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Reducing Residential Indoor Exposure to Pesticides: a Toolkit for Practitioners

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evidence review

Summary

- The scientific literature indicates that avoidance of pesticide use and alternative practices, such as Integrated Pest Management (IPM), may be effective methods for reducing indoor residential pesticide exposure.
- Safe use of pesticides, indoors and outdoors, involves following label directions and taking precautionary measures, such as wearing gloves and protective clothing.
- Track-in and take-home of pesticides used outdoors can contribute to pesticide exposure indoors and can likely be reduced by such simple measures as removing shoes at door entries and using doormats.
- Once pesticide residues are indoors, cleaning may reduce levels. Bare floors are easiest to clean and, for carpets, vacuuming with a power brush in combination with steam cleaning may be an effective way to reduce pesticide residues by reducing dust accumulation.
- A major evidence gap is the lack of good intervention studies that are effective in reducing pesticide exposure (not just reducing pesticide use) in households and residential areas.

Introduction

Pesticides are a broad range of chemicals used to control or kill unwanted organisms, such as indoor insects and rodents and outdoor weeds in lawns and gardens. Exposure to pesticides can result from use in and around the home. Some pesticide products are not easily identified because they are combined with other products, for example, weed 'n feed products that contain fertilizer in combination with herbicides. Another source, that consumers usually do not identify as products containing pesticide, is tick and lice treatment.[1] Other sources of potential pesticide exposures include indoor spraying, to control flies or bed bugs, and other pests, such as mice. Commonly used pesticides include pyrethroids for indoor and outdoor insects and 2,4-D for weed control. Even if residents are not using pesticides themselves, they can be exposed to these chemicals, e.g., neighbourhood spraying or take-home pesticides used on public lands, such as parks.

Pesticides vary in toxicity, but exposure to some pesticides has shown to be associated with health effects, such as cancer, reproductive effects, and asthma. Children are particularly vulnerable to exposure and health effects. For example, a recent systematic review showed associations for childhood leukemia and in utero with childhood exposure to residential pesticides (especially insecticides).[2]

Residential exposure, from indoor or outdoor pesticides use, contributes to overall exposure to pesticides and may be a more important source of exposure for pyrethroids than diet, especially for small children.[3,4] Pesticide exposure through diet and strategies to reduce this exposure are discussed in a separate document http://www.ncceh.ca/en/practice_policy/ncceh_reviews/organic_diet

Although different pesticides exposures are difficult to quantify from various sources, there are simple and easy preventive measures to decrease the likelihood of exposure and contribute to overall pesticide exposure reduction. The methodology used to identify intervention studies is included in the appendix.

This toolkit intends to help public health inspectors (PHIs) and medical health officers (MHOs) inform the public about strategies to reduce non-agricultural residential pesticide exposure indoors. It focuses on the following exposure reduction strategies: prevention and alternatives; safe use of pesticides; minimizing take-home and track-in; and cleaning the home. For each of these strategies, a number of recommendations have been derived from the scientific literature. Recommendations for the public are listed in Table 1 and the evidence is presented below. References to and details of the original scientific studies are included in Table 2.

Prevention and Alternatives

Avoiding the use of pesticides in and around the house will minimize exposures. Prevention is one way to avoid pest problems indoors. In the case of garden or lawn pests and weeds, public acceptance of some pests along with cultural changes, e.g., the North American idea of a perfect lawn, may be necessary.[5] As opposed to pesticides used in agriculture or indoors, this *cosmetic* use of pesticides does not have direct health benefits.

Pests can be controlled by removing their basic survival elements: air, moisture, food, and shelter. Integrated pest management (IPM) is based on this concept. IPM is a combination of measures to prevent, manage, and treat pest infestations and consists of several elements, such as closing entryways, removing food sources, monitoring pest populations, and using the least toxic pesticides or mode of delivery. It is important that the elements be practiced together to reach a maximum effect. A professional exterminator, specializing in integrated pest management, can help determine individual needs for repairs and pesticide use,[6,7] but residents can also practice integrated pest management on their own. IPM can be regarded as a way to reduce pesticide exposure, as well as control pests.

Most studies only evaluate the effectiveness of IPM in terms of the ability to control indoor pests and their allergens, but fail to provide information about pesticide reduction. Although it is likely that many of these studies have reduced the use of traditional pesticides in their IPM strategies, it is not possible to assess whether they were effective in reducing pesticide use and level of exposure; most studies did not conduct pre- and post-pesticide measurements.

The recommendations in Table 1 are derived from four studies that specifically assessed pesticide exposure in their IPM programs. Three U.S. studies compared an intervention group to a control group that did not receive the IPM intervention[6-8] and one Canadian study used a pre- and post-test design.[9] All four IPM studies found that individual residents could successfully control cockroach infestations in their apartments without using chemical pesticide sprays. Furthermore, traditional pest control (i.e., with pesticides) may not have a direct impact on objectively determined cockroach levels,[8] implying that the use of pesticides alone is ineffective and unnecessarily introduces pesticides into the environment.

All four studies introduced an educational component and the three U.S. studies provided baits and gels as less toxic alternatives to aerosol pesticides.[6-8] The Canadian study did not provide baits but encouraged IPM-compatible chemical treatment instead of sprays in their educational material. Pest control products, promoted during the educational session, were baits (either boric acid paste or hydramethylnon gel). Investigators used a questionnaire to test knowledge, attitudes, and practices and concluded that these had improved after the intervention.[9] In the three U.S. studies, researchers used interviews to elicit pesticide use, followed by individually tailored education; also provided participants with cleaning supplies and storage and garbage containers.[6-8] In two of the U.S. studies, apartments were cleaned thoroughly, as part of the intervention, to make them less attractive to pests.[7,8]

All studies conducted follow-up, which is important for ensuring success, but duration of follow-up varied.[6-9]

Safe Pesticide Use

If pesticide use is unavoidable, safer alternatives or applications can often be used for indoor situations, such as baits and gels instead of aerosol sprays. If safer applications are not available, it is important that any pesticide product be used safely and exposure be kept to a minimum.

Recommendations in Table 1 are derived from research studies. For some recommendations, no direct evidence is available so recommendations are derived from other literature, such as exposure assessment studies.

Research has shown that many people have difficulty understanding labels on pesticide products, which may result in avoidable exposure.[1,10] A large U.K. study interviewed families with children who did and did not report pesticide use in a previously administered questionnaire. Almost all of the families, who reported no pesticide use in the questionnaire, reported their use in the interview, likely due to different perceptions of the term *pesticide*. For example, prior to the interview participants may not have realized that tick and lice treatments and pest strips were considered pesticides. Families only reporting pesticide use in the interview were generally more risk averse and tended to perceive a higher risk and lower benefit of pesticide use than people who reported pesticide use in both the questionnaire and the interview. People, who initially did not report pesticide use, stated that they did not understand everything on the label and that it did not provide all the information they needed.[1] Of the people who did report the use of pesticides in the interview, most always followed the label exactly. Forty-five percent of the users tried to read the label but did not understand everything. The same proportion did read and understand the label. Most people took notice of warnings on labels, washed their hands after use, and kept children and pets away after using a pesticide, but less than half used gloves for treating weeds and garden pests; even fewer wore gloves when treating pests indoors. For 45% of families, safety was the most important feature that influenced the purchase of a pesticide to treat an outdoor pest. Improved risk communication about the risks associated with pesticide use could have strong effects on parental use of nonchemical alternatives to pesticides or in using pesticides safely, potentially reducing exposure.[10]

From the occupational health literature, it is clear that personal protective equipment (PPE) protects against dermal contact and inhalation exposures. This knowledge is used in recommendations in Table 1.

Gloves are generally found to be effective in reducing hand loadings and to lower pesticide metabolite levels in urine, as compared to not wearing gloves.[11,12] However, inside contamination of gloves may still occur as it is difficult to avoid touching the glove exterior when taking them off.[13,14] One experimental study that compared different types of gloves found that nitrile gloves were more protective than polyvinyl chloride (PVC) gloves against a permethrin-based pesticide,[13] but the effectiveness of different types of gloves depends on the chemical. Both the nitrile and the PVC gloves used in the study were impermeable to pesticides over an 8-hour time period, yet inner glove contamination still occurred. This contamination was likely due to behaviour of participating study volunteers (e.g., pulling up gloves that did not fit properly).[13] When people are not using pesticides themselves, they can still limit their exposure to pesticides; especially important for sensitive individuals, such as young children, pregnant women, and asthmatics who need to stay away from sprayed areas whenever possible.[15]

A review on the toxicology of pyrethrins and pyrethroids discusses two case reports of known asthmatics who died shortly after treating their dog with a pyrethrin-based pet shampoo to treat ticks. Both cases were asymptomatic at the time of exposure but died of severe acute asthmatic attacks. The relative contributions from dermal and inhalation exposure routes are unknown.[16] These cases indicate that sensitive individuals may need to avoid certain pesticide products or take protective measures when using them.

Reduction of Take-home and Track-in Exposures

Take-home and track-in of pesticides refer to the transfer of pesticides from outside to inside the home. People who apply pesticides around their homes can better protect themselves and their families by minimizing take-home and track-in. Even people who do not use pesticides in their garden can track in pesticides that are used elsewhere, such as in parks, neighbouring lawns, and from neighbourhood spraying.[16] Knowledge of these pathways is very important in order to design effective strategies to reduce take-home and track-in exposures. Most recommendations in Table 1 are not directly derived from intervention studies, but adapted from studies that assess the take-home and track-in pathways. Education about these exposure pathways and the importance of PPE can work to change behaviour and reduce exposures.[17-19]

Take-home Exposure

Professional applicators (e.g., agricultural workers) often have residues of pesticides on their clothes and vehicles,[11,12,20-22] which can result in take-home exposure to their families.[20-22] Although primarily studied in agricultural areas, take-home exposure is also possible among those who apply pesticides to their own gardens or lawns. The evidence from agricultural studies, as presented below, can therefore be applied to residential environments.

As discussed previously, gloves can help reduce hand loadings among people who apply pesticides, but can also reduce exposure to their families, if contaminated gloves are taken off before entering the home. It is unknown to what extent hand loadings result in home contamination, but limiting the possibility for home contamination as much as possible is desirable.

Several studies showed that pesticides can be almost completely removed from hands, by washing. In most studies, handwashing was one of the strategies to reduce pesticide exposures among agricultural workers,[11,12,17] but there are two experimental studies that assessed the effect of handwashing with soap and warm water. Results showed the amount that can be washed off differed between pesticides (94% for mancozeb, 80% for propoxur, 96% for acephate).[23,24]

Family members of people who apply pesticides can also be exposed to pesticides through contaminated clothing (e.g., handling laundry or storing contaminated clothing in the house), but quantitative data are not available.[25] One study showed that organophosphorous (OP) pesticide residue levels in house dust were significantly associated with farm workers who reported waiting more than two hours before changing out of their work clothes, after returning home.[26] Although organophosphorous pesticides are no longer available for consumer use in Canada and the U.S., take-home exposure of other pesticides applied outdoors can still occur.

Track-in Exposure

Track-in exposure is similar to take-home exposure, but usually refers to transfer of residues from residents (including pets) to the indoor environment on shoes and feet; e.g., from walking or playing on pesticide-applied areas, such as lawns and gardens.[27] Once indoors, pesticides can accumulate in dust and on surfaces.[28]

Nishioka and colleagues conducted a number of studies on track-in of some common herbicides (2,4-D and dicamba). In one of those studies, taking off shoes prevented the track-in of the commonly used herbicide 2,4-D, after lawn application.[27] Taking off shoes before entering the home also helps to keep more volatile pesticides, that are less likely to be trapped in an entry mat, out of the house.[29] Another study showed that levels of 2,4-D and dicamba in the carpet surface and in carpet dust were associated with dislodgeable residues on the turf.[30] The gradient in 2,4-D dust loading through the house followed the traffic pattern from the entryway; loadings were generally highest in the entry room, especially for carpeted homes.[27] It is important to trap any potential contamination to prevent it from spreading into the house. Doormats have been shown to be partially effective, but they do not trap all dirt and pesticides tracked-in on shoes.[31] Rubber mats with polypropylene fibres have been shown to reduce carpet surface residues by 25% and carpet dust residues by 33%.[30] It is easier to prevent track-in than to remove dust (that may be contaminated with pesticides) from a carpet.[32]

Active children and the presence of indoor-outdoor pets were important factors that increased the amount of 2,4-D found in homes after lawn application.[27] The amount of 2,4-D and dicamba residues after lawn application decreased with time, but a major factor in reducing dislodgeable residues was rainfall.[30]

Cleaning the Home

As described previously, there are several ways that pesticide residues can enter the home. Once pesticides are in the home, they can be an important source of exposure, particularly for young children who tend to play on the floor and place household items and their hands in their mouths. Some pesticides can be very persistent in indoor environments because they are protected from the elements (rain, sunlight) and do not break down easily.

Pesticides can accumulate in dust, but more volatile substances remain in air and later deposit onto surfaces and toys.[28] Carpeting can also absorb pesticides from liquid and aerosol sprays used indoors.[32] It also contains settled dust particles and collects potentially contaminated soil particles tracked in from outdoors.[27,33] The bulk of pesticide residues are generally found in the carpet fibres, binding, and padding.[34]

The volatile OP pesticides diazinon and chlorpyrifos, which are no longer available for consumer use in Canada and the U.S., were still found on surfaces in 2005-2006,[35] while non-volatile pesticides, such as pyrethroids, tend to accumulate in dust.[32] The commonly used lawn herbicide 2,4-D tends to accumulate in the larger dust fraction (PM10), rather than in the smaller fraction (PM2.5).[33] From this information, an assumption can be made that simply removing dust from floors and carpets will reduce pesticide loadings indoors; however, there are no studies that measured levels of pesticide residues in homes before and after removing dust. Instead, information is available on the effectiveness of cleaning methods on dust levels. Good cleaning practices have the advantage of reducing other environmental contaminants as well, such as house dust mites, bacteria, and fungi.[32] Most recommendations in Table 1 are derived from an extensive review about reducing exposure of infants to pollutants in house dust. Some recommendations are derived from a study that measured pesticides in indoor environments (air, dust), but good quality intervention studies are not available.[32]

For dust, bare floors are faster and easier to clean than carpeted floors.[32] Flat and level loop carpets (used in office buildings) are the easiest carpets to clean, followed by short plush carpets, and deep plush carpets. Shag carpets are the most difficult to clean. Plush furniture collects dust the same way plush carpets do, so cleaning them thoroughly or covering them likely reduces exposure to accumulated dust. Old carpets generally have high dust and contaminant loadings. Larger dust particles are easier to remove by vacuuming than smaller particles. Normal vacuuming does not remove the deep dust in carpets, and often redistributes the dust (unless a vacuum cleaner with a HEPA filter is used). Vacuum cleaners that have a power head and a power brush are generally more effective than vacuum cleaners that do not have these devices.[32]

Whether or not cleaning is effective to remove pesticides from indoor environments likely depends on the type of cleaning applied (vacuuming, steam-cleaning), the surface to be cleaned (carpets, bare floors), and the physical-chemical properties of the pesticide, such as the volatility.[32] In one study, steam cleaning was found to reduce the concentrations of most OP pesticides in carpets, even up to a year after steam cleaning.[36] The same study showed that the number of homes where pesticides were found was lower after a cleaning intervention (mopping of floors, vacuuming carpets), for most pesticides studied. However, no data were available regarding individual home pesticide residue levels before and after the intervention.[36]

Discussion

It is largely unknown to what extent families in non-agricultural areas are exposed to non-dietary pesticides, but one study found that household use of pyrethroid insecticides contributes as much to children's exposure as dietary intake.[3] For very young children, exposure to pyrethroids from non-dietary sources (e.g., ingestion of dust) may be even higher. Children, including the foetal development period, are generally more susceptible to the effects of pesticides than healthy adults; therefore, reducing pesticide exposure in residential settings seems prudent.

The literature suggests that often the general public are unaware of their pesticide use (e.g., weed 'n feed or tick shampoos). Education around pesticide products and promotion of alternatives may be effective to reduce use and improve awareness of safe handling. Although only a handful of IPM studies assessed pesticide exposure, education and provision of tools and alternatives appeared to be effective in reducing both pests and pesticide use, at least in the period of follow-up (which was often short). Repeated follow-up of an IPM strategy may be necessary to ensure long-term success.

Most of the literature about reducing take-home and track-in exposures stems from studies of agricultural workers and others who are occupationally exposed to pesticides. Although these people usually have higher exposures to a variety of pesticides, many of the exposure reduction strategies can be implemented in residential settings (such as wearing personal protective equipment during application and removal of clothing and shoes at the door). Some strategies focus on reducing the use of pesticides (IPM, which can be controlled by the resident), others on reducing exposures (take-home and track-in and cleaning).

Although pesticide residues are commonly found indoors, little information is available on the effectiveness of cleaning to reduce these levels. As some pesticides are found in dust, removing dust will likely reduce pesticide levels, as well as other environmental contaminants.

Medical officers of health and public health inspectors play an important role in educating the public about individual-level strategies for reducing residential pesticide exposures, both indoors and outdoors. Public health messaging to sensitive populations (such as asthmatics or children) should include information about pesticide avoidance and safe pesticide use and protective measures, when necessary. However, in order to achieve long-term reduction or elimination of exposure to pesticides, policy changes may be necessary to ensure pesticide product labels are understandable. Restrictions on the availability of certain pesticides or banning of certain application types (e.g., aerosol sprays, weed 'n feed) or uses (e.g., cosmetic use on lawns and gardens) may be another option to protect the public from exposure. Many municipalities across Canada and some provinces (Quebec, Ontario, Prince Edward Island, amongst others) already restrict the use of cosmetic pesticides for residences and on public lands; golf courses and sports fields are sometimes exempt from restrictions.[37] In addition, acceptance of some pests, such as weeds or insects that lead to imperfect lawns, could lead to less pesticide use for cosmetic purposes. Education and media involvement may be needed to achieve this.

Evidence gaps

There are several gaps in evidence about the effectiveness of interventions to reduce pesticide exposures in residential settings:

- Except for education and wearing PPE in occupational settings, there are few studies that examine interventions to reduce pesticide exposure in residential settings, such as preventing track-in and take-home and cleaning.
- There are few studies that investigate the extent of pesticide exposure reduction from IPM and whether any effects are long-term.
- There is no clear evidence as to what extent controlling dust levels in homes, through vacuuming (with filters) and other cleaning methods, reduce pesticide exposure.

Table 1: *Overview of recommendations directed to the general public for reduction of residential exposure to pesticides used indoors and outdoors*[a]

Prevention and alternatives (integrated pest management)
- Avoid pesticide use if there is no current pest problem.
- Close entryways for pests: identify sources of pest entry and carry out repairs if necessary, for example, by caulking, sealing cracks and crevices, and fixing plumbing leaks.
- Remove food sources for pests. Store food in airtight containers, clean up food spills, sweep kitchen floor, and remove garbage as often as possible.
- If pesticides are necessary, use less toxic alternatives and baits, traps, and gels instead of sprays and foggers, to reduce the potential for airborne exposure.
- Monitor the IPM program to assess efficacy.
Safe pesticide use
- Follow the instructions on the label and only use pesticide products for the purpose they are intended. Failure to do so may result in high exposure and health effects.
- Ensure that pregnant women and children are not present during spraying and, if possible, stay away for 8-10 hours; ideally 24-48 hours.
- Remove or cover household items in the areas being sprayed.
- Store pesticides out of reach of children and in their original labelled containers to avoid accidental poisoning and improper use.

[a] Recommendations can be used directly to educate the public, or adapted with reference to the NCCEH.

- Wear personal protective equipment (PPE) such as gloves and overalls when applying pesticides indoors or working in a garden with pesticides and remove them before entering the house (see also the section on Track-in). Make sure protective gloves fit properly.
- Wear gloves and other PPE such as a mask when treating pets with tick or flea shampoo or spray.
- If possible, wash pets outdoors. Or, if washing outdoors is not possible, do it in a well-ventilated area.
- For asthmatics and other sensitive individuals, take caution when using pesticides, for example, when using pet shampoos containing pyrethrins.
- If disposing of unused pesticides, do not pour down drain, sewer or put in garbage; consult your local municipality for safe disposal instructions.

Take-home

- Wear PPE, such as gloves and overalls when applying pesticides or working in a garden with pesticides; remove them before entering the house.
- Wash hands thoroughly with soap and water after contact with a treated lawn or garden and after applying pesticides in the garden, even if gloves and other PPE were worn during application.
- Wear gloves to handle clothing that was worn during application and wash these clothes separate from other laundry. If these clothes are not washed immediately after application, store them in a clean plastic bag. After washing, clean washing machine by running it without clothing.
- Remain indoors with windows closed when the neighbourhood is being sprayed.

Track-in

- Remove shoes before entering the home, after treating the lawn or garden or even if you don’t apply pesticides yourself. If shoes cannot be removed before entering the home, they should be removed immediately after entering.
- Use entry mats and enter the house in an uncarpeted area, if possible.
- Keep pets and children away from treated turf or garden. Wash exposed pets frequently in the first week after lawn or garden treatment.
- Stay away from the treated lawn or garden until after a hard rainfall.
- If possible, place a clean sheet over home carpeting before allowing young children to play there.

Cleaning (based on dust removal)

- Vacuum the house regularly, preferably using a vacuum cleaner with a power brush and a HEPA filter.
- If possible, use a vacuum cleaner with a dirt detector that indicates when all removable dust has been vacuumed from a carpet.
- In addition to vacuuming, dry steam clean the carpets.
- Vacuum plush furniture with a vacuum cleaner attachment or hand vacuum cleaner or cover plush furniture with a washable fabric cover.
- If possible, replace old carpets (>10 years old) with bare floors.
- To clean bare floors, use a good vacuum cleaner and/or a wet mop instead of a broom.

Table 2: *Overview of intervention studies to reduce residential pesticide exposure*

Author	Aim of Study & Study Design	Intervention Components	Population, Setting, Duration	Exposure Assessment	Outcomes & Conclusions	Applicability & Recommendations
Integrated pest management						
Brenner et al. 2003	To test whether IPM techniques and targeted education at the household level can reduce cockroach infestation and exposure to chemical pesticides in urban households. Intervention-control	Education and instruction on: nontoxic IPM methods; instruction in better housekeeping and sanitation; garbage removal practices; repair services; fixing plumbing leaks; least-toxic supplies; expert advice from pest control experts; advocacy with building management to introduce safe pest control practices	Women (intervention n=41, control n=32) who received prenatal care in East Harlem, NYC 6 months follow-up	Cockroach infestation levels at baseline and follow-up; pesticide use at baseline	Proportion of intervention homes with cockroaches declined from 80.5% to 39.0%; control group levels were unchanged (from 78.1% to 81.3%) IPM techniques are effective and relatively economical in controlling cockroach infestation in urban apartment dwellings, at the household level	Integrated pest management
Campbell et al. 1999	To assess the effectiveness of a pilot IPM program in controlling cockroaches in an apartment complex, without pesticide sprays. Pre-test, post-test	Educational session, information booklet, promotion of non-spray methods	Apartment tower in Toronto (n=80 residents) 16 months: 8 months prior to intervention, 8 month demonstration period	Cockroach counts at pre- and post-test; telephone questionnaire at pre- and post-test	Knowledge, attitudes, and practices improved and there were lower cockroach counts after intervention	Integrated pest management
Kass et al. 2009	To implement and evaluate IPM compared with traditional practice for its impact on pests, allergens, pesticide use, and resident satisfaction in a large urban public housing authority. Intervention-control	Mechanical and steam cleaning, latex caulking of cracks and crevices, apply boric acid and cockroach baits, instruction in sanitation, provision of food containers and cleaning supplies	280 apartments (intervention n=169, control n=111) in Brooklyn and Manhattan, NYC 6 months (baseline, 3 and 6 months after intervention)	Cockroach and mouse populations, cockroach and mouse urinary protein allergens in dust, interviews (included pesticide use)	Among intervention homes: Lower counts of cockroaches after 3 months and 6 months; lower allergen levels in kitchens at 3 months and in beds and kitchens at 6 months; reduced pesticide use	Integrated pest management

Author	Aim of Study & Study Design	Intervention Components	Population, Setting, Duration	Exposure Assessment	Outcomes & Conclusions	Applicability & Recommendations
Williams et al. 2006	To assess the feasibility of reducing prenatal exposures to pests and insecticides through an IPM intervention. Intervention-control	Professional cleaning, building repairs, sealing pest entry points, professional insecticide placement, one-on-one education	Pregnant New York City African-American and Latina women; 25 intervention and 27 control homes One month	Cockroach infestation levels, 9 different insecticides in 2-week integrated indoor air samples and maternal and umbilical cord blood at delivery	Cockroaches: decrease in interventions, but not in controls. Indoor air: post-intervention levels of 4 insecticide ingredients were lower than pre-intervention levels for both groups; no difference between interventions and controls. Maternal blood: insecticides present in some controls, but not in interventions. No insecticides in cord blood. IPM is an effective strategy for reducing pest infestation levels and the internal dose of insecticides during pregnancy.[b]	Integrated pest management
Track-in and take-home						
Salvatore et al. 2009	To improve farmworkers' behaviours, at work and after work, to reduce occupational and take-home exposures to pesticides. Community-based participatory research worksite intervention	Worker education, availability of warm water and soap, protective clothing	Farmworkers (n=130) employed at 2 strawberry farms in Monterey County, CA 2 months	Interview to assess farmworkers' characteristics and behaviours	Glove use (OR=15.5, 95%CI 2.5-94.4), wearing clean work clothes (OR=7.2, 95%CI 1.6-33.2) and washing hands at the midday break (OR=10.7, 95%CI 1.4-84.3) and before going home (OR=7.6, 95%CI 1.7-34.4) improved. Hand washing before	Wear PPE, wash hands

[b] The study's conclusion is not valid: the level of that particular insecticide in indoor air was decreasing in both intervention and control groups, and the difference between the decreases was not significant. There was no proper statistical testing *between* the two groups, but only *within* each group.

Author	Aim of Study & Study Design	Intervention Components	Population, Setting, Duration	Exposure Assessment	Outcomes & Conclusions	Applicability & Recommendations
					eating and many targeted after-work behaviours (e.g., store work shoes and clothes outside, change outside) did not improve.	
Thompson et al. 2008	To examine the effectiveness of a randomized community intervention to reduce pesticide exposure among farmworkers and their children.	Intervention activities at several levels. Community: health fairs, community festivals, etc. Organizational: elementary schools, churches, farmworker union, etc. Small group: lay health education, home health parties. Individual: volunteer door-to-door education.	24 agricultural communities in the Yakima Valley, WA 2 years	Cross-sectional surveys at baseline and after 2 years. Sub-study: urine from farmworker and child, dust from home and vehicle	Geometric mean concentrations of urinary metabolites were higher after 2 years in interventions and controls for children and adults; difference between the groups was not significant. Dust levels remained the same. Intervention was not effective. Increases were likely due to uncontrolled factors	Take off shoes
Strong et al. 2009	To evaluate the effectiveness of a community-intervention in promoting adoption of behaviours to reduce the take-home pathway of pesticide exposure in farmworker households.	Intervention messages about risks of pesticide exposure at community level, organizational environment, within social and family groups and one-on-one. Events included health fairs, videos etc. See also Thompson et al. (2008)	11 intervention and 12 comparison agricultural communities in the Yakima Valley, WA 2 years	Recent behaviours taken by farmworkers to reduce the take-home pathway (from survey): wash hands after work, take-off work boots, wash work clothes separately	Pesticide safety practices increased in both intervention and comparison communities over time, but significantly more in intervention communities for removing work shoes before entering the home (*p*=0.003).	Take off shoes
Bradman et al. 2009	To reduce malathion exposure to strawberry harvesters and the potential for take-home exposure to their	Education, encouragement of handwashing, the use of gloves, the use of removable	Strawberry harvesters (intervention n=25, control n=15) in the	Pre-intervention: questionnaire, dislodgeable foliar residues.	Workers wearing gloves had 3.4 times lower MDA[c] metabolite levels compared to	Wear PPE and gloves, wash hands

[c] MDA = malathion dicarboxylic acid, a metabolite of malathion

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	families. Intervention-control	coveralls.	Salinas Valley, CA. 8 weeks (6 weeks intervention period)	Post-intervention: malathion metabolites in urine, malathion in hand rinse, clothing patch, skin patch.	those who were not. Hand loadings were also lower. Malathion was detected on 76% of clothing patches and on 3% of skin patches.	
Van der Jagt et al. 2004	To determine the effectiveness of control measures available to pest control operators who engage in the application of pesticides in and around man-made settings. Pre-test, post-test	Adjustments to PPE[d]: tight-fitting, full-face respirator, fit-testing (of respirator), long gloves, chemical-proof boots, a hood, and an instruction video	15 pest-control operators employed by the same company in 8 different locations in the Netherlands	Exposure (various pathways) measured by the urinary metabolite TCP	Decrease in dermal exposure, lower TCP[e] levels post-intervention, but no statistical testing PPE program is protective	Wear PPE and gloves, wash hands
Creely et al. 2001	To evaluate the effectiveness of three types of protective gloves using a novel method when workers were applying a non-agricultural pesticide. Simulation/experiment	Testing of three types of gloves: two nitrile and one PVC in a standardized simulation test with a permethrin-based pesticide	Five inexperienced volunteers, U.K.	Mean protection factors, calculated as the ratio of the outer and inner contamination of gloves	Measurable inner glove contamination occurred in 25 of 30 occasions. Protection factors were 470, 200, and 96 for the two nitrile and PVC gloves	Wear PPE and gloves
Curwin et al. 2003	To measure the concentration of acephate residue on the hands of tobacco harvesters and the effectiveness of handwashing in reducing the acephate residue. Pre-test, post-test.	Washing hands with soap and water	12 tobacco harvesters in Kinston, NC 2 days	Prewash and postwash hand-wipe samples, leaf-wipe samples from 15 tobacco plants.	Handwashing with soap and water significantly reduced acephate levels on the hand, with levels reduced by 96%. (GM[f] overall prewash 10.5 ng/cm^2, postwash 0.4 ng/cm^2)	Wash hands
Marquart et al. 2002	To assess the effectiveness of handwashing to reduce dermal loadings by mimicking normal	Washing hands with soap and water	Pilot study: 14 workers from 5 greenhouses in the Netherlands	Pilot & field study: model relating dislodgeable foliar residue to	Between 24.5% and 50.7% of three pesticides was removed in the field studies;	Wash hands

[d] PPE = personal protective equipment

[e] TCP = 3,5,6-trichloro-2-pyridinol, a metabolite of chlorpyrifos

[f] GM = geometric mean

Author	Aim of Study & Study Design	Intervention Components	Population, Setting, Duration	Exposure Assessment	Outcomes & Conclusions	Applicability & Recommendations
	hygienic washing in agricultural practice. Experiment		Field study: 40 greenhouse workers Laboratory study: 24 healthy volunteers	exposure; water used for washing Lab study: water used for handwashing	45.8% of mancozeb and 85.7% of propoxur were removed in the lab study	
Cleaning						
McCauley et al. 2006[g]	To assess the effectiveness of cleaning windowsills, floors and carpets to reduce pesticide levels indoors. Experiment	Cleaning linoleum floors, wiping windowsills, and steam cleaning carpets	10 farmworker homes in Hood River, OR Baseline measures, follow-up of 24-48h and 12 months after intervention	Dust samples from floors, windowsills and carpets	Cleaning of linoleum floors was ineffective (median pre-cleaning level 0.0025 µg/cm^2, median decrease 0.00089 µg/cm^2, *p*= 0.11); cleaning of windowsills was effective (median pre-cleaning level 0.0032 µg/cm^2; median decrease 0.0029 µg/cm^2, *p*= 0.01); steam cleaning the carpet reduced amounts of total OP pesticides to non-detectable levels. For some homes, the number of pesticides per home increased after the intervention.	Vacuuming and steam-cleaning

[g] The study has some major methodological limitations: concentrations before and after cleaning are not reported, but instead the number of homes that had detectable levels of OP pesticides is presented. Also, before-cleaning samples and after-cleaning samples are analyzed at the aggregate level and not at the individual level, which makes it impossible to draw conclusions about cleaning effectiveness in individual homes. Finally, it is possible that the sampling method before cleaning already removed some or all of the pesticide residues.

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Appendix: Search Methodology

Studies about interventions and strategies to prevent or reduce residential pesticides were identified by using the following search terms in Ebsco, Web of Science and Agricola: pesticides in combination with home exposure/residential exposure, take home exposure, general population, track-in, removal of (pesticides), reduce exposure, residues, home contamination, transfer/transport. Search terms also included pesticides in combination with prevent(ion) and home exposure/residential exposure, take home exposure, track-in.

Terms included, but were not limited to:

(home exposure) or (residen* exposure) or (take home exposure) or (take-home exposure) or (track in) or track-in AND pestic* AND prevent*

(home exposure) or (residen* exposure) or (take home exposure) or (take-home exposure) or (track in) or track-in or (home contamin*) or tran* AND pestic*

(pesticide label*) NOT farm* AND exposure

(pesticide*) AND (label*)

pyreth* or insecticid* AND exposure AND residen* or home or house* or "living area*" NOT agricultur* or occupation* or diet*or malaria

effectiveness or efficacy AND (clean* or decontaminat* or removal) AND (house* or residence or farmhouse or home) AND (pesticide or “agricultural chemical”)

dust or allergens AND cleaning or mopping or washing or ventilating AND effective or efficacy AND house or home or residence or farmhouse or cottage or building

Limits were set for papers published between 2000 and the beginning of 2011. Follow-up by author searches was performed and bibliographies were reviewed, if necessary.

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