A., Shih, M., Song, L., Tachdjian, R., and H.C. Oettgen. 2004. Effect of environmental intervention on mouse allergen levels in homes of inner-city Boston children with asthma. Annals of Allergy, Asthma, and Immunology. 92: 420-425.

Quarles, W. 1999. Dust mites, cockroaches and asthma. Common Sense Pest Control Quarterly. 15(1): 4-18.

Rauh, V.A., Chew, G.R., and R.S. Garfinkel. 2002. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. Environmental Health Perspectives. 110 (Supplement 2): 323-7.

Reed, K.J., Jimenez, M., Freeman, N.C.G., and P.J. Lioy. 1999. Quantification of children's hand and mouthing activities through a videotaping methodology. Journal of Exposure Analysis and Environmental Epidemiology. 9: 513-520.

Rice, D., and S. Barone. 2000. Critical periods of vulnerabilities for the developing nervous system: Evidence from humans and animal models. Environmental Health Perspectives. 108(Supplement 3): 511-534.

Roinestad, K.S., Louis, J.B., and J.D. Rosen. 1993. Determination of pesticides in indoor air and dust. Journal of AOAC International. 76: 1121-1126.

Ross, J., Fong, H.R., Thongsinthusak, T., et al. 1991. Measuring potential dermal transfer of surface pesticide residue generated from indoor fogger use: Using the CDFA Roller Method, interim report II. Chemosphere 22: 975-984.

Rudel, R.A., Camann, D.E., Spengler, J.D., Korn, L.R., and J.G. Brody. 2003. Phthalates, alkylphenols, pesticides, polybrominated diphenyl ethers, and other endocrine-disrupting compounds in indoor air and dust. Environmental Science & Technology. 37(20): 4543-53.

Safer Pest Control Project of Illinois. Factsheet 2. Safer Solutions: Integrated Pest Management in Public Housing. Available online at: www.spcpweb.org.

San Francisco Department of the Environment Pesticide Program, Integrated Pest Management (IPM) Ordinance. Available online at:
http://www.sfgov.org/sfenvironment/aboutus/toxics/ipm/.

Selevan, S.G., Kimmel, C.A., and P. Mendola. 2000. Identifying critical windows of exposure for children's health. Environmental Health Perspectives. 108 (Supplement 3): 451-455.

Sexton, K., Adgate, J.L., Eberly, L.E., Clayton, C.A., Whitmore, R.W., Pellizzari, E.D., Lioy, P.J., and J.J. Quackenboss. 2003. Predicting children's short-term exposure to pesticides: Results of a questionnaire screening approach. Environmental Health Perspectives. 111(1): 123-128.

Sheets, L.P. 2000. A consideration of age-dependent differences in susceptibility to organophosphorous and pyrethroid insecticides. Neurotoxicology. 21: 57-63.

Sherman, R.A. 1979. Preliminary behavioral assessment of habituation to the insecticide permethrin. U.S. Army Environmental Hygiene Agency Rpt No 75-51-002679, Aberdeen Proving Ground, Maryland.

Siddiqi, Z. 2001. New technologies in pest management prevent pathogen spread. Food Processing. 62(2): 63.

Simcox, N.J., Fenske, R.A., Wolz, S.A., Lee, I.C., and D. Kalman. 1995. Pesticides in housedust and soil: Exposure pathways for children of agricultural families. Environmental Health Perspectives. 103: 1126-1134.

Smith, L.M. II, Appel, A.G., Mack, T.P., Keever, G.J., and E.P Benson. 1993. Integrated pest management effectively controls smokybrown cockroaches. Highlights Agric. Res. Ala. Agric. Exp. Stn. 40(2): 7.

Smith, L.M. II, Appel, A.G., Mack, T.P., Keever, G.J., and E.P Benson. 1995. Comparative effectiveness of an integrated pest management system and an insecticidal perimeter spray for control of smokybrown cockroaches (Dictyoptera: Blattidae). Journal of Economic Entomology. 88: 907-17.

Smith, L.M. II, Appel, A.G., Mack, T.P., Keever, G.J., and E.P Benson. 1997. Evaluation of methods of insecticide application for control of smokybrown cockroaches (Dictyoptera: Blattidae). Journal of Economic Entomology. 90: 1232-42.

Staatz, C.G., Bloom, A.S., and J.J. Lech. 1982. A pharmacological study of pyrethroid neurotoxicity in mice. Pesticide Biochemistry and Physiology. 17(3): 287-292.

Stubner, A.H., Dillon, H.K., and C.L. Kohler. 2000. Home remediation for respiratory health: A feasibility study (statistical data included). Family and Community Health. 22(4): 1.

University of Nebraska Cooperative Extension. 1997. Signs and Symptoms of Pesticide Poisoning. Available online at: www.ianr.unl.edu/pubs/pesticides/ec2505.htm.

Vaughan, J.W. and T.A. Platts-Mills. 2000. New approaches to environmental control. Clinical Reviews in Allergy and Immunology. 18(3): 325-39.

Wang, C., Scharf, M.E., and Bennett, G.W. 2004. Behavioral and physiological resistance of the German cockroach to gel baits (Dictyoptera: Blattellidae). Journal of Economic Entomology. 97: 2067-2072.

Wang, C., Scharf, M. E., and G.W. Bennett. 2006. A Genetic Basis for Resistance to Gel Baits, Fipronil, and Sugar-Based Attractants in German Cockroaches (Dictyoptera: Blattellidae). Journal of Economic Entomology. Vol. 99 (in print).

Watson, W.A., Litovitz, T.L., Rodgers, G.C., Klein-Schwartz, W., Youniss, J., Rose, Rutherfoord, Borys, D., and M.E. May. 2003. 2002 Annual Report of the American Association of Poison Control Centers Toxic Exposure Surveillance System. Americal Journal of Emergency Medicine. 21(5): 353-421.

Weaver, T. 1998. Curbing cockroaches and their allergens. Agricultural Research. 46(6): 4(3).

Weiss, B. 2000. Vulnerability of Children and the Developing Brain to Neurotoxic Hazards. Environmental Health Perspectives. 108 (Supplement 3): 375-381.

Whitmore, R.W., Immerman, F.W., Camann, D.E., Bond, A.E., Lewis, R.G., and J.L. Schaum. 1994. Non-occupational exposures to pesticides for residents of two U.S. cities. Archives of Environmental Contamination and Toxicology. 26: 47-59.

Whitney, K.D., Seidler, F.J., and T.A. Slotkin. 1995. Developmental neurotoxicity of chlorpyrifos: Cellular mechanisms. Toxicology and Applied Pharmacology. 134: 53-62.

Whyatt, R.M., Rauh, V., Barr, D. B., Camann, D. E., Andrews, H. F., Garfinkel, R., Hoepner, L. A., Diaz, D., Dietrich, J., Reyes, A., Tang, D., Kinney, P. L., and F. P. Perera. 2004. Prenatal insecticide exposures, birth weight and length among an urban minority cohort. Environmental Health Perspectives. 112(10): 1125-32.

Whyatt, R.M., Barr, D.B., Camann, D.E., Kinney, P.L., Barr, J.R., Andrews, H.F., Hoepner, L.A., Garfinkel, R., Hazi, Y., Reyes, A., Ramirez, J., Cosme, Y., and F.P. Perera. 2003. Contemporary-use pesticides in personal air samples during pregnancy and blood samples at delivery among urban minority mothers and newborns. Environmental Health Perspectives. 111(5): 749-756.

Whyatt, R.M., Camann, D.E., Kinney, P.L., Reyes, A., Ramirez, J., Dietrich, J., Diaz, D., Holmes, D., and F.P. Perera. 2002. Residential pesticide use during pregnancy among a cohort of urban minority women. Environmental Health Perspectives. 110(5): 507-514.

Wilson, N.K., Chuang, J.C., Lyu, C., Menton, R., and M.K. Morgan. 2003. Aggregate exposures of nine preschool children to persistent organic pollutants at day care and at home. Journal of Exposure Analysis and Environmental Epidemiology. 13(3): 187-202.

Worthing, C.R. (ed). (1983). The Pesticide Manual: A World Compendium. The British Crop Protection Council.

Wu, D., Scharf, M.E., Neal, J.J., Suiter, D.R., and G.W. Bennett. 1998. Mechanisms of Fenvalerate resistance in the German cockroach, *Blattella germanica* (L.). Pesticide Biochemistry and Physiology. 61: 53-62.

Zartarian, V.G., Ozkaynak, H., Burke, J.M., Zufall, M.J., Rigas, M.L., and E.J. Furtaw. 2000. A modeling framework for estimating children's residential exposure and dose to Chlorpyrifos via dermal residue contact and non-dietary ingestion. Environmental Health Perspectives. 108: 505-514.

Zeichner, B.C., Hoch, A.L., and D.F. Wood. 1998. Heat and IPM for cockroach control. The IPM Practitioner: Monitoring the Field of Pest Management. 20(2): 1-6.

Appendix A. Additional Internet Resources

In addition to the references and links appearing in the reference list above, the following table provides selected links with additional information related to pesticides and integrated pest management.

Sponsoring Organization/Topic	Internet Web Site Address
Centers for Disease Control and Prevention	http://www.cdc.gov/healthyplaces/healthyhomes.htm
Environmental Health Watch	http://www.ehw.org/Asthma/ASTH_HUDRoach_Sum.htm
Michigan State University	http://www.pested.msu.edu/CommunitySchoolIpm/
National Pesticide Information Center	http://npic.orst.edu/
U.S. EPA Pesticide Home Page	http://www.epa.gov/pesticides/
University of Rhode Island	http://www.uri.edu/ce/factsheets/indices/0houseinsectindex.html
Washington State Department of Health	http://www.doh.wa.gov/ehp/ts/iaq.htm

Appendix B. Example IPM Programs

The San Francisco Pesticide Program. The city of San Francisco has one of the most progressive and innovative urban pesticide-reduction programs in the country. The San Francisco Pesticide Program, established by the Integrated Pest Management (IPM) Ordinance, was enacted to regulate and reduce the use of chemical pesticides in and on city property by city departments, agencies, and contractors. The IPM ordinance bans the use of the most toxic pesticides including carcinogens and reproductive toxicants. The ordinance also requires the posting of notices to inform the public whenever a pesticide is used on city property and requires a public access telephone number for questions regarding pesticide use. Highlights of the programs include phased reductions in pesticide use (e.g., most toxic banned in 1997, etc.), departmental accountability for city agencies (e.g., monthly reporting and development of an IPM implementation plan), and extensive training of city staff in alternative methods for controlling pests. The San Francisco Department of the Environment also works with other City departments to educate businesses, residences, and other communities on reduced risk and effective means of controlling pests. To date, use of the most toxic pesticides has been eliminated and in most areas of the city, overall pesticide use has dropped by over 50%. The city's pest control contractor has also eliminated the use of chemical pesticides in more than 70% of visits to city buildings (Hom, 1999). Additional information is available on the SF Department of the Environment's web site: www.sfgov.org/sfenvironment/aboutus/toxics/ipm/.

The Safer Pest Control Project in Chicago. Residents and building managers at the Henry Horner Public Housing Development in Chicago participated in a one-year pilot program (1997), sponsored by the Safer Pest Control Project, an Illinois nonprofit organization that promotes IPM. The program targeted improvements in maintenance and sanitation, promoted resident involvement and education, and included regular inspections and targeted insecticidal gel bait applications. The Henry Horner program was successful (90% of surveyed residents reported declined pest populations and declined pesticide use) and has since influenced programs sponsored by housing authorities in other cities (*Safer Pest Control Project –* factsheet 2).

The Chicago Community-Based Asthma Intervention Trial. The National Cooperative Inner City Asthma Study (NCICAS) is an important national effort that addresses asthma triggers and allergen remediation in inner-city homes. The purpose of the Chicago Community-Based Asthma Intervention Trial, as part of the NCICAS, was to show the feasibility of a peer educator program for children with asthma and the effectiveness of peer education on modifying levels of indoor allergens. An inner-city Chicago population with high rates of asthma was targeted and intervention strategies included IPM for cockroach control, which emphasized housekeeping, identification of roach sources, selective use of baits, caulking leaky faucets and repair to areas that allowed roach entry. The project successfully demonstrated the feasibility of a peer educator program. The program was generally well received by educators and community residents; however, results from the study suggest that future intervention programs should focus more on reducing cockroach allergens than was previously targeted, while at the same time working to minimize the use of pesticides (Persky et al., 1999).

The Mount Sinai and Columbia Center for Children's Environmental Health Projects in New York City. "Growing up Healthy in East Harlem," sponsored by the Mount Sinai Center for Children's Environmental Health and Disease Prevention Research, is a community-based intervention project that has been shaped by the Henry Horner program. This research trial, undertaken in New York City, was designed to evaluate the effectiveness of IPM in households based on measures of pesticide levels in house dust, pesticide metabolite levels in urine, and roach infestation levels (www.cehn.org/cehn/resourceguide/mscfcer). Also in New York City, the Columbia Center for Children's Environmental Health (CCCEH) is sponsoring an IPM project to reduce pests and allergens in the home. Their IPM intervention includes: repair of cracks, holes, and water leaks; intensive cleaning to reduce existing allergen and pesticide levels; use of low toxicity control practices (gels and baits); and education for residents on how to maintain IPM efforts. Thus far, the pilot program has shown promising results in reducing cockroach populations in kitchens, but further evaluation of the intervention's impact on allergen levels and pesticide levels is still needed (cpmcnet.Columbia.edu/dept/sph/ccceh/ research/community-education).

The Home Remediation for Respiratory Health Study in Birmingham, Alabama. This study examined the feasibility of conducting home interventions to lower allergen levels in low-income, inner-city households in Birmingham, Alabama. The goals of the interventions were: (1) to lower levels of allergens in the homes; (2) to modify the home to prevent future problems; and (3) to educate the residents on how to maintain a healthy indoor environment. The home interventions varied according to need, but they included IPM to eliminate harborage, remove access to food, and minimize water sources. The authors concluded that the interventions were successful, but results related to respiratory health were inconclusive (Stubner et al., 2000).

Environmental Health Watch in Cleveland, Ohio. This organization conducted a small project to explore the effectiveness of different methods of cockroach control and allergen cleanup in public housing. The control intervention included "precision-targeted IPM" designed by the USDA Imported Fire Ants and Household Insects Research Unit (Agricultural Research Station, Gainesville, Florida). The intervention to clean up cockroach allergens included the standard lead cleaning protocol and two modifications for cleaning lead dust on hard surfaces (one used a wet vacuum instead of a mop to clean up dirty wash and rinse water and the other used a wet vacuum and substituted bleach/detergent cleaner for the detergent-only cleaner.) The IPM method used decreased the cockroach population by 95%. All three cleaning interventions significantly reduced allergen concentrations immediately following the treatment. However, standard lead cleaning was more effective in reducing allergen concentrations during the follow-up period to levels near the proposed levels of sensitization. The full report is available online at: http://www.ehw.org/Asthma/ASTH_RoachFinalRpt.pdf.