

REVIEW AND ASSESSMENT OF TIMES AND PRACTICES
RECOMMENDED FOR REENTRY INTO BUILDINGS AFTER
APPLICATION OF RESIDUAL INSECTICIDES

by

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**REVIEW AND ASSESSMENT OF TIMES AND PRACTICES RECOMMENDED
FOR RE-ENTRY INTO BUILDINGS AFTER APPLICATION OF RESIDUAL
INSECTICIDES**

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Review and Assessment of Times and Practices Recommended for Reentry
into Buildings after Application of Residual Insecticides

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Abstract

The application of many commonly used residual insecticides indoors using current techniques is a potential hazard to human health. Pest managers and others who advise on safe reentry times and practices after such applications have few regulations or guidelines to assist them. However, the scientific basis for the various regulations and guidelines is unclear and they are often inconsistent.

To understand how the issue of reentry into buildings is dealt with in Canada, I first reviewed Federal, Provincial and Municipal legislation governing reentry. Second, I surveyed pesticide and public health regulators, and pest control companies to determine the reentry times and practices they use. Third, the literature on air and surface residues after the application of insecticides indoors is reviewed and compared with currently recommended reentry times and practices. Finally, I conducted an experiment to determine if general ventilation reduced residues of chlorpyrifos in air.

Pesticide applicators should prepare insecticidal solutions carefully, monitor and control spray-tank pressure, follow label application rates, select the lowest-risk application technique, select the lowest toxicity insecticide and make the application to allow the longest possible time before

iv.

reentry to reduce the hazard to health. Bystanders at risk of exposure to residues should avoid direct skin contact with treated surfaces, use general ventilation that ensures good air mixing, and recognize that insecticide residues will move into adjacent untreated rooms. I recommend that the current British Columbia Ministries of Health, and Environment, Lands and Parks guidelines on reentry be revised to reflect these findings and that the training course for structural pesticide applicator certification in British Columbia emphasise safe practices to reduce exposure to residues.

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TABLE OF CONTENTS

LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
I. INTRODUCTION.....	1
II. CURRENT PROCEDURES.....	8
A. ACTS, REGULATIONS AND BYLAWS.....	8
1. PEST CONTROL PRODUCTS ACT AND REGULATIONS.....	8
2. PROVINCIAL REGULATIONS.....	10
3. MUNICIPAL BYLAWS.....	11
B. REGULATORY GUIDELINES.....	13
C. CURRENT PRACTICES.....	18
1. STRUCTURAL PEST CONTROL INDUSTRY.....	18
2. PUBLIC HEALTH AND PESTICIDE MANAGEMENT AGENCIES...	20
III. INSECTICIDE RESIDUES FOLLOWING INDOOR APPLICATION...	26
A. RESIDUES IN AIR.....	26
B. RESIDUES ON SURFACES.....	44
IV. ASSESSING HEALTH RISK.....	52
V. VENTILATION AND RESIDUES.....	58
A. INTRODUCTION.....	58
B. MATERIALS AND METHODS.....	58
C. RESULTS.....	61
VI. DISCUSSION AND CONCLUSIONS.....	65
LITERATURE CITED.....	77

List of Tables

Table 1.	Reentry times recommended by Greater Vancouver pest control companies after broadcast application of insecticide to control fleas in a home.....	21
Table 2.	Reentry times and practices recommended by public health agencies after indoor broadcast application of insecticides.....	23
Table 3.	Summary of studies of residues of insecticides in indoor air after broadcast application.....	27
Table 4.	Summary of studies of residues of insecticides in indoor air after crack and crevice application.....	28
Table 5.	Summary of studies of residues of insecticides on surfaces after indoor broadcast application.....	45
Table 6.	Surface residues measured by deposition sampling after indoor broadcast application.....	46
Table 7.	Surface residues measured by wipe sampling after indoor broadcast application.....	47
Table 8.	Summary of studies of residues of insecticides on non-target surfaces after indoor crack and crevice application.....	48
Table 9.	Surface residues measured by deposition sampling after indoor crack and crevice application.....	49
Table 10.	Surface residues measured by wipe sampling after indoor crack and crevice application.....	49

List of Figures

Figure 1.	Residues of diazinon in indoor air after broadcast application.....	29
Figure 2.	Residues of chlorpyrifos in indoor air after broadcast application (samples taken from ≤ 32 cm above treated surfaces).....	30
Figure 3.	Residues of chlorpyrifos in indoor air after broadcast application (samples taken 90-120 cm above treated surfaces).....	31
Figure 4.	Residues of chlorpyrifos in indoor air after broadcast application (samples taken 150-175 cm above treated surfaces).....	32
Figure 5.	Residues of bendiocarb in indoor air after broadcast application.....	33
Figure 6.	Residues of dichlorvos in indoor air after broadcast application.....	34
Figure 7.	Residues of diazinon in indoor air after crack and crevice application.....	35
Figure 8.	Residues of chlorpyrifos in indoor air after crack and crevice application.....	36
Figure 9.	Residues of bendiocarb in indoor air after crack and crevice application.....	37
Figure 10.	Residues of d-trans allethrin in indoor air after crack and crevice application.....	38
Figure 11.	Residues of abamectin in indoor air after crack and crevice application.....	39
Figure 12.	Residues of cypermethrin in indoor air after crack and crevice application.....	40
Figure 13.	Chlorpyrifos residues in the air of classrooms after broadcast application (A. 0 air changes per hour B. 2.48 air changes per hour).....	62
Figure 14.	Chlorpyrifos residues in the air of classrooms after broadcast application (A. 3.64 air changes per hour B. 4.22 air changes per hour).....	63

I. Introduction

Integrated pest management programs are more highly developed and widely implemented in agriculture and forestry than in the urban setting (Owens, 1986). As a result, the urban pest control industry relies almost exclusively on chemical methods to control household pests, mainly because chemical controls are highly effective and economical in quickly reducing pest numbers. In addition, pesticides that provide long-term residual control are readily available and the techniques required to apply them are simple (Graham-Bryce, 1987). Licensed structural pest control companies applied 12,089 kg of pesticide active ingredients in British Columbia in 1991 (British Columbia Ministry of Environment, Lands and Parks/Environment Canada, 1993).

The use of such pesticides with current application techniques can, however, be potentially hazardous to human health. While the majority of human exposures to pesticides occur without apparent adverse biological effects, concerns have been expressed about exposure to pesticides indoors (Krieger *et al.*, 1992) and about appropriate times for persons to reenter buildings after the application of insecticides to control household pests (Health Canada, 1992). These concerns are fueled, in part, by reports of pesticide residues in homes, businesses and public areas, and of illness in

bystanders after standard applications of insecticides commonly used for household pest control.

Wright *et al.* (1993) found residues of cypermethrin in the air and on surfaces in rooms treated by crack and crevice application¹ and in rooms adjacent to treated rooms 84 days after application. Wright *et al.* (1992) detected small quantities of abamectin in the air of dining facilities 90 days after application of a dust formulation to cracks and crevices. Leidy *et al.* (1982) found low levels of diazinon in the air of untreated rooms immediately above, below and beside a treated room 21 days after a crack and crevice application.

Acute poisoning incidents soon after the application of insecticides indoors are apparently not uncommon. Muldoon and Hodgson (1992) reviewed reports of acute poisonings from United States regional poison control centres and concluded that 60,000 to 70,000 nonoccupational pesticide poisonings may have occurred annually in a 5 year period. A review of United States Environmental Protection Agency Pesticide Incident Monitoring System records for a 12 year period showed that acute anticholinesterase poisoning incidents from exposure to the organophosphate insecticides diazinon, malathion and

1. Crack and crevice application is the application of small amounts of insecticide into cracks and crevices in which insects hide or through which they may enter a building. Insecticide is applied as a pin stream with a handheld compressed air sprayer or from a pressurized canister.

3.

chlorpyrifos, and the carbamate insecticide propoxur in residential settings accounted for 15% of all reported pesticide poisonings (Hodgson et al., 1989).

Reports of chronic toxicity from long-term exposure to insecticide residues in nonoccupational settings and of delayed health effects from much earlier exposures have also appeared. Thrasher et al. (1993) reported several immunological abnormalities in 12 people 1 to 4.5 years after they were exposed to chlorpyrifos applied indoors by licensed pest control operators. Richter et al. (1992) found diethyl phosphate, a metabolite of diazinon, in the urine of residents experiencing symptoms suggestive of organophosphate insecticide poisoning 4.5 months after application of diazinon in a home by a commercial exterminator. Significant positive associations between childhood brain cancer (Davis et al., 1993) and childhood leukemia (Lowengart et al., 1987) and pesticide use by home owners (nuisance pest control, flea collars, pediculicides, weed control) have been claimed.

Pesticide regulators have begun to respond to such concerns. The United States Environmental Protection Agency (EPA) conducted the Nonoccupational Pesticide Exposure Study (Immerman and Schaum, 1990) to provide initial estimates of the extent of exposure to pesticides in nonoccupational settings. The study found low levels (ng/m³) of commonly used

4.

household pesticides in the air and on surfaces inside homes. Based on this initial estimate of exposure to indoor ambient pesticide residues the EPA concluded that the hazard indices for noncancer health risks were low. In the United States some states now specify a time during which buildings should be vacated. A 1992 Michigan regulation requires that liquid spray or aerosol insecticide applications shall not be made in a room of a school building unless the room will be unoccupied by students for not less than 4 hours after the application. The 4 hour reentry period was chosen to ensure that the insecticide spray would be dry when children reentered the classroom (Fedder, 1993). The 12 hour period required before reentry into schools after pesticide applications in Texas was chosen to allow residues to dry even under humid conditions (Borgelt, 1993). There are no such regulation yet in Canada and the Federal Pest Control Products Act and Regulations do not require that labels for insecticides used for indoor pest control carry information on reentry time. However, because of growing concern about the unwilling exposure of bystanders to pesticides indoors after application, Health Canada may soon adopt guidelines (Health Canada, 1992). These guidelines will require product registrants to assess the residue levels occupants might be exposed to after application of insecticides indoors.

Pest managers, public health officials and others attempting

to answer the question of when is it safe to allow persons to reenter a building after indoor application of insecticides have a limited number of regulations, guidelines and recommendations available to assist them in answering such questions. The scientific basis for these is unclear and there is often inconsistency between the various regulations, guidelines and recommendations.

Some Provincial pesticide, occupational health and public health agencies in Canada provide limited guidance on reentry into buildings after insecticide application. In British Columbia the Pesticide Control Act and Regulation require that "no person shall use a pesticide in a manner that would cause an unreasonable adverse effect" but provide no specific recommendations on reentry times or practices. Operationally, the British Columbia Ministry of Environment, Lands and Parks (1990) recommends following the reentry time specified on the product label or, if not specified, waiting until surfaces on which the pesticide has been applied are thoroughly dry. Also, the Ministry has produced *Guidelines for Structural Pest Control Treatments in Public Use Areas* which include recommended reentry times and practices for use by pest control service companies (British Columbia Ministry of Environment, 1992). The British Columbia Ministry of Health has developed quantitative guidelines for timing of reentry into areas used by the public after insecticide application.

These guidelines are provided to staff in the Ministry's public health units to assist staff in dealing with questions from the public about reentry (British Columbia Ministry of Health, 1991). The Workers' Compensation Board of British Columbia (1990) recommends the use of a restricted entry interval equivalent to that for open agricultural fields for pesticides applied to enclosed structures where there is any likelihood of a worker coming into contact with harmful residues.

The results of a number of studies measuring air and surface residues after indoor insecticide application have been reported. These results can provide estimates of the level of exposure for persons reentering buildings after insecticide application. Additionally, there have been a few quantitative risk assessments in which attempts have been made to measure the insecticide absorbed, especially by infants, living in homes after indoor applications. The risk assessment results and the information on the changes in the residue levels with time can help to establish appropriate reentry times and practices.

To understand how the issue of reentry into buildings after application of pesticides is dealt with in Canada, I first reviewed federal, provincial and municipal legislation and guidelines governing reentry. Next, I surveyed Canadian

7.

public health agencies, pesticide use regulators and pest control companies to determine reentry times and practices now in use. I then reviewed the literature on air and surface insecticide residues after indoor application of common insecticides and compared this information to current legislation and practices. Additionally, I conducted a study on the effectiveness of general ventilation of buildings after broadcast application¹ of chlorpyrifos in reducing air residues of the insecticide. Based on my review of current reentry legislation and practices and on the literature on residues, I made recommendations to pest managers and others who must advise persons reentering buildings after the application of insecticides on practices which I believe will reduce exposure to insecticide residues.

1. Broadcast application is the application of insecticide to the entire floor surface of a room. Insecticide is applied with a handheld compressed air sprayer using a nozzle producing a coarse or fine droplet fan-shaped spray pattern.

II. Current Procedures

A. Acts, Regulations and Bylaws

1. Pest Control Products Act and Regulations

The primary federal legislation controlling the use of pesticides is the Pest Control Products Act of 1968-69 and its current Regulations, administered by Agriculture and Agri-Food Canada. The Act is intended to ensure that pesticides are effective and that no person uses a pesticide under conditions that are unsafe to human health (Ritter and Curry, 1988). The Division receives information on a pesticide's toxicity and efficacy and may require restrictions about its use to be printed on the pesticide's label.

Information on dermal toxicity, inhalation toxicity, environmental chemistry studies and, recently, exposure studies must be submitted by a manufacturer wishing to register a pesticide in Canada (Agriculture Canada, 1986). Several federal departments review this information. The Environmental Health Directorate of Health Canada reviews the information to assess the potential for health risks to persons involved in the application of the pesticide or those who might be exposed to it (Ritter and Curry, 1988) and the question of reentry may be addressed during this review.

Directions on the pesticide's label may describe practices (reentry time, ventilation and hygiene practices) to be

followed before reentry into areas treated with the pesticide to minimize exposure (Morison, 1993). For example, the label directions for reentry after indoor broadcast application of Dursban L.O.® (DowElanco, Registration Number 19611, Pest Control Products Act) are: "other than applicator, treated areas should be vacated during application; do not permit humans or pets to contact treated surfaces until the spray has dried; and, avoid breathing vapours and spray mist". Reentry times are not indicated on the Dursban L.O.® label.

Health Canada has proposed the adoption of *Guidelines for Indoor Occupant Exposure Assessment for Pesticides* for registrants of insecticides used for surface treatment within residences. The purpose of these guidelines is to develop a set of standard procedures for studies of air and surface residues indoors after pesticide application by broadcast or total release aerosol¹ techniques. This should serve as a scientific foundation for regulatory decisions (Health and Welfare Canada, 1992). Respiratory and dermal exposure sampling for up to 25 hours after treatment is required. Sources of ventilation or air exchange must be off or closed during application and air exchange is to be minimal during sampling. Respiratory exposure samples are collected from a

1. Total release aerosol applicators (indoor foggers) are small canisters of liquid insecticide solution pressurized with a propellant gas. When the nozzle is activated the entire contents of the canister are released as an aerosol fog.

height of 25 cm and 100 cm above treated surfaces to estimate respiratory exposure for a child on the floor and for a seated adult. Total deposition and wipe samples of treated and untreated surfaces are used to evaluate dermal exposure. The guidelines state that there are at present no commonly accepted and validated methods that allow the calculation of exposure of occupants based on residue levels. The Department places the responsibility on registrants to calculate and justify levels of exposure (Curry and Iyengar, 1992). These guidelines are currently undergoing external review.

2. Provincial Regulations

In British Columbia the Pesticide Control Act of 1977 and its current Regulation control the application of Federally registered pesticides. The Regulation states, in part, that no person shall use a pesticide in a manner that would cause an unreasonable adverse effect but does not specifically regulate reentry times or practices. I reviewed pesticide management legislation from elsewhere in Canada and found that there is similar legislation in all other Provinces but that times and practices for reentry into buildings are not regulated in any of them.

The Worker's Compensation Board of British Columbia's Industrial Health and Safety Regulations apply to nearly all workers and workplaces in British Columbia. They have

occasionally been used to regulate application of, and exposure to, pesticides applied indoors (for example, see Vancouver Sun, 1989). Regulation 12.01.(d) requires that when workers are exposed to any substance likely to cause adverse health effects, the employer shall ensure that safe means of using the substance are followed. Regulation 13.01.(1) requires that a worker's exposure to airborne contaminants, including many pesticides used indoors, be limited to specified permissible concentrations in the air of their workplace (Workers's Compensation Board of British Columbia, 1978). The permissible concentration (time weighted average concentration for a normal 8 hour work day) for chlorpyrifos is 0.2 mg/m^3 , 5.0 mg/m^3 for pyrethrum and 0.1 mg/m^3 for diazinon. There is similar workplace legislation and exposure limits for airborne pesticide residues in all other Provinces.

3. Municipal Bylaws

A few Municipal governments use "pesticide notification" bylaws to indirectly regulate reentry into buildings after pesticide application. I surveyed approximately 90 urban centres in Canada and found that pesticide notification bylaws are currently in force in 5 cities, all in the Greater Vancouver area (District of North Vancouver, 1991; City of Richmond, 1990; City of Burnaby, 1990; City of North Vancouver, 1989; City of Vancouver, 1989).

All of the bylaws are similar; they regulate indoor application of pesticides only in multiple family dwellings and public facilities. Occupants in multiple family dwellings must be notified in writing at least 72 hours before pesticides are applied in their living areas. The notice must include a description of the area to be treated, the trade name, active ingredient and concentration of the pesticide, the date and time of the proposed application and safety advice and precautions (including reentry recommendations) for the occupants. In common public areas of multiple family dwellings (hallways, laundry rooms, etc.) and in public buildings, signs giving notification of the pesticide application must be prominently displayed for 72 hours before and after the application. The bylaws generally require that the signs contain the words "warning" and "avoid contact with treated area" in bold letters, the trade name, active ingredient and concentration of the pesticide, the date and time of application and a telephone number for the local poison control centre.

These bylaws were initially drafted to prevent pesticides from being applied in rental units without warning to tenants, and in response to concerns about herbicide applications on public lands such as playing fields. The rationale for the 72 hour post-application warning period in buildings is unclear but appears to represent a compromise between warning periods

originally proposed by the pest control industry and by environmental advocate groups. Before drafting its bylaw the City of Vancouver sought input from an association representing the local pest control industry and an environmental law association. The pest control industry proposed a 24 hour post-application warning period while the environmental law group proposed an unspecified period longer than 72 hours (City of Vancouver, 1986). The compromise 72 hour period in the Vancouver bylaw was evidently adopted as the standard for use in the other bylaws. The public health departments enforcing these bylaws do not indicate that they believe that a hazard exists for a full 72 hours after pesticide application in buildings nor that 72 hours is the required reentry time.

B. Regulatory Guidelines

I surveyed members of the Canadian Association of Pesticide Control Officials to determine whether any Province had adopted guidelines on reentry times and practices. There are currently formal guidelines promoted by regulatory authorities only in British Columbia and Ontario.

The British Columbia Ministry of Health (1991) has distributed *Guidelines for Pesticide Treatments in Public Use Areas* to all Provincial and Municipal public health units and departments. These guidelines are to be used by Environmental Health

Officers and other public health officials when they advise members of the public about safe pesticide use practices. The guidelines recommend that occupants of dwellings be notified verbally or in writing at least 24 hours before an intended pesticide application to any room occupied as living accommodation. The contents of the notice are not specified, but elsewhere in the guidelines "advice and precautions" to occupants are defined as including information on re-entry times and conditions, ventilation recommendations and recommended precautions for individuals who may be more susceptible to adverse effects from pesticides.

When pesticides are applied to public facilities or common public areas the guidelines recommend that signs notifying of the application be posted at all public entrances 24 hours before the application and for at least 24 hours after it. The signs should include, among other information, the recommended reentry time. The requirement to post signs does not apply if the pesticide is to be applied inside a building at least 24 hours before use by occupants or visitors (e.g. applications made after the close of business on a Friday in buildings not open on the weekend) or if the pesticide being applied is formulated as a wettable powder and is applied only to perimeter baseboards or to cracks and crevices.

Specific guidance on timing and reentry is provided in the

guidelines:

Pesticide applications within structures should be timed to provide a maximum possible interval between treatment and human activity or re-entry. In cases where buildings are used only on weekdays, an early weekend treatment would be appropriate. Currently a 6-8 hour minimum interval in well-ventilated rooms is recommended in the absence of specific label requirements.

The rationale behind the 6-8 hour minimum interval is unclear. The Ministry of Health informed me (Carmichael, 1993) that the interval was selected after consideration of advice from the British Columbia Ministry of Environment, Lands and Parks, a review of a limited amount of the published literature on air and surface residues and on the basis of a 3-6 hour period recommended by the Ontario Ministry of the Environment (see Ontario Ministry of the Environment, 1987).

The British Columbia Ministry of Environment, Lands and Parks (1992) has produced *Guidelines for Structural Pest Control Treatments in Public Use Areas* to "reduce the risk of public exposure to pesticides and to avoid conflicts between applicators and the public". These guidelines have been distributed to Ministry-licensed pest control service companies and are published in a booklet contained in a study kit used by those wishing to write the examination for an applicator's certificate in general structural pest control. The guidelines advise on notification and posting requirements prior to pesticide applications and on reentry times and practices and are virtually identical to the British Columbia

Ministry of Health's *Guidelines for Pesticide Treatments in Public Use Areas*.

In its *Handbook for Pesticide Applicators and Dispensers* the British Columbia Ministry of Environment, Lands and Parks (1990) advises structural pesticide applicators to:

Make certain building residents know how long to wait before re-entry to treated building areas after a treatment. Observe re-entry times specified on the label or, if not specified, wait until pesticide sprays are thoroughly dry (time depends on building heat and humidity).

Ensure that children and domestic pets are prevented from entering a building or treated area before the safe re-entry time.

Specify that treated interiors of buildings should be aired out before re-entry.

When pesticides are applied to confined or enclosed structures (for example, office buildings, warehouses and farm buildings) the Workers' Compensation Board of British Columbia's *Standard Practices for Pesticide Applicators* manual (Workers' Compensation Board of British Columbia, 1990) recommends the use of a "restricted entry interval" (defined as a period of time that must elapse after pesticides are applied to an area before workers not wearing suitable protective clothing and equipment are permitted to enter) equivalent to that for open agricultural fields in those applications where there is any likelihood of a worker contacting harmful levels of residue. The Workers' Compensation Board of British Columbia bases

these restricted entry intervals for open agricultural fields on a pesticide's acute oral and dermal LD₅₀ values. The restricted entry interval after broadcast application to a confined or enclosed structure of standard pest control insecticides such as diazinon and chlorpyrifos, both having moderate acute LD₅₀ values, is a minimum of 48 hours. The manual also recommends that the space be adequately ventilated before reentry.

The Ontario Ministry of Environment (1987) provides *Guidelines for Proper Treatment of Apartment Buildings to Control Cockroaches* to commercial pest control firms. These guidelines are to be applied during "clean-out" operations only and apply to the complete range of insecticides registered for control of cockroaches. The Ministry advises that:

Tenants should be advised to leave the suite for 3 to 6 hours. This stipulation is not mandatory, but is advisable because the presence of emulsions and solvents in the insecticide may release odours for several hours that cause health concerns to some people. Tenants should be advised to ventilate their premises following spray treatment. Treatment during winter months may require longer vacancy time by tenants.

This advice appears to indicate that the rationale behind the reentry time is the minimization of possible complaints about odours rather than the reduction of a health risk. Some regulators believe that the trend toward use of "low odor" insecticides makes the risk of poisoning more likely as occupants will not be able to rely as readily on a warning

odor (United States Environmental Protection Agency/United States Public Health Service/National Environmental Health Association, 1991).

C. Current Practices

1. Structural Pest Control Industry

In Canada there is not only a significant legal onus placed on the certified pesticide applicator to handle pesticides safely but also the expectation by regulators and the public that the applicator will knowledgably advise persons occupying buildings on methods to minimize their exposure to pesticide residues, including reentry time. In the preamble to *Guidelines for Structural Pest Control Treatments in Public Use Areas* (British Columbia Ministry of Environment, 1992) the Ministry recommends that "all certified applicators follow these guidelines as may be reasonably possible, or provide adequate or better means of notifying people and minimizing public exposure and environmental contamination". As previously indicated, these guidelines require verbal or written notification of a pesticide application and posting of treated areas. Pesticide notification bylaws in Canada require an applicator to provide safety information and precautions, including reentry recommendations, in a notice to occupants of areas being treated. In my survey of Canadian public health and pesticide management agencies, 46% of the agencies referred all inquiries regarding reentry times and

practices to the pest control company making the application (see below).

The Alberta Structural Pest Control Association, in cooperation with Alberta Environment, has established standard notification guidelines which its members provide to residents of buildings before any indoor pest control operation (McIntosh, 1994). The Alberta industry-recognized reentry time is 6 to 8 hours although longer periods (overnight, 24 hours) are recommended for pregnant or nursing women, children less than 1 year old or those with respiratory problems. Alberta Environment does not make any other recommendations on reentry and considers the Associations guidelines to be adequate to ensure safety.

The degree to which Canadian pest control companies meet this expectation is unknown. Whitemore *et al.* (1993), in reviewing the results of the U.S. National Home and Garden Pesticide Use Survey, reported that only 20.67% of an estimated 16 million households that used commercial pest control services in 1989-90 received written safety recommendations from the applicator. The survey did not ask whether pest control operators advised customers verbally about safety precautions such as reentry times and practices.

To determine reentry practices recommended by local pest

control operators, I conducted a telephone survey of pest control companies in the Greater Vancouver area using a standard "interview" format. Companies were presented with the following scenario: a fully carpeted single family home requires control of fleas (which would usually require a broadcast application of an insecticide solution or emulsion); the house is occupied by two adults, a six year old child and a one year old child. Twenty two companies provided information on the insecticide that would be applied and the reentry period that would be required, given the scenario. The results of the survey are summarized in Table 1.

2. Public Health and Pesticide Management Agencies

Public health departments and pesticide management agencies frequently receive inquiries from the public about the risks of exposure to insecticides which have been applied to their homes or workplaces or are asked for recommendations on reducing the risk. In particular, concerned members of the public ask "when is it safe to go back in?".

Using a questionnaire, I surveyed public health departments and other agencies to determine what recommendations these agencies make to the public or to the pest control industry on appropriate reentry times and practices. The survey included all Municipal and Provincial public health units or

Table 1. Reentry times recommended by Greater Vancouver pest control companies after broadcast application of insecticide to control fleas in a home ¹ (responses from 22 companies).

A. Insecticide: Diazinon (Basudin[®] or unspecified)

REENTRY TIME	NUMBER OF COMPANIES RECOMMENDING		
	ADULTS ONLY ²	ADULTS & CHILDREN	NOT SPECIFIED
4-6	0	0	0
6	1	0	0
8	0	0	3
12	0	0	1
24	0	1	0

B. Insecticide: Chlorpyrifos (Dursban L.O.[®])

REENTRY TIME	NUMBER OF COMPANIES RECOMMENDING		
	ADULTS ONLY ²	ADULTS & CHILDREN	NOT SPECIFIED
4	5	0	5
5	0	0	1
4-6	0	0	5
6-8	0	2	0
8	0	2	3
24	0	1	1

1. The following scenario was presented: fleas have infested a three bedroom detached single family home. The home is fully carpeted. Fleas have been noted in the living room and at least one bedroom. The house is occupied by two adults, a six year old child and a one year old child.
2. A number of companies indicated a reentry time if only the adults were present ("adults only"), another time if the children and adults were present ("adults & children") or indicated a reentry time without any reference to the children ("not specified").

departments in Canada with an urban population of at least 35,000 within their jurisdiction, pesticide regulators from all Provinces (members of the Canadian Association of Pesticide Control Officials) and Occupational and Environmental Health Services of Health Canada (responsible for occupational health in Federal government and Federally-regulated agency facilities). Fifty nine of 69 agencies contacted (85%) responded to the survey.

Twenty two of the 59 agencies (36%) recommend reentry times. Reentry times ranged from immediately after application to 24-48 hours after it. (Table 2). In 4 cases the specific reentry time is based on conditions such as the age and health of the person exposed (these agencies believe that a longer reentry time is appropriate if a small child, a pregnant woman or a person with a special sensitivity to the insecticide is present). In other cases, a single reentry time is recommended for all situations.

Thirteen agencies (22%) make recommendations on reentry practices either instead of or in addition to specific reentry times (Table 2). These practices generally involve ventilation of the treated area and practices to prevent small children from contacting treated surfaces.

Many agencies do not recommend reentry times and practices

Table 2. Reentry times and practices recommended by public health agencies after indoor broadcast application of insecticides.

REENTRY TIME	PRECAUTIONS	RATIONALE / SOURCE
0 hours	ventilate while applying	Ontario Ministry of Environment guidelines
minimum 2 hours	do not reenter until treated area is dry; open doors and windows to ventilate; use fan	trade manual information; discussion with B.C. Ministry of Environment; common sense
2-4 hours	—	allows pesticide aerosols to settle
2-4 minimum; 6-8 preferred; 24 hours	—	24 hours for pregnant women or small children
about 3 hours	ventilate area and allow to dry before reentry	—
3 hours if window open; 4 hours if closed	stay out overnight if person has respiratory problems	Ontario Ministry of Environment information
3-4 hours	—	Ontario government fact sheet
about 4 hours	—	—
4 hour	—	Ontario Ministry of Environment
4 hours	—	—
4 hours	—	allows surfaces to dry and aerosols to settle
4 hours minimum	leave windows open in homes; treat offices in evening and ventilate overnight with outdoor air if possible	—
4 hours minimum	give time to air out the premises	rough assessment of times from Ontario Ministry of Environment
4 hours; 8 hours; 12 hours or overnight	—	assessment of LD ₅₀ values and settling time for aerosols; guidelines used by other jurisdictions [not specified]
4-5 hours	—	allows aerosols to settle
4-6 hours minimum	area must be dry and well ventilated before reentry	—
4-6 hours; 24 hours	cover carpets if a crawling child is present	24 hours is for pregnant women; allows time for insecticide to dry
4-8 hours minimum	businesses: spray after regular hours and ventilate overnight	—
6 hours; 24 hours	—	24 hours for pregnant women and toddlers; Ontario Ministry of Environment and University of Guelph information
24-48 hours	—	reentry time depends on chemical used and application method [not specified]
"several hours"	ventilate as well as possible	"little scientific basis for this advice"
"case specific"	—	—
—	block access to treated areas; do not use residual insecticides if an infant is present	—
—	vacate until surfaces have dried; wash surfaces used for food contact	—
—	house should be aired out; surfaces on which young children play should be washed	—

and, instead, refer such inquiries to others. Twenty nine agencies (49%) refer the inquiry to the pest control company making the application. Ten agencies (17%) refer inquiries regarding reentry to their Provincial pesticide management authority (the agency responsible for licensing of pesticide applicators). Twelve agencies (20%) refer the person inquiring to the pesticide label. Two agencies (3%) ask the person to refer to the pesticide's material safety data sheet although the federal Hazardous Products Act and Controlled Products Regulations do not require suppliers of pest control products registered under the Pest Control Products Act to provide material safety data sheets (Workers's Compensation Board of British Columbia, 1989).

Thirteen of the agencies (22%) provided some rationale or basis for the recommendations they make on reentry times and practices (Table 2). Six of the 13 agencies cite information from the Ontario Ministry of the Environment as the basis for their recommendations. This Ministry does not have regulations on reentry times and practices but as has been discussed, provides some guidance on reentry following cockroach "clean-out" operations (which involve extensive crack and crevice and limited broadcast application of residual insecticides to all areas of a building) in apartment buildings (Ontario Ministry of the Environment, 1987). The Ministry deals with public inquiries about reentry times

through discussions on the risks and benefits of any pesticide application, the advantages and disadvantages of residual and non-residual insecticide formulations and the advantages of integrated pest management approaches (Cutten, 1992). The Ministry further states that the same question of reentry times is often asked of the Ministry by the pest control industry. In such cases the pest control company is usually advised to consult the product label, to call the Canadian registrant of the product or to call the Agriculture and Agri-Food Canada Pesticide Data Callline (a toll-free telephone service which provides consumer-oriented information on pesticide use).

None of the 13 British Columbia agencies surveyed cited the Ministry of Environment, Lands and Parks or Ministry of Health reentry guidelines but some did cite pesticide notification bylaws.

III. Insecticide Residues Following Indoor Applications

A. Residues in Air

Reentry times and practices should be chosen to ensure that persons reentering a building are not exposed to harmful levels of insecticide. The residue levels that are produced by standard pesticide application techniques used in urban pest control, how these levels change with time and how they are influenced by environmental conditions (for example, temperature or ventilation rate) must be known to establish appropriate reentry times and practices.

A number of studies of levels of insecticide residues in air after application indoors have been reported. Studies of residues of diazinon, chlorpyrifos, bendiocarb, d-trans allethrin, dichlorvos, abamectin and cypermethrin in the air after being applied by broadcast or crack and crevice application were reviewed. The results are summarized in Tables 3 and 4 and Figures 1 to 12.

Direct comparison of these studies is difficult. Research into methods for monitoring exposure of building occupants to pesticides used indoors has only recently begun (Curry and Iyengar, 1992). Although several standard sampling protocols have been proposed (NACA, 1990; ASTM, 1991; Health Canada, 1992) no one method has been adopted and sampling methodologies differed in these studies.

Table 3. Summary of studies of residues of insecticides in indoor air after broadcast application.

REFERENCE	APPLICATION SITE	SURFACE	% ACTIVE INGREDIENT (1)	APPLICATION RATE	APPLICATION METHOD	VENTILATION	SAMPLING METHOD (2)	SAMPLING HEIGHT
Currie et al., 1990	offices	carpet	1.0 DZ	estimated 30 ml emulsion/m ²	coarse fan	"unventilated" windows, doors shut	Chromosorb 102 and GFF	"approximately 1.0 m"
Siddiqi & Braun, 1985	apartments	carpet	1.0 DZ	?	?	?	Florissil PR-60	1.5 m
Takacs, 1993	apartments and houses	carpet and vinyl	0.48 C	?	fan	various	Chromosorb 102	0.25, 0.5 and 1.0 m
Fenske et al., 1991	apartments and houses	carpet and vinyl tile	0.48-0.50 C	14-55 ml emulsion/m ²	?	various	Teflon filter	0.12, 0.6 and 0.9-1.4 m
Currie et al., 1990	offices	carpet	0.5 C	estimated 30 ml emulsion/m ²	coarse fan	"unventilated" windows, doors shut	Chromosorb 102 and GFF	"approximately 1.0 m"
Fenske et al., 1990	apartments	carpet	0.5 C	?	fan	various	ORBO-44	0.25 and 1.0 m
Fenske and Lu, 1990	dormitories	carpet	0.5 C	?	fan	various	ORBO-44	0.25, 1.0 and 1.75 m
Nafziger et al., 1985	house	carpet and vinyl	0.5 C	?	fan	?	Carbowax 400 on Porasil	0.3 m
Siddiqi & Braun, 1985	apartments	carpet	0.5 C	?	?	?	Florissil PR-60	1.5 m
Ware & Cahill, 1978	office	vinyl tile	0.5 C	340 ml emulsion	20 psi	"ventilation system blocked"	MI with ethylene glycol	1.01 m
Currie et al., 1990	office	vinyl tile	1.0 B	estimated 30 ml emulsion/m ²	fine fan	"unventilated" windows, doors shut	Chromosorb 102 and GFF	"approximately 1.0 m"
Gold et al., 1984	houses	various	0.5 DV	?	fine fan @ 20 psi	?	MI with ethylene glycol and ethanol	?

(1) DZ = diazinon

C = chlorpyrifos

DV = dichlorvos

B = bendiocarb

Florissil PR-60 = Supelco ORBO-60 (Florissil PR) adsorbent tube

Chromosorb 102 = SKC Chromosorb 102 adsorbent tube

GFF = 37 mm glass fibre filter

Carbowax/Porasil = Supelco Carbowax 400 stationary phase material on Porasil adsorbent tube

ORBO-44 = Supelco ORBO-44 (Supelapak 20E) adsorbent tube

MI = midjet impinger

Table 4. Summary of studies of insecticides in indoor air after crack and crevice application.

REFERENCE	APPLICATION SITE	% ACTIVE INGREDIENT (1)	APPLICATION RATE	APPLICATION METHOD	VENTILATION	SAMPLING METHOD (2)	SAMPLING HEIGHT
Siddiqi and Braun, 1985	apartments	1.0 DZ	?	?	?	Florisil PR-60	1.5 m
Leidy et al., 1984	domitories	1.0 DZ	7.2 - 8.6 g AU/room	multijet @ 20 psi	"windows remained closed"	PUF	1.2 and 0.31 m
Leidy et al., 1982	domitories	1.0 DZ	1.8 - 1.9 g AU/room	fine pin 0.7 - 1.0 kg/cm ²	"windows closed during application"	PUF	"approximately 0.46 m"
Wright et al., 1981	domitories	1.0 DZ	3.3 ± 0.2 g AU/room	pin	"windows closed during treatment"	MI with hexylene glycol	"approximately 0.46 m"
Siddiqi and Braun, 1985	apartments	0.50 C	?	?	?	Florisil PR-60	1.5 m
Wright et al., 1981	domitories	0.50 C	1.7 ± 0.2 g AU/room	pin	?	MI with hexylene glycol	0.46 m
Wright and Leidy, 1980	restaurant	0.50 C	?	pin	various	MI with hexylene glycol	?
Wright and Leidy, 1978	domitories	0.50 C	2.0 ± 0.14 g AU/room	pin @ 0.7-1.0 kg cm ²	open window and "air circulator"	MI with hexylene glycol	?
Wright et al., 1981	domitories	0.50 B	1.7 ± 0.1 g AU/room	pin	?	MI with hexylene glycol	0.46 m
Eitzer, 1991	cafeteria	0.25 d-T	?	Whitmore PT 565+	"normal operation of cafeteria"	Chromosorb 102	?
Wright et al., 1992	cafeteria	0.05 AB	32-45 mg AU/cafeteria	dusting tube	doors and windows closed, no HVAC	ORBO-42	?
Wright et al., 1993	domitories	0.2 CY	0.25 ± 0.1 g/room	pin @ 1.4 kg/cm ²	doors and windows closed, no HVAC	ORBO-42	?

(1) DZ = diazinon C = chlorpyrifos B = bendiocarb d-T = d-trans allethrin AB = abamectin CY = cypermethrin

(2) Florisil PR-60 = Supelco ORBO-60 (Florisil PR) adsorbent tube PUF = polyurethane foam plug MI = midgeet impinger Chromosorb 102 = SKC Chromosorb 102 adsorbent tube ORBO-42 = Supelco ORBO-42 (Supelapak 20P) adsorbent tube

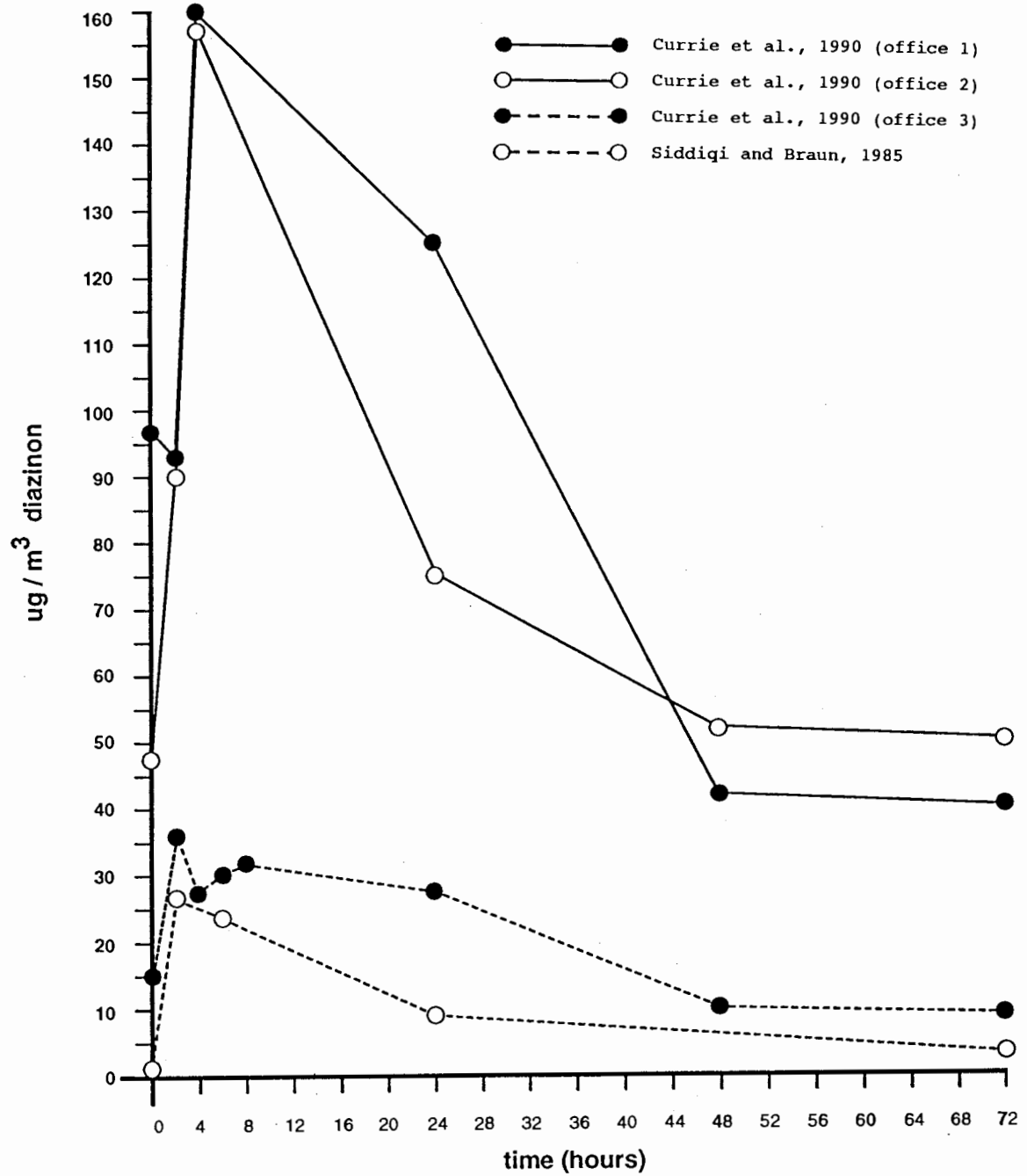


Figure 1. Residues of diazinon in indoor air after broadcast application.

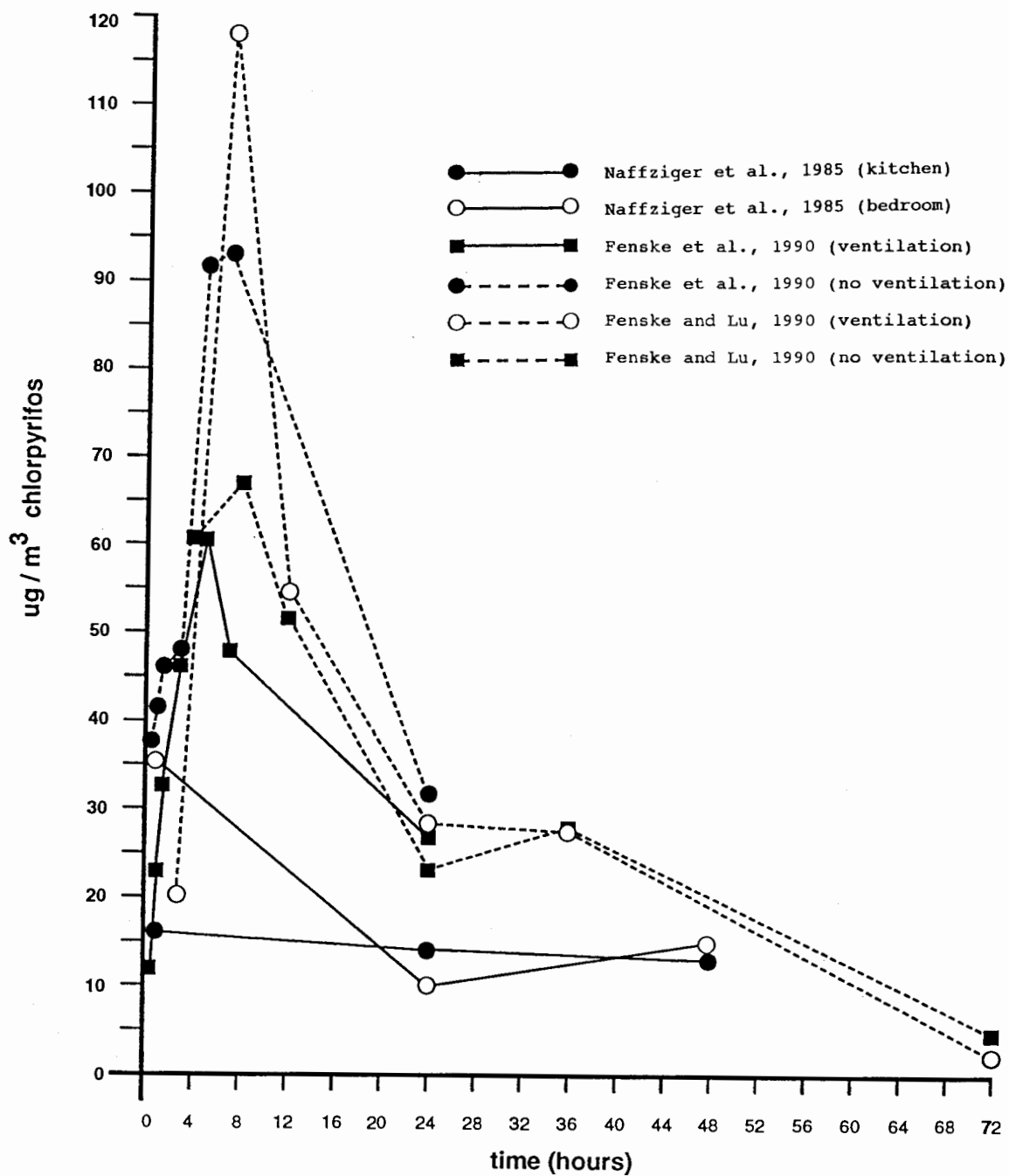


Figure 2. Residues of chlorpyrifos in indoor air after broadcast application (samples taken from ≤ 32 cm above treated surfaces).

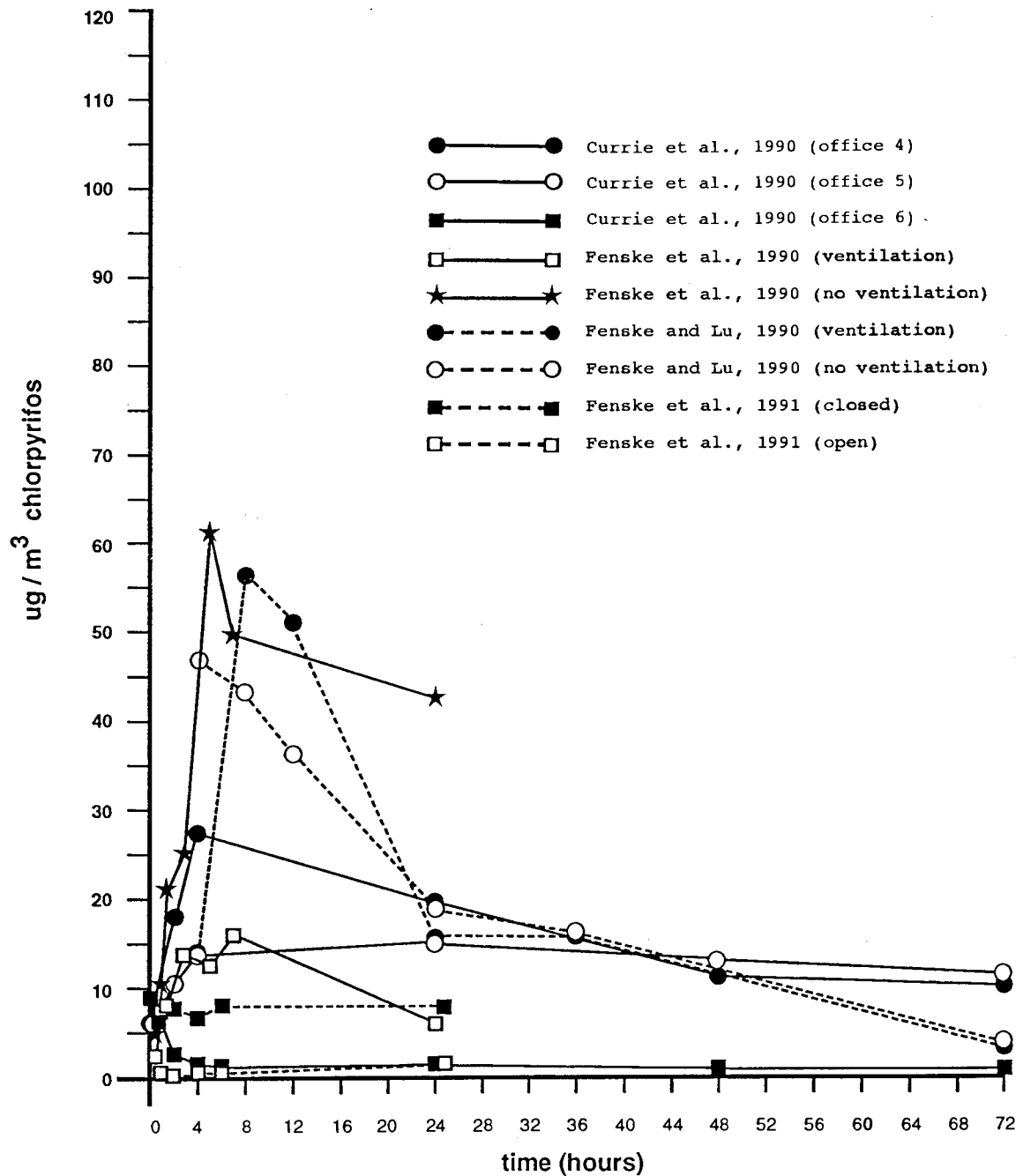


Figure 3. Residues of chlorpyrifos in indoor air after broadcast application (samples taken 90-140 cm above treated surfaces).

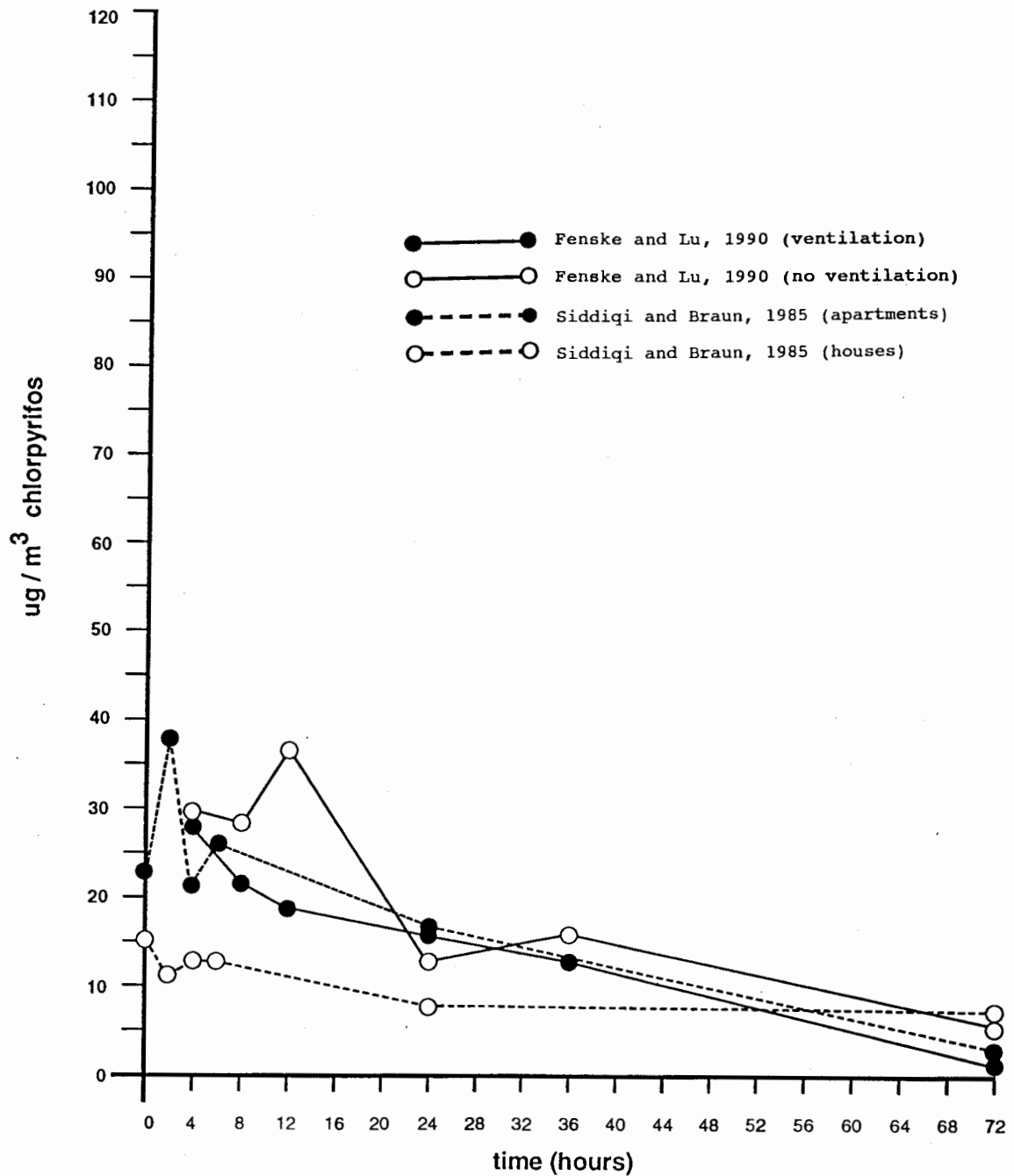


Figure 4. Residues of chlorpyrifos in indoor air after broadcast application (samples taken 150-175 cm above treated surfaces).

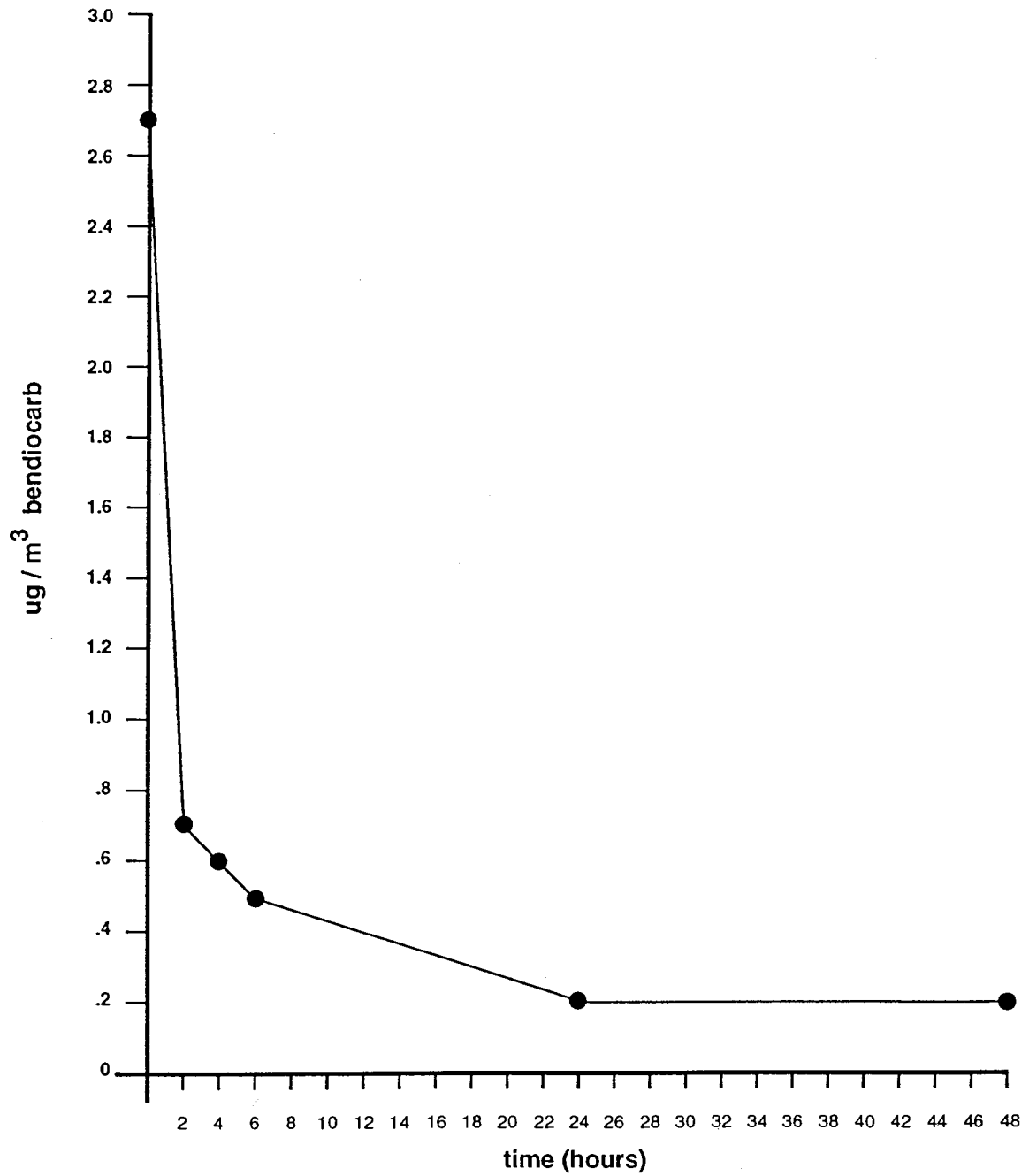


Figure 5. Residues of bendiocarb in indoor air after broadcast application (after Currie et al., 1990).

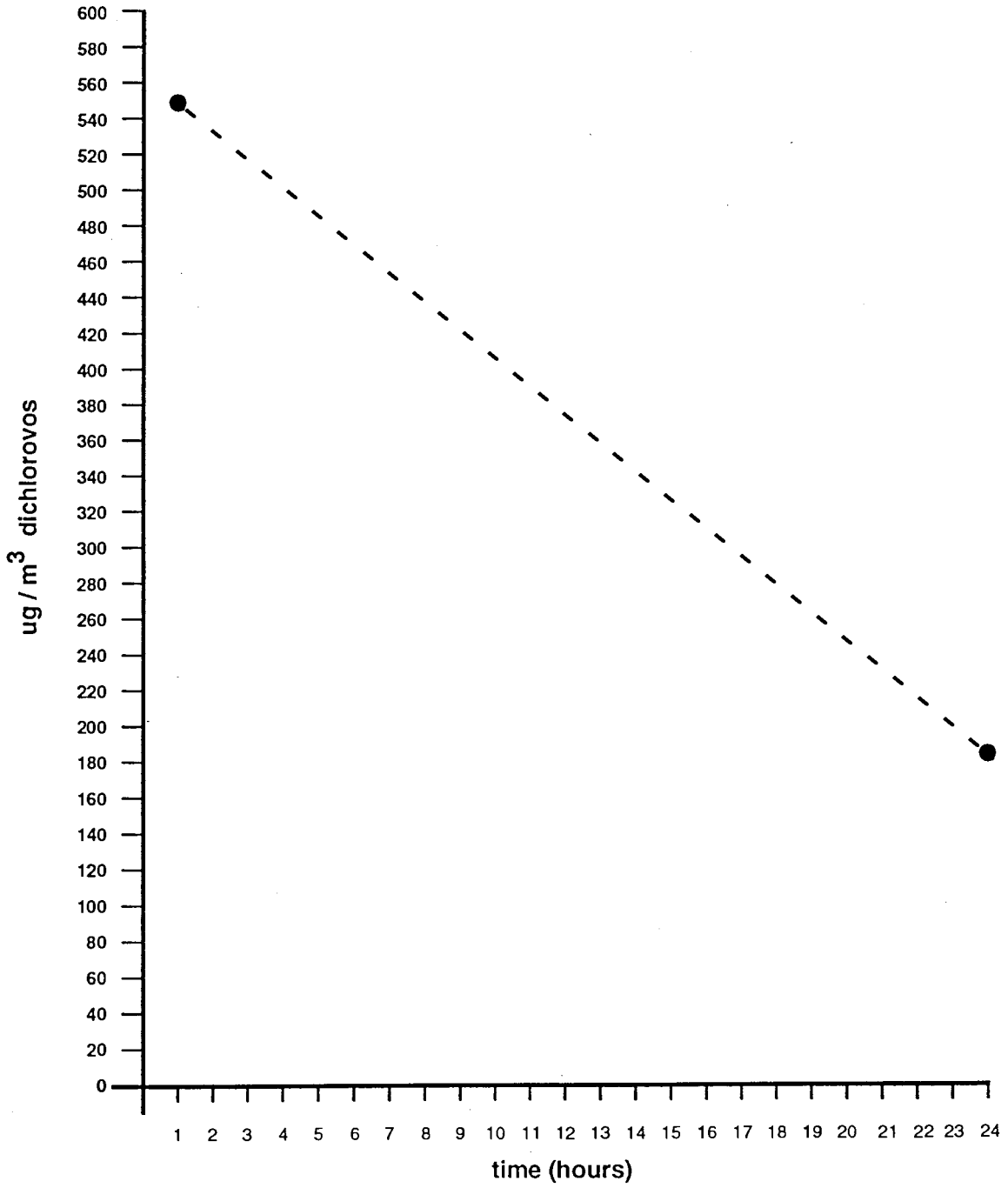


Figure 6. Residues of dichlorvos in indoor air after broadcast application (after Gold et al., 1984).

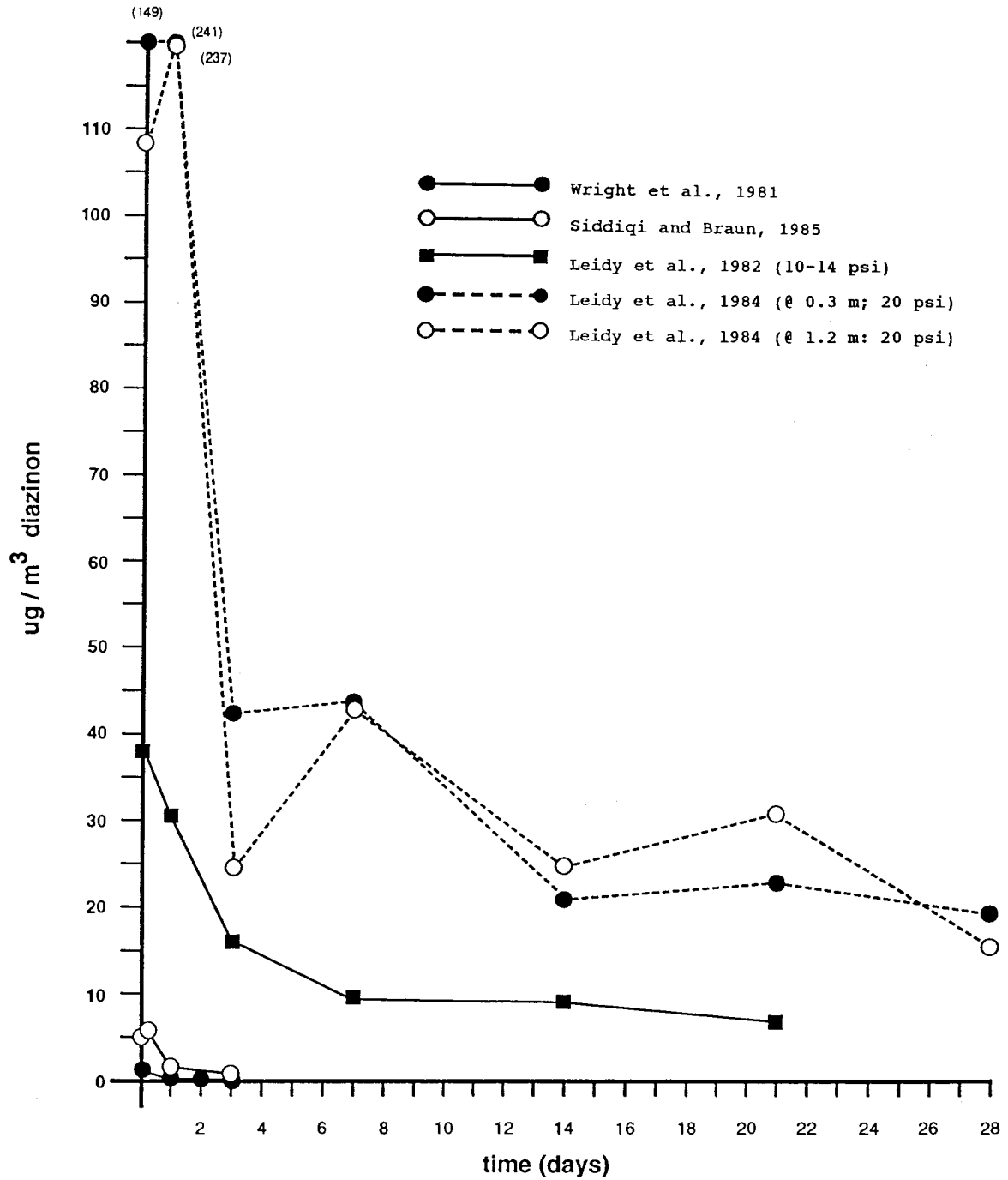


Figure 7. Residues of diazinon in indoor air after crack and crevice application. (values in brackets are off-scale)

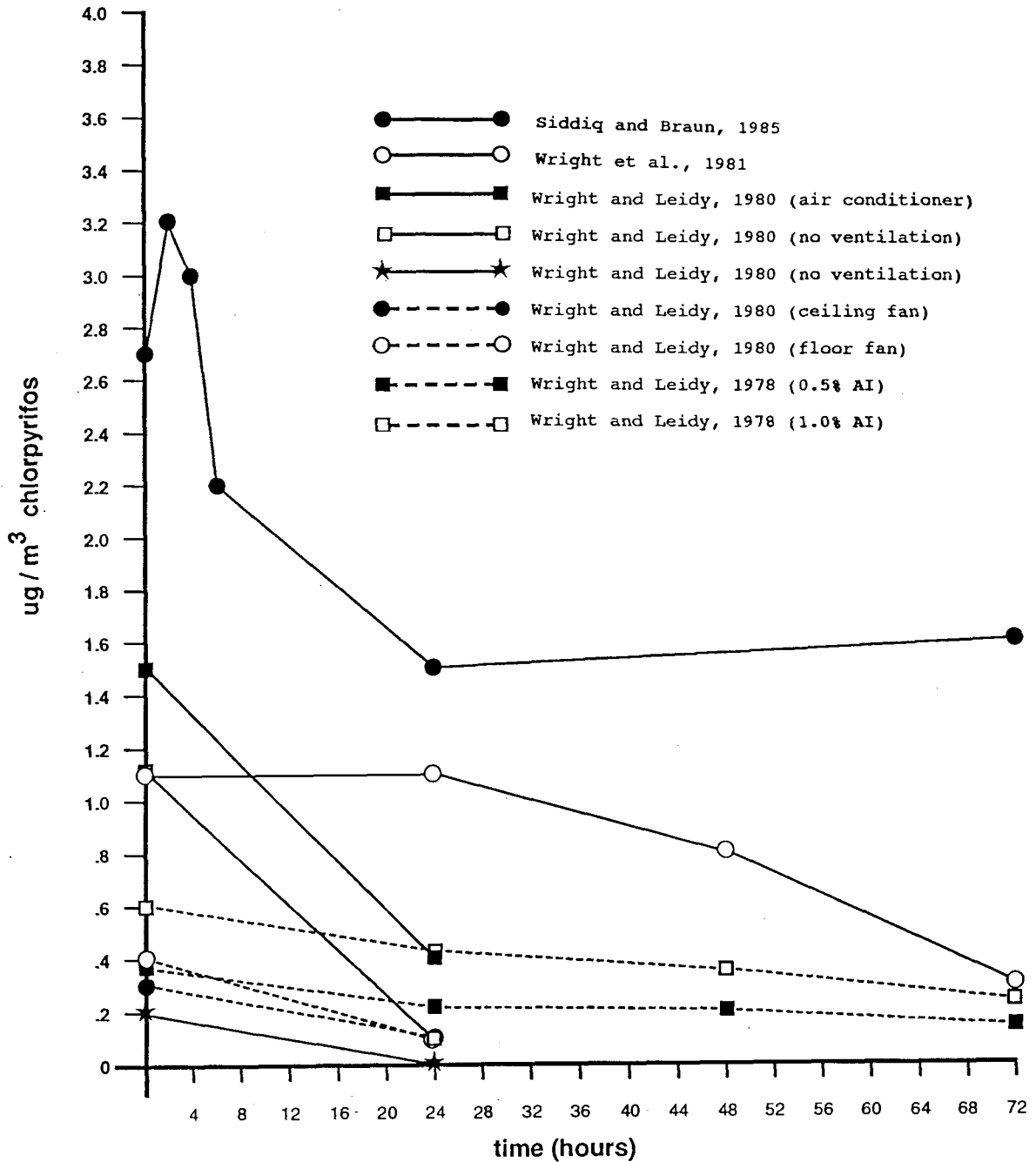


Figure 8. Residues of chlorpyrifos in indoor air after crack and crevice application.

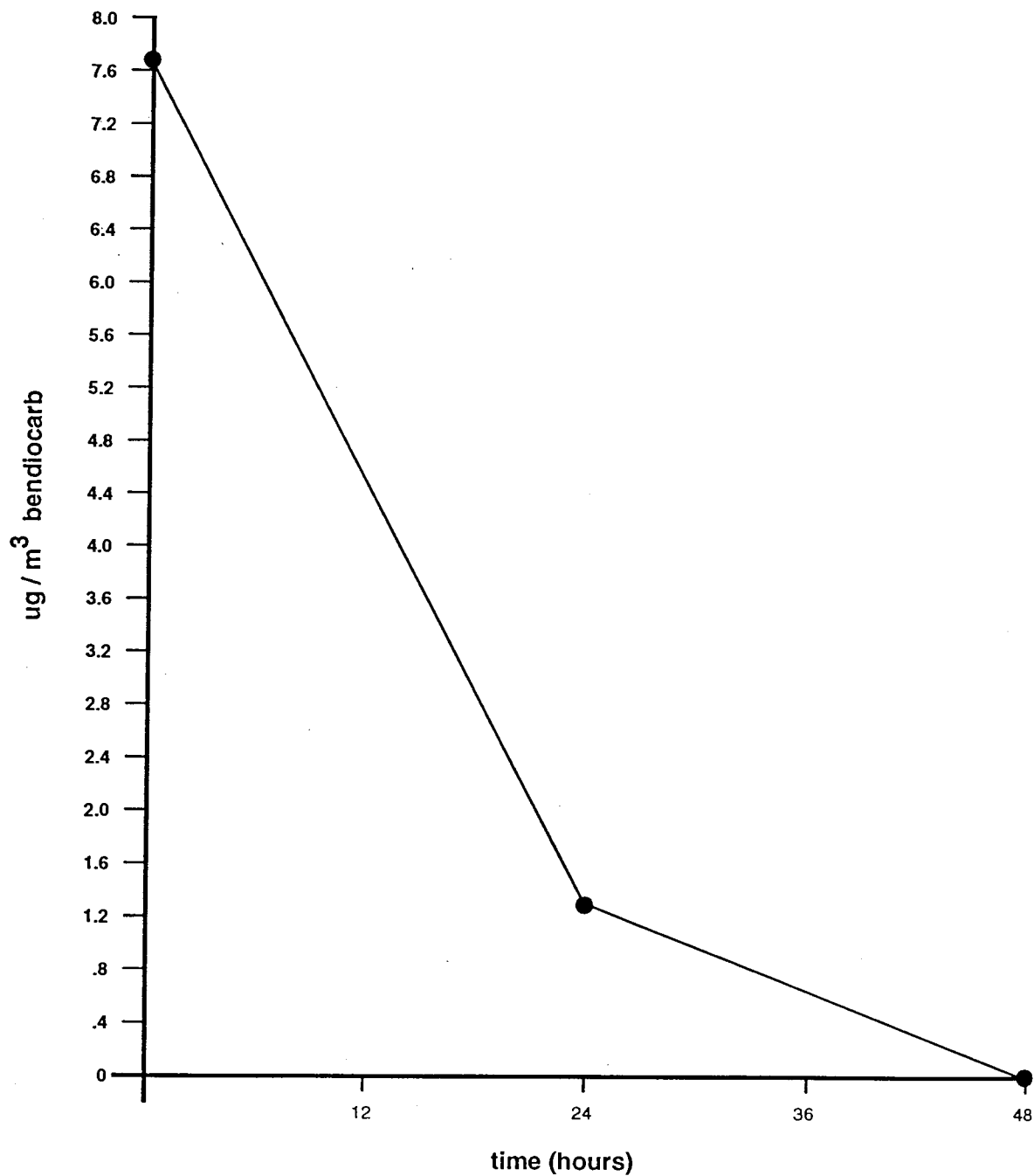


Figure 9. Residues of bendiocarb in indoor air after crack and crevice application (after Wright et al., 1981).

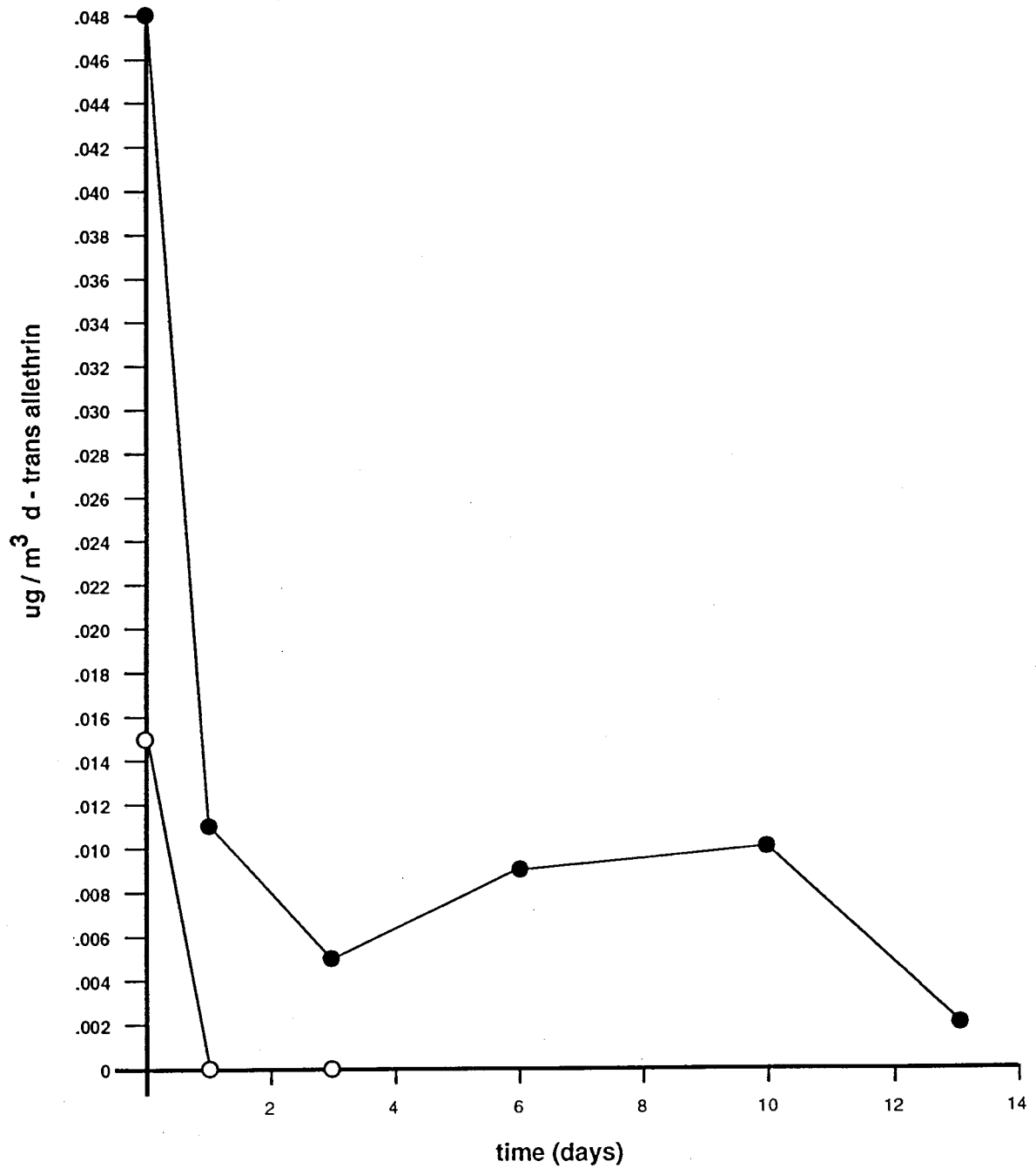


Figure 10. Residues of d-trans allethrin in indoor air after crack and crevice application (after Eitzer, 1991).

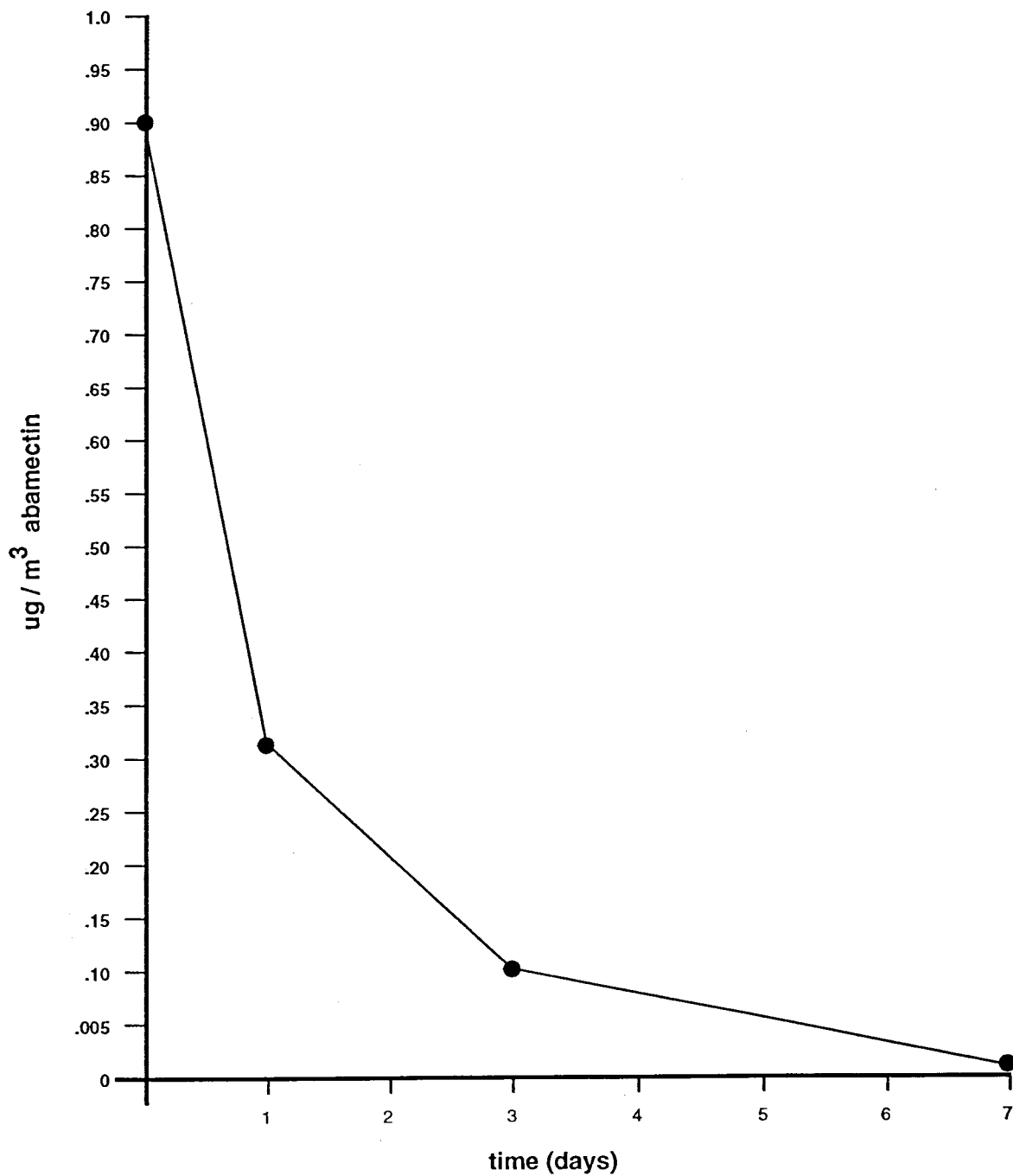


Figure 11. Residues of abamectin in indoor air after crack and crevice application (after Wright et al., 1992).

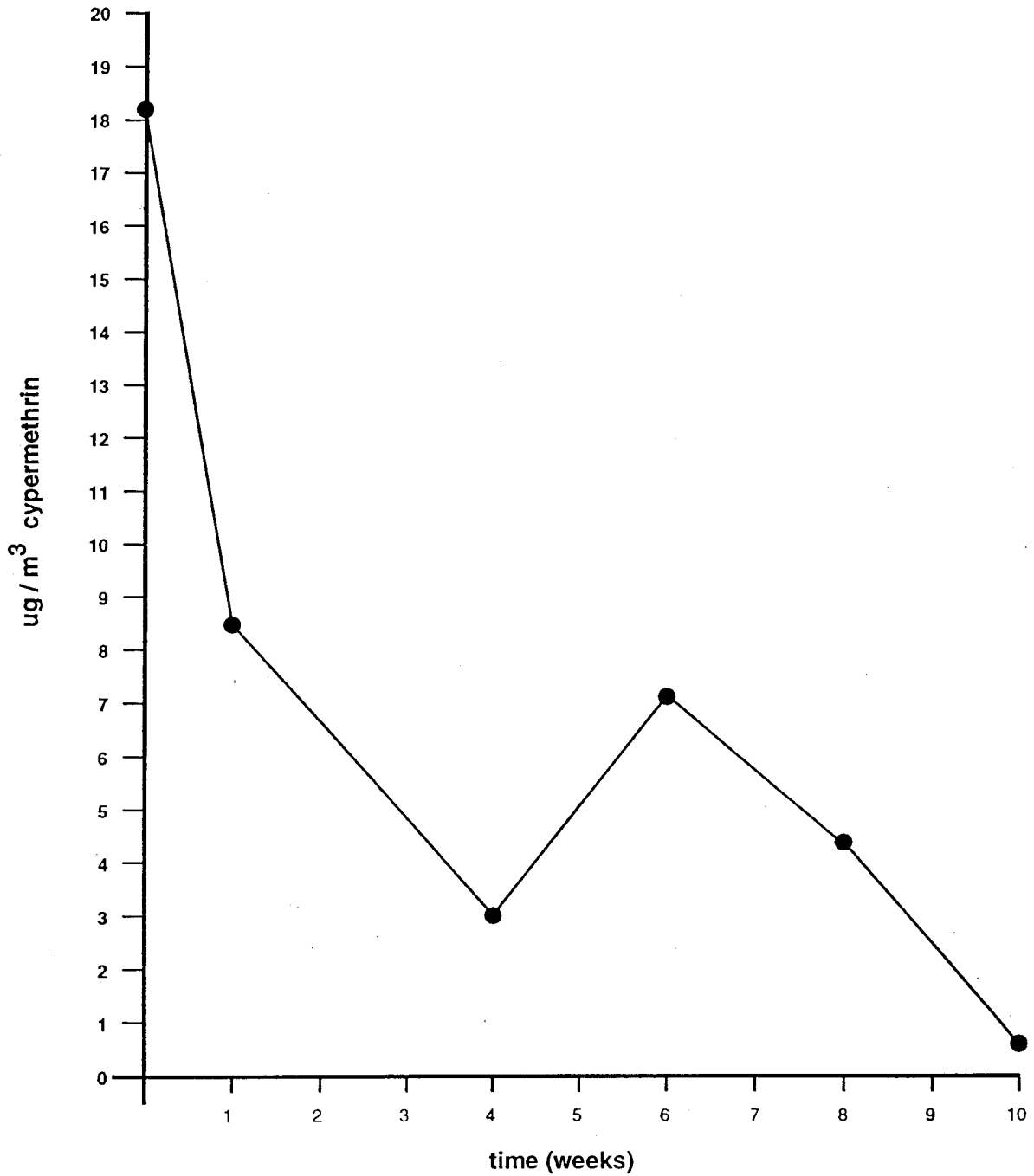


Figure 12. Residues of cypermethrin in indoor air after crack and crevice application (after Wright et al., 1993).

Several generalizations can be made however:

1. There is a vertical "stratification" of chlorpyrifos residues after broadcast application with the treated floor surface apparently releasing volatilized insecticide (Fenske, 1992). Residues at approximately 30 cm above the floor (an infant's or small child's breathing zone when seated or laying) are higher than residues at approximately 100 cm (seated adult's breathing zone) or 150 cm (standing adult's breathing zone). Insufficient data are available to determine whether a similar effect occurs after broadcast application of diazinon, bendiocarb or dichlorvos but it probably does. In recognition of this concentration gradient Health Canada's *Guidelines for Indoor Occupant Exposure Assessment for Pesticides* (Health Canada, 1992) require that samples for air residues be taken 25 and 100 cm above the treated surface.

There are insufficient data in the literature to determine whether stratification occurs after crack and crevice application but the the data reviewed indicate lower concentrations in air and therefore less significant stratification.

2. Broadcast application produces higher levels of residues in air than does crack and crevice application. Fogging with so-called total release aerosols has been shown to produce very high levels of residues in air and on surfaces (Vaccaro, 1993)

but is not an application technique currently used in Canada.

3. Air residue levels rise after broadcast application of chlorpyrifos and diazinon and reach maximum levels approximately 4 to 10 hours after application. This has not been adequately measured for bendiocarb or dichlorvos.

I could not determine whether a significant rise in air residue levels occurs with time after crack and crevice application because samples were seldom taken 4 to 10 hours after application.

Health Canada's sampling guidelines (Health Canada, 1992) require sampling for 7 hours post-application and at 24 hours after application.

4. Although ventilation of a building following insecticide application probably affects air residue levels, the extent and significance of the effect is not clear from a review of the literature, again because of a lack of standard experimental methodology. In some studies windows and doors in the treated area were closed or the mechanical ventilation system shut down or both and the room was considered to be unventilated. In other studies doors and windows were opened to "ventilate" a room while in others a simple fan was used to move air. In many studies no description of ventilation was

given. In no study was air exchange, airflow pattern or other ventilation parameter measured. Most proposed standard methods for air residue level assessment require that air exchange be minimal during sampling or that ventilation patterns be properly characterised.

Takacs (1993) found significantly lower air residues of chlorpyrifos in ventilated (windows and doors open) dwellings compared with unventilated ones only after 24 hours. Fenske *et al.* (1991) reported that ventilation from open doors and windows substantially reduced air concentration of chlorpyrifos after broadcast application. Fenske *et al.* (1990) found that open windows provided mixing and dilution of air 1.0 meter above a carpet treated by broadcast application of chlorpyrifos but had much less effect on concentrations near the floor. Fenske and Lu (1990) report a more pronounced vertical concentration gradient of chlorpyrifos after broadcast application in ventilated (open doors and windows; box fan in doorway) rooms. The box fan alone reduced air concentrations substantially while ambient air ventilation (doors and windows) had little effect.

5. While higher temperatures and lower relative humidities might be expected to increase volatilization of insecticides from treated surfaces there is little information available in the literature. [Wright *et al.* (1993) found no correlation

between cypermethrin levels in air after crack and crevice application to dormitory rooms and temperature (ranged from 19 to 29°C) or relative humidity (60 to 86%). Leidy et al. (1982) reported that analysis of temperature (25.8 to 32.2°C) and humidity (45.5 to 62.5%) effects on diazinon residues in the air of rooms adjacent to a room treated by crack and crevice application showed no differences due to either variable but they did not report on any effects in the treated room.

B. Residues on Surfaces

Studies of residues of diazinon, chlorpyrifos, bendiocarb, abamectin and cypermethrin on surfaces after broadcast and crack and crevice applications in indoor environments were reviewed. Those with detailed results are summarized in Tables 5 to 10.

Direct comparisons are again difficult because of differences in sampling methods and because of major difficulties in relating the amount of insecticide detected on a surface first to the amount that will be transferred to a person's skin and second, to the amount that will ultimately be taken up through dermal absorption. There is currently no generally accepted method for evaluating insecticide residues on indoor surfaces. Some researchers measured only the mass of active ingredient

Table 5. Summary of studies of residues of insecticides on surfaces after indoor broadcast application.

REFERENCE	APPLICATION SITE	% ACTIVE INGREDIENT (1)	APPLICATION RATE	APPLICATION METHOD	VENTILATION	SAMPLING METHOD (2)
Currie et al., 1990	offices	1.0 DZ	estimated 30 ml emulsion/m ²	coarse fan	"unventilated" - windows and door shut	D: aluminum plate W: gauze with isopropanol
Fenske et al., 1991	apartments and houses	0.48-0.50 C	14-55 ml emulsion/m ²	?	various	D: aluminum plate W: gauze with isopropanol or distilled water
Fenske et al., 1990	apartments	0.50 C	?	fan	various	D: aluminum plate W: gauze with distilled water
Fenske and Lu, 1990	dormitories	0.50 C	?	fan	various	D: gauze on foil W: gauze with distilled water
Currie et al., 1990	offices	0.50 C	estimated 30 ml emulsion/m ²	coarse fan	"unventilated" - windows and door shut	D: aluminum plate W: gauze with isopropanol
Naffziger et al., 1985	houses	0.50 C	?	fan	?	W: dry gauze diaper
Currie et al., 1990	office	1.0 B	estimated 30 ml emulsion/m ²	fine fan	"unventilated" - windows and door shut	D: aluminum plate W: gauze with isopropanol

(1) DZ = diazinon C = chlorpyrifos B = bendiocarb
 (2) D = deposition samples W = wipe samples

Table 6. Surface residues measured by deposition sampling after indoor broadcast application.

REFERENCE	INSECTICIDE (1)	HOURS AFTER APPLICATION	RESIDUE ($\mu\text{g}/\text{cm}^2$)	VENTILATED	NOTES
Currie et al., 1990	DZ	1-2	0.006	No	0.6 m above floor
		24	0.005		
	DZ	1-2	0.005	No	"
		24	0.005		
	DZ	1-2	0.001	No	"
		24	<0.001		
DZ	1-2	0.002	No	1.5-2.1 m above floor	
	24	0.010			
DZ	1-2	0.001	No	"	
24	0.015				
Currie et al., 1990	B	1-2	0.002	No	0.6 m above floor
		24	0.003		
	B	1-2	0.002	No	"
24		0.003			
B	1-2	0.002	No	1.5-2.1 m above floor	
24	0.003				

(1) DZ = diazinon B = bendiocarb

Table 7. Surface residues measured by wipe sampling after indoor broadcast application.

REFERENCE	INSECTICIDE (1)	HOURS AFTER APPLICATION	RESIDUE (ug/cm ²)	VENTILATED	SURFACES SAMPLED
Currie et al., 1990	DZ	1-2/24/48	0.022/0.016/0.013	No	treated carpet, untreated furniture
	DZ	1-2/24/48	0.018/0.016/0.016	No	"
	DZ	1-2/24	0.017/0.028	No	"
	DZ	1-2/24	0.038/0.032	No	"
	DZ	1-2/24	0.029/0.038	No	"
Fenske et al., 1991	C	24/48	0.688/0.279	Yes	treated carpets
	C	24/48	1.557/0.478	No	"
	C	24/48	0.001/0.003	Yes	untreated furniture
	C	24/48	0.001/0.005	Yes	"
Currie et al., 1990	C	1-2/24/48	<0.001/0.004/0.006	No	treated carpets untreated furniture
	C	1-2/24/48	<0.001/0.004/0.004	No	"
	C	1-2/24	0.002/0.001	No	"
	C	1-2/24	0.005/0.004	No	"
	C	1-2/24	0.003/0.004	No	"
Fenske et al., 1990	C	0.5/6.5/24	1.69/0.69/0.28	Yes	treated carpet
	C	0.5/6.5/24	0.004/0.002/<0.001	No	"
Fenske and Lu., 1990	C	24/48/72	3.90/1.56/0.48	Yes	treated carpet
	C	24/48/72	0.104/0.019/0.020	No	"
Naffziger et al., 1985	C	1/24/48	0.200/0.093/0.084	No	treated indoor / outdoor carpet
	C	1/24/48	0.178/0.104/0.049	No	treated nylon carpet
	C	1/24/48	0.150/0.065/0.088	No	treated shag carpet
Currie et al., 1990	B	1-2/24	0.020/0.025	No	treated carpet, untreated furniture
	B	1-2/24	0.025/0.017	No	"
	B	1-2/24	0.022/0.011	No	"

(1) DZ = diazinon C = chlorpyrifos B = bendiocarb

Table 8. Summary of studies of residues of insecticides on non-target surfaces after indoor crack and crevice application.

REFERENCE	APPLICATION SITE	% ACTIVE INGREDIENT (1)	APPLICATION RATE	APPLICATION METHOD	VENTILATION	SAMPLING METHOD (2)
Wright & Jackson, 1976	dormitories	1.0 DZ	1.6 ± 0.1 g AI/room	Whitmire PT260/270 @ 1.9-2.4 kg/cm ²	various	D: aluminum plates
Wright & Jackson, 1975	dormitories	1.0 DZ	796 - 1218 mg AI/room	medium pin @ 3.2-3.4 kg/cm ²	windows closed, doors sealed	D: aluminum plates
Wright & Jackson, 1974	apartments	1.0 DZ	5.9-8.6 g AI/apt.	medium pin @ 3.2-3.4 kg/cm ²	windows and doors closed	D: aluminum plates
Wright & Jackson, 1976	dormitories	0.5 C	0.4-1.0 g AI/room	Whitmire PT260/270 @ 1.9-2.4 kg/cm ²	various	D: aluminum plates
Wright and Jackson, 1975	dormitories	0.5 C	499-598 mg AI/room	medium pin @ 3.2-3.4 kg/cm ²	windows closed, doors sealed	D: aluminum plates
Wright et al., 1992	cafeteria	0.05 AB	32-45 mg AI/cafeteria	dusting tube	doors and windows closed, no HVAC	W: cotton ball with 2-propanol
Wright et al., 1993	dormitories	0.2 CY	0.25 ± 0.1 g AI/room	pin @ 1.4 kg/cm ²	doors and windows closed, no HVAC	W: cotton ball with 2-propanol

(1) DZ = diazinon

C = chlopyrifos

AB = abamectin

CY = cypermethrin

(2) D = deposition samples

W = wipe samples

Table 9. Surface residues measured by deposition sampling after indoor crack and crevice application.

REFERENCE	% ACTIVE INGREDIENT (1)	HOURS AFTER APPLICATION	RESIDUE (ug/cm ²)	VENTILATED	SURFACES SAMPLED
Wright & Jackson, 1976	1.0 DZ	0.5/5/24	0.006/<0.001/<0.001	No	floor of treated room
	1.0 DZ	0.5/5/24	0.005/<0.001/<0.001	Yes	"
Wright & Jackson, 1975	1.0 DZ	0/5/24	0.005/0.001/<0.001	No	floor of treated room
Wright & Jackson, 1974	1.0 DZ	5/24	0.002/<0.001	No	floor of treated room
	1.0 DZ	5/24	0.001/<0.001	No	"
	1.0 DZ	5/24	0.004/<0.001	No	countertop of treated kitchen
	1.0 DZ	5/24	0.018/<0.001	No	in cabinet of treated kitchen
Wright & Jackson, 1976	0.5 C	0.5/5/24	0.003/<0.001/<0.001	No	floor of treated room
	0.5 C	0.5/5/24	0.002/<0.001/<0.001	Yes	"
Wright & Jackson, 1975	0.5 C	0.5/5/24	0.002/0.003/<0.001	No	floor of treated room

(1) DZ = diazinon C = chlorpyrifos

Table 10. Surface residues measured by wipe sampling after indoor crack and crevice application.

REFERENCE	% ACTIVE INGREDIENT (1)	HOURS AFTER APPLICATION	RESIDUE (ug/cm ²)	VENTILATED	SURFACES SAMPLED
Wright et al., 1992	0.05 AB	0/24/72	all <<0.001	No	surfaces in treated kitchen
Wright et al., 1993	0.2 CY	0/168	0.023/0.012	No	dresser top of treated room

(1) AB = abamectin CY = cypermethrin

deposited on collecting devices such as aluminum plates placed on treated and untreated surfaces (deposition sampling). Others measured the mass of active ingredient (dislodgeable residue) that could be removed from surfaces with solvent-wetted gauze pads (wipe sampling). Such sampling is, at best, an indirect measure of dermal exposure. McArthur (1992) has suggested that wipe sampling methods are not standardized and fail to relate mass of contaminant on a surface to the mass transferable to the skin. While other techniques for more direct measurement of dermal exposure have been proposed, Marquart et al. (1994) believe that such techniques still need extensive research and development.

Only very basic generalizations can be made from the surface residue data. First, the amount of insecticide deposited on target surfaces is usually different from the expected "theoretical deposition" which can be calculated from the label-recommended application rate. This indicates one or more of the following: the applicator has incorrectly mixed the solution, the application has been uneven or some of the insecticide has been deposited on nontarget surfaces.

Second, surface residue levels generally decline for at least the first three days after application but there are exceptions in the data. Because these insecticides typically provide residual control of insects for 30 days or more it

seems unlikely that this reduction is due to decomposition alone. Therefore, the lower residue levels occurring with time after application may be the result of some volatilization of the active ingredient or the insecticide may be adsorbed to surfaces and not "dislodged" by the sampling method. Also, in many cases samples were taken soon after application (0.5 hours, 1-2 hours) and then not until well after the application (24 hours or more), making it difficult to understand the decay pattern.

Third, nontarget surfaces near treated surfaces do become contaminated with measurable residues, regardless of whether a broadcast or crack and crevice application is made. Broadcast application produces higher levels of residue on nontarget surfaces than does crack and crevice application, but the data is not strong.

Finally, ventilation appears to reduce surface residue levels but it is unclear whether ventilation truly reduces the potential for dermal exposure and absorption (that is, does it reduce the amount of dislodgeable residue available for transfer to the skin).

IV. Assessing Health Risk

The pest manager or pesticide regulator concerned about safe reentry after indoor insecticide application must assess the risks before recommending appropriate reentry times and procedures. This assessment involves identifying the hazards, understanding the pesticide dose-physiological response relationships and measuring exposure levels (Gibson, 1992).

Given the residues measured in air and on surfaces after indoor application of insecticides, a number of researchers have attempted to assess the degree of risk to those exposed to the residue when reentering at various times after the application. The literature contains a number of different approaches. In many cases residues in air alone are compared to an exposure standard. Two exposure standards, the Threshold Limit Values (TLV) and the National Academy of Science Committee on Toxicology guidelines have been used to assess risk but these standards may be inappropriate. Threshold Limit Values "refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse affect" (American Conference of Governmental Industrial Hygienists, 1993). Threshold Limit Values are therefore not appropriate for the occasional domestic exposure to pesticides or for uninterrupted or extended periods of exposure to a pesticide. While applicable

to workplaces, TLV's clearly should not be applied when assessing the risk of exposure to insecticides in residences. The guidelines of the National Academy of Science Committee on Toxicology were intended only to provide guidance in estimating the health risks of seven pesticides (chlordane, heptachlor, aldrin, dieldrin, lindane, pentachlorophenol and chlorpyrifos) used for termite control in U.S. military family housing and not as a guarantee of absolute safety (National Academy of Science, 1982). The guideline for chlorpyrifos was 10 ug/m³ for continuous exposures not exceeding 3 years. This was an "interim" guideline and there has been no update. In a small number of cases, respiratory and dermal exposure data have been combined to predict the risk (see below).

Diazinon

Currie et al. (1990) recognized that the TLV's probably are not stringent enough for commercial buildings where the old or the chronically ill may work, where there may be mixtures of contaminants and where ventilation may be inadequate. They compared residues of diazinon in air for 10 days after broadcast application to offices with the TLV-TWA¹ of diazinon (100 ug/m³). They concluded that for applications of diazinon comparable to that in their study, building occupants would be

1. Threshold Limit Value - Time Weighted Average, the time-weighted average concentration of a chemical substance for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect

prudent to stay out of unventilated rooms for at least 2 days after spraying. Siddiqi and Braun (1985) studied diazinon levels after broadcast and crack and crevice applications to apartments and residences and found that residues in air were well below the TLV-TWA at all times up to 6 days after application. Williams *et al.* (1987) measured diazinon residues in the air of an animal facility after periodic crack and crevice applications of a 1.0% solution and concluded that diazinon levels fell quickly to $<0.5 \text{ ug/m}^3$, well below the TLV-TWA and TLV-STEL¹. Leidy *et al.* (1984) measured diazinon levels in the air in treated and adjacent rooms for 35 days after crack and crevice application and found that none of the levels, except at day 0 and day 1 in treated rooms, were above the TLV-TWA.

Chlorpyrifos

Currie *et al.* (1990) compared chlorpyrifos residues in air for 10 days after broadcast application to offices with the TLV-TWA of chlorpyrifos (200 ug/m^3) and concluded that reentry into a room 1 day after treatment would be safe. Siddiqi and Braun (1985) found that chlorpyrifos residues in air for up to 6 days after broadcast and crack and crevice applications to apartments and residences were well below the TLV-TWA. Ware

1. Threshold Limit Value - Short-Term Exposure Limit, the concentration of a chemical substance to which workers can be exposed continuously for a short period of time without suffering adverse effects; defined as a 15 minute time-weighted average with limits on number of exposures per day

and Cahill (1978) found that the highest measured air level of chlorpyrifos in an unventilated room after broadcast application of a 0.5% emulsion was one eleventh of the TLV-TWA. Gold et al. (1981) found that the TLV-TWA was exceeded in 20% of the spray applications of a slow-release formulation of 2.0% chlorpyrifos to room perimeters, shelves and beneath appliances in homes. Wright and Leidy (1980) reported that the 4 hour time-weighted average chlorpyrifos levels in the air for up to 24 hours after crack and crevice application in food preparation areas were far below the TLV-TWA.

As part of a more complete risk assessment, Fenske (1992) found that at 24 hours after application, chlorpyrifos residues in adult and child breathing zones in ventilated and unventilated rooms all exceeded the guidelines of the National Academy of Science (10 ug/m^3). Naffziger et al. (1985) studied chlorpyrifos levels in air for 96 hours after broadcast application and concluded that because the levels dropped below the National Academy of Science guidelines by 24 hours after application, broadcast application could be used without undue risk to occupants.

Gibson (1992) reported on an unpublished study which monitored trichloropyridinol (a chlorpyrifos metabolite) excretion in adult test subjects simulating infant play for 4 hours on carpets treated by broadcast application of a 0.5%

chlorpyrifos emulsion (room ventilated for 2 hours after application by an air conditioning system). Total exposure was estimated to be 20 ug/kg/day. Comparing this dose to the repeated dose No Observable Effect Level (NOEL; effect: cholinesterase inhibition) of 30 ug/kg/day, Gibson concluded that exposure to chlorpyrifos under similar conditions would not lead to dosages above the NOEL for cholinesterase inhibition in humans. Fenske et al. (1990) estimated the total absorbed chlorpyrifos dose for infants on the first and second days after broadcast application of a 0.5% emulsion in ventilated and unventilated rooms. Estimates were based on 100% respiratory absorption and 3% dermal absorption. Calculated total absorbed doses on day 1 exceeded the NOEL (0.03 mg/kg/day) by 2.5 times in ventilated rooms and 5.3 times in unventilated rooms. On day 2 calculated total absorbed dose in a ventilated room exceeded the NOEL by 1.3 times and by 1.8 times in an unventilated room. They concluded that despite uncertainties in their model, their risk assessment raised a public health concern regarding broadcast application of chlorpyrifos in homes. Berteau et al. (1989) calculated a "worst case" dose for an infant exposed to chlorpyrifos after broadcast application although the calculations were limited by their lack of accurate dermal absorption data (100% dermal and respiratory absorption were assumed), little residue data and they did not consider chronic effects. They concluded that a potentially toxic dose

of 2.68 mg/kg might be absorbed in the first 24 hours by an infant.

Other Insecticides

Berteau *et al.* (1989) also calculated a worst case dose for an infant exposed to propoxur after broadcast application. The calculated dose (2.2 mg/kg in the first 24 hours of exposure) exceeded both the single dose effect level and the repeated dose effect level for propoxur. They suggested that there was a definite possibility for an adverse reaction in a very young child playing on a treated carpet. They also concluded that data on the relationship between exposure and changes in cholinesterase activity did not appear to be adequate to assure safe use of propoxur by broadcast application in households. Gold *et al.* (1984) found dichlorvos levels to be 54.8% of the TLV-TWA at 2 hours after application of a 0.5% solution to baseboards and 21.3% at 24 hours after application. Leidy *et al.* (1993) reviewed a number of North Carolina State University studies of residue levels of pesticides applied by broadcast or crack and crevice application indoors (including abamectin, acephate, bendiocarb, carbaryl, propoxur and resmethrin) and concluded that although very small quantities of the insecticides were detected, the maximum levels detected were usually far less than recommended threshold limit values (note that except for carbaryl, these insecticides do not have TLV's).

V. VENTILATION AND RESIDUES

A. Introduction

Regulators and applicators often suggest that a room treated with insecticides be "adequately" or "thoroughly" ventilated prior to reentry. The value of air movement through an area treated with residual insecticide in reducing air and surface residue levels under some conditions has been demonstrated. However, it is unclear what minimum amount or type of ventilation will produce the desired reduction in residue levels. Fenske et al. (1991) noted that in the published literature, the characterization of ventilation during and following insecticide applications has been limited to a description of the ventilation system or simply a statement that the windows and doors were open or closed. They believe that there is a need for more detailed studies of air exchange rates and the effects of specific ventilation recommendations on residues.

I conducted an experiment to determine the effect of ventilation rate on air residues of chlorpyrifos after indoor broadcast application.

B. Materials and Methods

Insecticide was applied by broadcast application to four classrooms of the same size (area of 66.32 m², volume of 188.21 m³). Each was furnished with typical student's desks,

teacher's desk, various shelves and cabinets and was fully carpeted with nylon carpet. Insecticide had never been applied in these classrooms.

Chlorpyrifos (Dursban L.O.[®]; DowElanco; Registration No. 19611 Pest Control Products Act) was applied as a water-based emulsion according to label directions for control of a heavy infestation of fleas or for extended residual control of fleas (0.48% dilution applied at 4 litres per 160 m²).

The emulsion was applied with a B&G compressed air sprayer (B&G Equipment Company, Plumsteadville, PA.) equipped with a tank pressure gauge. Insecticide was applied to the carpet as a fine, flat fan spray from a height of 30 cm. Tank pressure was maintained at 20 psi (138 kPa). Sprayer output was measured and the application timed to ensure that 1658 ml of emulsion (= 8 g chlorpyrifos) was applied to each room.

Immediately after the insecticide was applied each room was ventilated using an axial-type exhaust fan (Vent-Axia TX9WW, 230 mm diameter impeller) located at a height of 2.4 meters in an outside wall. Makeup air was drawn from two floor vents located at the opposite end of the room. Fan speed was controlled to provide 0, 2.48, 3.64 or 4.22 air changes per hour in the classrooms. Windows were closed during insecticide application and until completion of all sampling,

forced air furnaces were turned off and gaps around door frames were sealed to prevent air movement other than through the fan and makeup air vents.

Window blinds were closed and light levels in the classrooms averaged less than 5.0 lux during the experiment. Room temperature was recorded throughout the experiment.

Samples were collected by drawing air through Chromosorb 102 adsorbent tubes (Cat. No. 226-107, SKC Inc., Eighty-Four, PA.) with SKC Airchek Samplers (Model 224-PCXR7, SKC Inc.). Chromosorb 102 is an efficient adsorbent for trapping airborne chlorpyrifos (Leidy and Wright, 1991; Thomas and Nishioka, 1985; Roper and Wright, 1984). Flow rates were set before sampling and confirmed after sampling with a manual soap film calibrator or a SKC Accuflow Film Calibrator (Cat. No. 712, SKC Inc.). Flow rates ranged from 1.80 to 2.02 litres per minute. Sampling times ranged from 1 to 4 hours. Samples were collected in the center of each room at a height of 25 cm. Blind samples spiked with a known amount of chlorpyrifos (4 per replicate) and blank samples (2 per replicate) were prepared, and handled and analyzed in the same manner as the field samples. Spike samples were prepared from commercial chlorpyrifos concentrate (480 g/l) to simulate air residues equivalent to 10, 50, 80 and 100 $\mu\text{g}/\text{m}^3$.

After sampling, adsorbent tubes were capped and stored frozen or at 4°C until analysis. The sampling media was extracted with hexane and extracts analyzed by a high resolution gas chromatograph coupled to a nitrogen-phosphorus detector.

Two replicates of the experiment were conducted two months apart in the same classrooms. Carpets were shampooed prior to the second experiment to minimize the amount of residual insecticide remaining from the first experiment.

Results were analyzed using the statistical package StatView (version 4.01, 1992, Abacus Concepts).

C. Results and Discussion

Air residue levels of chlorpyrifos after application are shown in Figures 13 and 14. Residue levels ranged from 32.4 - 97.3 ug/m³ at 1 hour after application to 7.5 - 14.7 ug/m³ at 62 hours after application.

Data was analyzed using stepwise linear regression using the explanatory variables trial, ventilation rate, time and temperature as possible predictors of chlorpyrifos levels in air. In all rooms air residue levels declined with time after application ($r = -0.027$). An increase in air residue levels appears to have occurred in some rooms at about 8 hours after application but was not significant. Chlorpyrifos levels

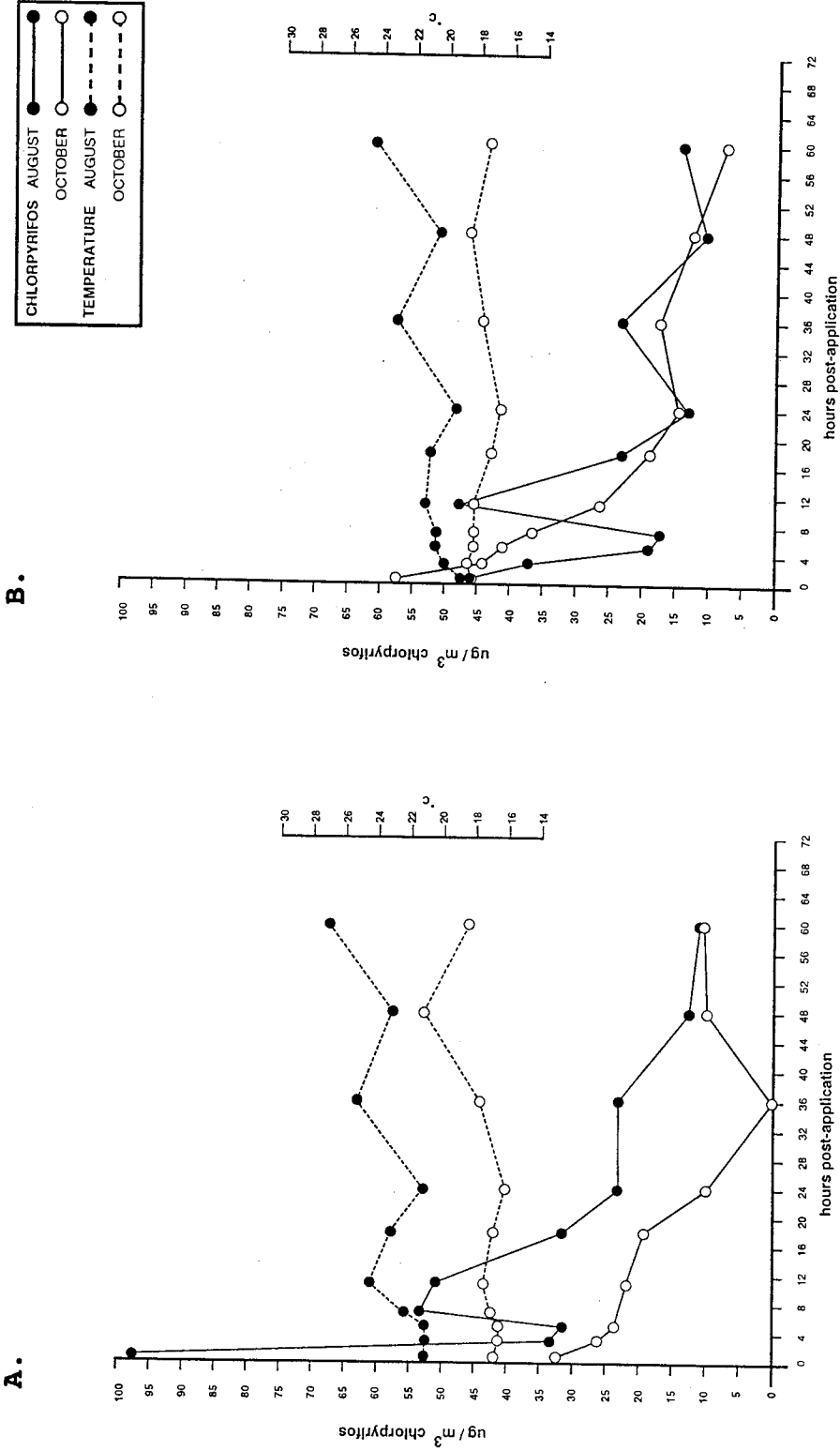
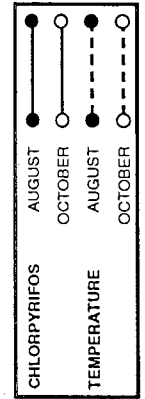
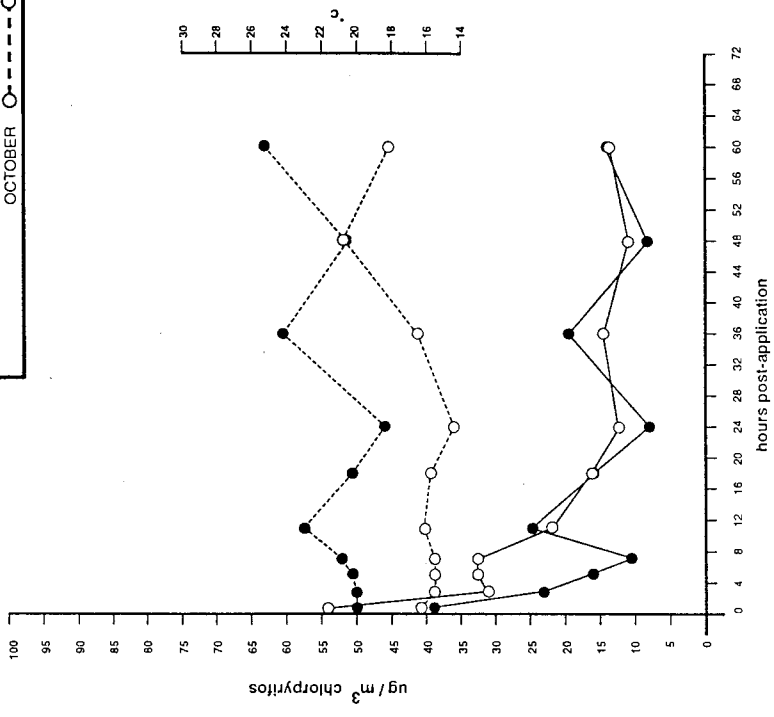


Figure 13. Chlorpyrifos residues in the air of classrooms after broadcast application (A. 0 air changes per hour B. 2.48 air changes per hour).



B.



A.

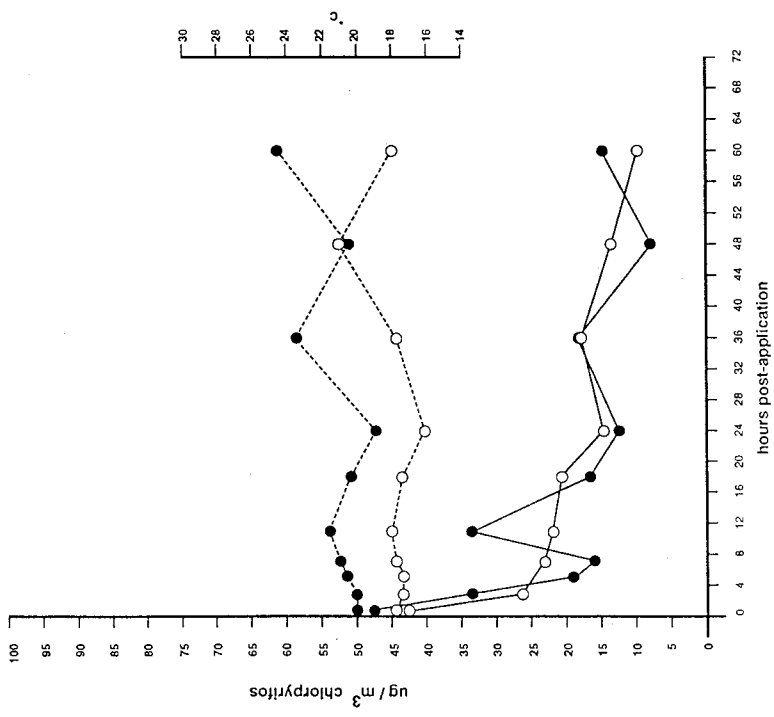


Figure 14. Chlorpyrifos residues in the air of classrooms after broadcast application (A. 3.64 air changes per hour B. 4.22 air changes per hour).

increased with room temperature ($r = 0.134$). Interactions between variables were not important predictors of chlorpyrifos concentration.

Increase in air exchange rate from 0 air changes per hour up to rates as high as 4.22 air changes per hour did not significantly decrease air residue levels. This rather surprising result lead to further investigation and characterization of airflow patterns in the rooms. Flow patterns were demonstrated using smoke from a mechanical smoke generator. In the rooms in which the general ventilation system was operating a clear pattern of "short-circuiting" was observed. Air quickly moved from the make-up air vents on the floor into an adult's breathing zone and toward the ceiling before moving toward the fan and being exhausted. However, air in a child's breathing zone (below 1.0 m) was slowly exhausted, if at all.

VI. DISCUSSION AND CONCLUSIONS

The pest manager or others who must recommend appropriate reentry times and practices for persons entering nonagricultural buildings after indoor application of pesticides is faced with a difficult task. Information from any authoritative source is generally lacking and what guidance does exist may not correspond with the scientific literature.

Reentry into nonagricultural buildings is weakly regulated in Canada. The Pest Control Products Act and Regulations currently do not normally require registrants of pesticides to routinely provide bystander exposure data as part of the registration package. Health Canada guidelines requiring such data have not yet been adopted and it is unclear how such data would actually be transmitted to those who would use it in the field. Labels on pesticides commonly used indoors list general reentry practices such as avoiding entry before treated surfaces have dried but do not provide specific reentry times or information on practices such as ventilation. Provincial legislation, which regulates how pesticides are used, does not address the question of reentry other than to require that pesticides be used "safely". The limited number of by-laws on pesticide use notification in force in Canada provide only general guidance on reentry times. The by-laws require that residents be provided with safety information

about the proposed pesticide application and that warning signs be posted for a given time. The posting periods are not reentry times and were not established on any scientific basis such as an actual assessment of risk to the occupants.

There are guidelines dealing with reentry in British Columbia and Ontario but the regulators responsible for these guidelines did not base the reentry times specified on scientific data. The British Columbia guideline of 6-8 hours in the absence of label recommendations and the Ontario guideline of 3-6 hours after cockroach cleanout operations are not supported by the experimental results. Air and surface residues at the recommended reentry times are often nearly as high as residue levels soon after application (see Figures 1 and 2, Table 7, etc.). Guidelines from the Workers' Compensation Board of British Columbia (1990) which are based on reentry into agricultural fields and acute LD₅₀ values are again not supported by the literature and would only be appropriate in a few situations.

Verbal recommendations made by regulatory agencies vary widely and often have no scientific basis. A disturbingly high number of public health agencies choose not to make even simple recommendations on reentry practices and refer the questions to others who are not qualified to assess health risks. Much of the verbal information that is offered by

public health agencies appears to have been drawn from pest control industry practices or is simply a "best guess" which incorporates some general safety advice based on common sense.

Many regulatory agencies refer reentry questions back to the applicator applying the pesticide. However, the structural pest control industry bases its own procedures on past practice, the origin of which has been lost, on the desire to generate business (a reentry time that keeps a person out of their residence for an unacceptably long period is not likely to lead to a sale) and on concerns regarding legal liability. The National Pest Control Association (1992) advises its members that "if you recommend beyond the label language, you take responsibility and assume liability". Reentry times typically recommended by the industry (Table 1) are not supported by scientific data and do not appear on product labels.

A major problem facing pest managers and others is that they are often required to advise on many levels of protection as a result of one pesticide application. Protection may be required for the applicator (short exposure time during any one application but potentially many exposures during a day of work) or for workers reentering a treated worksite (a wide variety of adults with exposure of 8 hours a day or more in which inhalation exposure is likely to be more important than

dermal exposure). Protection may also be required for residents of all ages reentering a residence (exposure of up to 24 hours per day; dermal exposure a significant route of exposure for some residents), for bystanders such as children in a classroom (up to 6 hours exposure per day), persons conducting business in public buildings and so on. The use of exposure limits such as Threshold Limit Values and the National Academy of Science guidelines are clearly inappropriate in many of these situations. The American Conference of Governmental Industrial Hygienists and the National Academy of Science have both stated that their exposure limits are applicable only in select situations and that the guidelines are for inhalation exposure only.

A further complication is the currently unanswered question of whether there is any health risk to any person reentering a building at any time after an application and exactly what the health risk is. While some researchers have conducted worst-case risk assessments based on residue data and concluded that at least some risk exists, the effect being considered in these studies is usually a decrease in blood cholinesterase activity. However, there is significant debate as to the value of using changes in cholinesterase activity as anything other than an indicator of pesticide exposure rather than a true adverse health effect (Brock and Brock, 1993; Wilson and Henderson, 1992).

Given this situation, I suggest that there are some practices which could be reasonably and effectively used to reduce overall exposure to pesticide residues at reentry:

Guidelines for the Applicator

1. **Prepare the insecticidal solution accurately to ensure that label requirements for active ingredient percentage are met.** There is a clear, direct relationship between amount of active ingredient in the formulated product and the air and surface residue levels (see Figure 8). Applicators must be provided with accurate measuring devices to ensure correct preparation. While the label for Dursban L.O.® provides simple dilution instructions, the instructions require that the applicator have a measuring device calibrated in millilitres. Some insecticide concentrates are now packaged to make preparation of correct dilutions a simple operation for the applicator. For example, an single 29.6 g envelope of Ficam Plus® concentrate is poured into 4 litres of water to prepare a 0.25% solution of bendiocarb. When possible, such pre-measured packages should be used.

2. **Handheld compressed air sprayers should be equipped with a pressure gauge and pressure in the tank should be monitored and controlled throughout an application.** The label for Dursban L.O. advises applicators to apply a "coarse, low

pressure (150 kPa or less) spray" as a crack and crevice treatment in food handling establishments. However, Rogers et al. (1973) observed spray patterns and drift from the industry-standard B&G handheld compressed air sprayer and recommended that the sprayer should not be operated at pressures above which the spray pattern was fully developed (about 68.9 - 137.9 kPa) to help prevent excessive runoff, splatter and drift. Applicators should maintain tank pressure at no greater than 138 kPa (20 psi). A regulator kit with pressure gauge is available as an option for all B&G compressed air sprayers.

3. Follow the application rates on the pesticide label carefully. A number of researchers have shown that the amount of active ingredient applied to an area directly affects air and surface residue levels and that during a typical broadcast or crack and crevice application applicators often apply sprays unevenly and without knowing the total volume of solution applied (e.g. Currie et al., 1990). While labels are quite specific on application rates (for example, Dursban L.O. is to be applied at a rate of 4 litres of diluted spray per 160 m² for broadcast application for control of fleas), structural pest control applicators seldom measure the actual output of their sprayers at various pressures and nozzle settings.

4. Where possible, use crack and crevice, baseboard-only or selective spot application rather than general broadcast application or total release aerosols. Broadcast application produces the highest surface residue levels and high air residue levels (Vaccaro, 1993; Fenske et al., 1991). Total release aerosols place insecticide residue in many areas where the target pest is not found or onto surfaces where dermal exposure is highly likely (counter and table tops, furniture, etc.) and should not be used by commercial applicators. Total release aerosols containing residual insecticides such as chlorpyrifos are currently not available to the public in Canada and Agriculture and Agri-Food Canada should not consider registering such products in the Domestic class.

5. Make applications on Friday evenings and do not allow reentry until Monday morning in those buildings which are unoccupied during the weekend. Eitzer (1991) demonstrated that after a Friday afternoon crack and crevice application of d-trans allethrin and pyrethrins, air residues declined to almost preapplication levels by Monday morning. Similar observations have recently been made after application of diazinon solutions in greenhouses (Lenhart and Kawamoto, 1994). This practice will be of less value in those buildings in which heating, ventilating and air conditioning systems are "set-back" for energy conservation overnight and during weekends.

6. Select the pesticide with the lowest mammalian toxicity and the formulation which produces the smallest amount of residue in air if there is an option. In general, pyrethroids have lower mammalian toxicity than carbamate and organophosphate insecticides. Wettable powder formulations appear to produce lower air residue levels than do emulsions. However, there has been little research and the relationship between formulation and residue level is not clear. Wright et al. (1981) reported that airborne concentrations of various insecticides applied by crack and crevice application to rooms were directly correlated with their saturated vapour pressure but a strong relationship was not evident from their data. Marshall and Roberts (1978) concluded that whereas the saturated vapour pressure of chlorpyrifos was reported to be low, a more important indicator of the ability of a pesticide to volatilize from a water solution may be its air-to-water partition coefficient. Bailey (1992) identified microencapsulation of liquid pesticides as a recent formulation trend likely to enhance environmental health protection. Microencapsulated formulations of chlorpyrifos (Duratrol®) and synergised pyrethrins (Sectrol®) are registered in Canada for long-term (up to 90 days) control of fleas in buildings.

Guidelines for the Bystander

1. **Direct skin contact with treated surfaces should be minimized.** For children in particular, dermal absorption and hand-to-mouth transfer are often the major routes of exposure to insecticide residues indoors (Fenske, 1992; Vaccaro, 1990). Children and others could be clothed to prevent direct skin contact with treated surfaces. Blankets could be placed over treated surfaces to prevent very young children from crawling directly on treated floors. If a person wishes to remove pesticide residues from specific surfaces, standard rug shampoo and floor cleaning materials have been shown to reduce surface residues available by wipe sampling (Naffziger *et al.*, 1985).

2. **There should be minimum reentry times for treated areas.** The literature on the decay of residues indicates that reentry times proposed by some regulators and the structural pest control industry allow people back into a treated room before air and surface residues have declined significantly. However more research is needed (for example, dermal transfer factors, dislodgeable residue dissipation curves) before meaningful reentry times could be specified and justified and that would assure safety after application of a particular insecticide under a particular set of circumstances. Reentry models for agricultural workers in contact with pesticide-treated foliage

have been developed (Van Hemmen, 1993; Dong et al., 1992) and indicate the information that regulators and manufacturers will need before they can design models to calculate appropriate reentry times. Until such models are developed I recommend the following times and practices for reentry:

- The time between application and reentry should be as long as practically possible.

- At the very least, a room should not be reentered until the treated surfaces are dry. Vaccaro (1993) reported that it took at least 3 hours for carpets in a room at 50% relative humidity to dry after broadcast application at the recommended rate with a chlorpyrifos emulsion.

- Effective dilution ventilation should be used to reduce air residues and to speed surface drying. Dilution ventilation is the dilution of contaminated air with uncontaminated air to control airborne health hazards (American Conference of Governmental Industrial Hygienists, 1992). Opening doors and windows may or may not provide effective ventilation of a treated room but if no other method is available then doors and windows should be opened during and after application. Because stratification of airborne residues occurs, as my experiment indicated, even some built-in mechanical ventilation systems may not be effective in ventilating a room. Therefore, any ventilation arrangement that mixes room air, especially in a child's breathing zone, should be used. A simple household fan could be used to mix air at the floor

level. Fenske (1992) recommended continually ventilating treated areas with a fan directed out of open windows or doors for at least 4 hours after application and intermittently for up to 24-48 hours after the application.

3. Bystanders should be advised that insecticides applied in a room will move into adjacent untreated rooms. Air residues (Leidy et al., 1993; Leidy et al., 1982) and surface residues (Leidy et al., 1987) of insecticides have been regularly detected in areas distant from treated rooms. Insecticides may be forced through cracks and crevices during application or move in air currents. In some cases there may be a significant lag between an application and the appearance of maximum residue levels in these untreated areas. Leidy et al. (1984) found maximum air residues in rooms above, below and beside treated rooms 3 days after application. Although the residue levels detected in these untreated rooms are lower (approximately one tenth the level) than levels in treated rooms, bystanders should ensure that rooms adjacent to treated rooms (and perhaps the entire house in the case of a residence) are effectively ventilated.

The current British Columbia Ministries of Health and Environment, Lands and Parks guidelines for reentering buildings treated with insecticides should be revised to

reflect this information. Current training for structural pesticide applicators, at least in British Columbia, does not adequately stress the importance of issues such as proper mixing and sprayer output measurement. My recommendations should also be incorporated into the new structural pest control certification course material being developed by the British Columbia Ministry of Environment, Lands and Parks.

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