2.0 PESTICIDE USE PATTERNS

Very limited data are available to EPA researchers on what pesticides are currently being used in non-occupational environments, where they are being used, and the frequency of use. The EPA has not conducted a large scale survey to collect data on pesticide use patterns in the U.S. since 1990, but use patterns are believed to have substantially changed since that time. The children's observational studies described in this report collected information on household pesticide use as ancillary information that could be used to address this serious data gap. Despite the limited coverage of geographic regions, a relatively small number of study participants, and the general lack of knowledge about the active ingredients in brand name products on the part of consumers, valuable information was obtained. The NERL studies described in this section covered a period from 1997 to 2001. The indoor residential use of chlorpyrifos was cancelled while data collection was still ongoing in several studies (JAX, CCC, and CTEPP).

The pesticides available to consumers or professionals for use in residential settings have changed over time. By the late 1980s the use of most organochlorine pesticides (*e.g.*, DDT, chlordane, dieldrin, and heptachlor) was severely restricted in the U.S. The organophosphate (OP) insecticides (*e.g.*, malathion, chlorpyrifos, and diazinon), appealing for their high insect toxicity, low costs, and low likelihood of pest resistance, quickly filled the void and became the pesticides of choice for both consumers and professional pest control operators (Karalliedde *et al.*, 2001). The popularity of pyrethroid insecticides increased throughout the 1990s because of the following favorable properties: higher insecticidal toxicity, lower mammalian toxicity, and more rapid environmental degradation (Baker *et al.*, 2004). Passage of the Food Quality Protection Act of 1996 led the EPA to consider aggregate childhood pesticide exposure. The OPs were the first class of pesticides whose tolerances were reassessed, leading to withdrawal of the registrations for indoor applications of chlorpyrifos and diazinon in 2001 and 2002, respectively, because of concern regarding the risk to children. Consequently, pyrethroids have become the leading residential insecticides. While household use of diazinon and chlorpyrifos is now restricted, these and other OPs are still widely used in agriculture, and some structural uses for chlorpyrifos, including the treatment of house foundations, are still approved.

2.1 Sources of Information

Important sources of information on pesticide use patterns in non-occupational environments include Market Estimates from EPA's Office of Pesticide Programs (US EPA, 2004), national pesticide usage surveys, the Residential Exposure Joint Venture (REJV), the National Health and Nutrition Examination Survey (NHANES), and published scientific literature.

The Office of Pesticide Programs uses proprietary data sources in producing "Market Estimates" of pesticide sales and use in various market sectors. According to their estimates, the annual amount of insecticide active ingredients used in the home and garden sector declined from 24 million pounds in 1982, to less than 13 million pounds in 1988. Although the figure rose to 17 million pounds between 1998 and 2001, it still represents a significant decline from the early 1980s. In contrast, the amount of herbicides applied steadily increased over the same period, nearly doubling from 37 million pounds in 1982 to 71 million pounds in 2001 (US EPA, 2004) as lawn coverage increased. In 2001, insecticides comprised nearly 60% and herbicides nearly 30% of the home and garden sector expenditures (US EPA, 2004).

The REJV is a program administered by eight pesticide registrants and is designed to provide home pesticide usage information critical for risk assessments on individual active ingredients as well as aggregate and cumulative risk assessments. Pesticide use by over 100,000 households in nine regions of the U.S. is recorded, with a year-long monthly diary of all residential pesticide applications in more than 4000 households. EPA expects to use the results of this comprehensive pesticide use survey to refine or replace many of its residential exposure default assumptions. Access to REJV results is restricted as confidential business information, thus only very limited data are publicly available.

Results from two other national surveys are available: the National Household Pesticide Usage Study (US EPA, 1980; Savage *et al.*, 1981) and the National Home and Garden Pesticide Use Survey (US EPA 1992). The National Household Pesticide Usage Study (1976-1977) found that 91% of the more than 8200 households surveyed reported using pesticides in their home, garden, or yard. According to the slightly more recent National Home and Garden Pesticide Use Survey (1990), 75% of American households reported using insecticides. These surveys, it should be noted, are old and the results are not considered relevant to current pesticide use patterns.

NHANES is an ongoing assessment of the exposure of the U.S. population to environmental chemicals. Beginning with the 1999-2000 cycle, the interview included, at the request of EPA, questions on pesticide applications performed in the past month. According to the most recent survey (2001-2002), 18% of households used insecticides inside the home within the past month, nearly 40% of which were professional treatments. Of households with private yards, 20% reported pesticide applications in the yard during the month, roughly 36% of which were professional treatments. NHANES does not report results by region or by season.

Studies in the open literature can also help to identify pesticide use patterns. Davis *et al*. (1992), Bass *et al*. (2001), Curwin *et al*. (2002), Freeman *et al*. (2004), and Carlton *et al*. (2004) address pesticide use patterns in various geographic locations within the U.S., including Missouri, Arizona, Iowa, Texas, and New York.

A study conducted in Missouri from June 1989 to March 1990 using telephone interviews (Davis *et al*., 1992) examined pesticide use in the home, garden, and yard. Nearly all 238 families (98%) used pesticides at least one time per year, and two-thirds used pesticides more than five times per year. Pesticides were most commonly used inside the home (80%), followed by in the yard (57%). Flea collars were the most popular pest control product (50%). Diazinon and carbaryl were identified as the two most commonly used active ingredients at that time.

The community-based survey conducted by Bass *et al.* (2001) in Douglas, Arizona in 1999 identified pesticides used in the home, use and storage locations, and disposal methods. All (100%) of the 107 randomly chosen study participants reported using pesticides in the six months prior to the survey, although only 75% reported pest problems. Over 30% used a professional exterminator. A total of 148 pesticide products, representing more than 50 unique active ingredients, were catalogued (1.4 products per home). The synergist piperonyl butoxide

(34%) was most common, followed by pyrethrins (24%), permethrin (18%), allethrin (17%), diazinon (16%), and boric acid (13%). The majority of the pesticides were stored inside the house (70%), typically in the kitchen (45%).

Curwin *et al.* (2002) investigated the differences in pesticide use for 25 farm homes and 25 non-farm homes in Iowa. The target pesticides included atrazine, metolachlor, acetochlor, alachlor, 2,4-D, glyphosate, and chlorpyrifos. Among the non-farm households, 84% used pesticides in their homes or on their lawns or gardens. Only 17% of reported residential pesticide use was by commercial application.

Freeman *et al.* (2004) examined pesticide use patterns during the summer 2000 and winter 2000-2001 seasons among families with very young children in a Texas border community. Pesticide use inside the home showed seasonal variation (82% of homes treated in summer versus 63% in winter). The primary room treated was the kitchen, and the primary structures treated were the floors, lower walls, and dish cupboards. The pesticides used were typically pyrethroid formulations. For nearly all of the pesticides analyzed, no differences were found in pesticide levels in house dust based on family reports of pesticide use in the home or yard.

Carlton *et al.* (2004) surveyed stores in New York City, NY in mid-2003 to determine whether the phase-out of chlorpyrifos and diazinon had been effective and what alternative pesticides were available. The authors found the phase-out to be more effective for chlorpyrifos than for diazinon. The summer after chlorpyrifos sales were to have ended, chlorpyrifos-containing products were found in only 4% of stores that sold pesticides; however, after diazinon sales were to have ended, 18% of stores surveyed, including 80% of supermarkets, still stocked diazinon-containing products. Lower toxicity pesticides, including gels, bait stations, and boric acid, were available in only 69% of the stores and were typically more expensive.

The children's exposure research program collected pesticide use information from homes and daycare centers in the MNCPES, JAX, CTEPP, CCC, and Daycare studies. Information on collection methods is available in Table 2.1. In the context of this report, pesticide use patterns include application frequency, locations, types, methods and active ingredients, as well as pesticides identified in inventories and detected in screenings. The following are highlights of the data collected on pesticide use patterns in these studies. A thorough discussion of MNCPES storage and use patterns is found in Adgate *et al.* (2000).

Table 2.1 Pesticides use information collection methods.

Study	Year	Setting	Inventory	Questionnaire	Screening Wipes
MNCPES	1997	Residence	Brand name, type, EPA registration number, use in past year.	Baseline usage (past year) by participant recollection. Recent use (past week and during monitoring period).	No
CTEPP	2000-2001	Residence and Daycare Center	None	Baseline usage (ever) of insecticides, herbicides, fungicides, or shampoos. Recent use (past week) of any pesticide.	No
CCC	2001	Daycare Center	None	Usage frequency (categories) and locations for specific active ingredients. Questionnaire administered to Center Director or professional applicator.	Yes
JAX	2001	Residence	Brand name, type, EPA registration number. Use in past 6 months, use frequency, use location, and targeted pest noted for each product.	Usage frequency (categories), locations, application methods, and anticipated future use.	Yes
Daycare	2000	Daycare Center	None	Specific active ingredient verified by professional applicator.	Yes

2.2 Application Frequency

The frequency of pesticide application, typically over the past month or year, is generally gathered through questionnaires. Although there is little supporting empirical evidence, it is believed that the frequency of application, along with the form and chemical properties of the pesticide, is an important determinant of indoor air and surface concentrations. It is assumed that residue levels within a residence will rise with increasing pesticide application frequency. Conversely, infrequent pesticide application is assumed to decrease the likelihood of measuring pesticide residues. Arguably, the more frequently pesticide applications occur, the more likely the occupant is to have contact with pesticide residue.

- As presented in Table 2.2, about 20% of study participants in Jacksonville, FL (JAX) reported using pesticides in the past seven days (August to October 2001) compared to 14% in CTEPP-NC (July 2000 to March 2001), 13% in CTEPP-OH (April to November 2001), and only 10% in Minnesota (MNCPES) (May to August 1997). This provides some evidence of a pattern of higher application frequencies in warmer climates. The North Carolina study was the only one to include winter months; the percentage would likely be higher if winter months were excluded.
- About the same proportion (unweighted) of participants that used pesticides in the past month (or planned to use them in the next month) in JAX (51%), used them in the past six months in MNCPES (52%). The percentage of JAX participants is substantially higher than 18-23% reporting insecticide use in the past month in NHANES (Table 2.2).
- Differences according to geographical region become more evident in the CTEPP studies (Table 2.3) when focusing on insecticides and rodenticides, as 74% of the participants in warmer climate North Carolina reported using insecticides or rodenticides compared to only 51% in colder climate Ohio.
- In Minnesota (MNCPES), 88% of the participants used pesticides in the past year, slightly more than the 84% reported by Curwin *et al.* (2002) in Iowa but less than the 98% reported by Davis *et al*. (1992) in Missouri and the 100% reported by Bass *et al.* (2001) in Arizona.
- In the CCC study, 74% of the facilities reported application of pesticides in the last year (63% reported interior and 42% reported exterior applications), and 7% were unsure if any application occurred. Up to 107 pesticide applications per year were reported.
- About a third of the interior and a quarter of the exterior applications in the nationwide CCC study were performed on a monthly basis. In the Daycare study, monthly or more frequent pesticide applications were anecdotally found to be standard practice in the Raleigh-Durham area of North Carolina.

Table 2.2 Proportion (unweighted) of participants reporting pesticide use by study. NHANES participant responses are included for comparison.

Study	Use within the past seven days	Use within the past one month	Use within the past six months
CTEPP-NC	14%	-- [a]	--
CTEPP-OH	13%	--	--
JAX	20%	51%	--
MNCPES	10% [b]	--	52%
NHANES 99-00	--	23% [c]	--
NHANES 01-02	--	18% [c]	--

[a] Information not available
[b] Recruited households
[c] Restricted to use inside of home

Table 2.3 The proportion of CTEPP participants reporting use of four types of pesticides.

Type of Pesticide	North Carolina	Ohio
Herbicides	38%	50%
Insecticides / Rodenticides	74%	51%
Fungicides	6%	4%
Shampoos / Lotions	8%	9%

2.3 Application Locations

Although applied pesticides are redistributed throughout a home following an application, a concentration gradient exists with higher concentrations in the application room and lower concentrations in more distant rooms (Stout and Mason, 2003). Since residential applications may be performed by someone other than the occupant (*e.g.*, professional pest control service, gardener, lawn service, or property management), the occupant may not know which locations were treated.

- In JAX, 58% reported treating all rooms in the home, and 15% reported treating just the kitchen.
- The most commonly treated room in the CCC study was the kitchen (62%), followed by the bathroom (52%) (Figure 2.1). All rooms were treated in 23% of the centers.
- Areas treated by professional crack and crevice applications in CPPAES represented 93% of the homes' living areas.

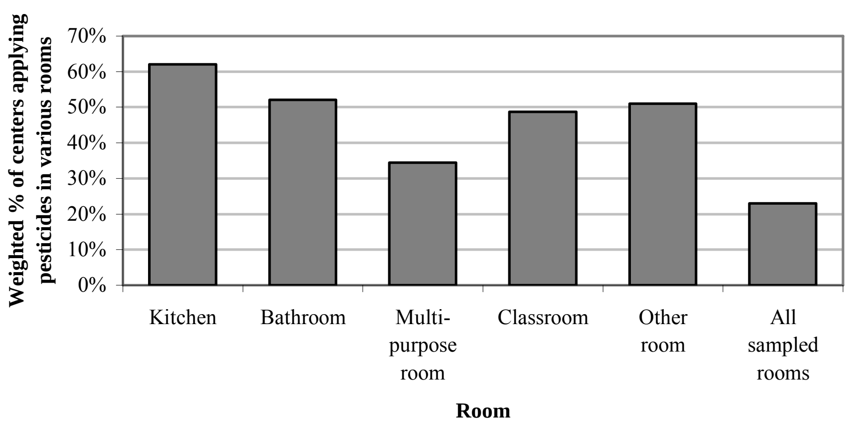

Figure 2.1 Weighted percentage of child care centers reporting treatment of various rooms in the Child Care Centers (CCC) study.

2.4 Application Types and Methods

The three common *types* of pesticide applications in the non-occupational environment are broadcast, total release aerosol, and crack-and-crevice. A broadcast application spreads insecticide onto broad surfaces, typically large sections of walls, floors, ceilings, or in and around trash containers (Rust *et al*., 1995). Total release aerosols, also known as "foggers" or "bug bombs," contain propellants that release their contents at once to fumigate a large area. Alternatively, a crack-and-crevice application is the application of small amounts of insecticide into areas where pests typically harbor or enter a building. Cracks and crevices are commonly found between cabinets and walls, at expansion joints, and between equipment and floors (Rust *et al*., 1995). Crack and crevice type applications, which usually produce lower airborne concentrations and surface loadings than broadcast or total release type applications, are favored by professional pest control services.

Method of pesticide application (as differentiated from "type" of application) refers to the equipment or product form used, and may include aerosol sprayer, hand pump sprayer, hose end sprayer, spritz sprayer, hand trigger sprayer, liquid, fogger, gel, granules/dust/powder/pellets, lotion, shampoo, bait station/trap, candle/coil, fly strip, pet collar, and spot-on pet treatment.

- Only very limited information on application type and method was collected in any of the field study questionnaires.
- In CCC, 36% of the interior applications were reported by the center directors as crack and crevice, and only 2% were reported as broadcast. In the Daycare study, all observed pesticide applications were crack and crevice.
- The most common application methods reported in JAX were as follows: 37% hand pump sprayer, 24% aerosol can, 3% fogger, and 3% bait.
- Applications in JAX were more likely to be performed by the respondent or respondent's family member (41%) than by a professional service (35%). These results are similar to NHANES 01-02, where 66% of the survey respondents reported non-professional treatments compared to professional treatments that were reported by 40% of the respondents. These results are also similar to the survey by Bass *et al.* (2001) in Douglas, Arizona, where 30% used professional services.

2.5 Pesticides Identified in Inventories, Records and Wipe Samples

- Pesticide products were found in 86% of the 36 homes inventoried in the JAX study (Table 2.4), with up to three products per household. Pyrethroids were the most common active ingredient (67% of homes), primarily cypermethrin (25%) and allethrin (12%), followed by imiprothrin, pyrethrins, and tralomethrin (all 14%). Only one organophosphate insecticide (diazinon) and one insect repellent (DEET) were found.
- The most commonly inventoried pyrethroids in JAX (Table 2.4) corresponded well with commonly reported pyrethroids in the Residential Exposure Joint Venture (Table 2.5).
- Cataloguing of pesticides in the CCC study (Table 2.6) gave results similar to JAX, with pyrethroid products most commonly identified (second only to products with unknown

active ingredients).

- The finding of 145 application events (Table 2.6) with unidentified active ingredients in the CCC study suggests that tracking of pesticide use in and around daycare facilities may require improved recordkeeping.
- As reported in Adgate *et al*. (2000), pesticide products were found in 97% (weighted) of the MNCPES households. The weighted mean number of pesticide products used per household was 3.1. Participants reported that fewer than 25% of the pesticides inventoried in their homes were used during the past year.
- In MNCPES, DEET-containing products were used in 47% of the homes during the last year (Table 2.7).
- Repellents, pyrethrins and pyrethroids, organophosphates, chlorophenoxy herbicides, and carbamates were present in more than 20% of the MNCPES households (Table 2.7).
- In the Daycare study, professional pest control services applied pyrethroid or pyrethrin pesticides in six of the eight facilities (data not presented). Esfenvalerate was applied in two facilities while cyhalothrin, pyrethrins, cypermethrin, and tralomethrins were each used in one.
- Cypermethrin, *cis*-permethrin, and *trans*-permethrin were <u>detected</u> in over 80% of the surface wipe samples collected in 46 homes in JAX (Table 2.8), consistent with the pesticide inventories. Chlorpyrifos and diazinon, although not identified in the inventories, were present in 89% and 91%, respectively, of the surface wipe samples.
- Permethrin and cypermethrin were the most frequently detected pyrethroid pesticides in both JAX (homes) and CCC (childcare centers) (Table 2.8). Chlorpyrifos and diazinon were the most frequently detected OPs, at frequencies comparable to permethrin.
- As of 2001, the synthetic pyrethroids appeared to be the most frequently used insecticides for indoor applications in homes and child care centers. It is anticipated that their use has become even more common since the cancellation of indoor use registrations of chlorpyrifos (2001) and diazinon (2002).

2.6 Demographic Factors Influencing Applications

- As reported by Adgate *et al.*, (2000), there were no statistically significant differences in the weighted total number of products found or reportedly used in MNCPES based on either population density (urban versus non-urban households) or other socio-demographic factors including race, ethnicity, home type, income, and level of education.
- Chi square analysis of CTEPP data (not presented) found no association between having applied pesticides within the past week and either income class or urban/rural status.

Table 2.4 Pesticides inventoried in 36 households in Jacksonville, FL (JAX) in fall 2001.

Active Ingredient	Pesticide Class	Number of Homes Where Found (% of Homes)
Cypermethrin	Pyrethrins/Pyrethroids	9 (25%)
Allethrin	Pyrethrins/Pyrethroids	8 (22%)
Pyrethrins	Pyrethrins/Pyrethroids	5 (14%)
Imiprothrin	Pyrethrins/Pyrethroids	5 (14%)
Tralomethrin	Pyrethrins/Pyrethroids	5 (14%)
MGK 264 [a]	Synergist	4 (11%)
Permethrin	Pyrethrins/Pyrethroids	4 (11%)
Fipronil	Phenylpyrazole	4 (11%)
Piperonyl butoxide	Synergist	4 (11%)
Hydramethylnon	Aminohydrazone	3 (8%)
Tetramethrin	Pyrethrins/Pyrethroids	3 (8%)
Cyfluthrin	Pyrethrins/Pyrethroids	2 (6%)
Esfenvalerate	Pyrethrins/Pyrethroids	2 (6%)
Prallethrin	Pyrethrins/Pyrethroids	2 (6%)
Bifenthrin	Pyrethrins/Pyrethroids	1 (6%)
DEET	Repellent	1 (6%)
Diazinon	Organophosphate	1 (6%)

[a] N-octyl bicycloheptene dicarboximide

Table 2.5 Most commonly applied pyrethroids in 1217 households with complete 12 month REJV survey data, as reported by Ozkaynak (2005).

Pyrethroid Pesticide	Number of Homes Where Applied (% of Homes)
Permethrin	518 (43%)
Pyrethrins	472 (39%)
Piperonyl Butoxide	461 (38%)
Allethrin	437 (36%)
Tetramethrin	342 (28%)
Phenothrin	293 (24%)
Tralomethrin	279 (23%)
Cypermethrin	163 (13%)
Resmethrin	106 (9%)
Bifenthrin	99 (8%)
Cyfluthrin	46 (4%)
Fenvalerate	37 (3%)
Esfenvalerate	25 (2%)
Deltamethrin	22 (2%)
Prallethrin	13 (1%)
Cyhalothrin	4 (<1%)

Table 2.6 Number of pesticide products applied during one year (2001) in 168 child care centers (CCC), as reported by the center directors and/or professional applicators.

Pesticide Class or Type	Number of Products Applied in Past Year (Unweighted % of All Products)
Unknown	145 (39%)
Pyrethroids	93 (25%)
Phenyl pyrazole or unclassified insecticide	44 (12%)
Pesticide mix	22 (6%)
Fungicide/insecticide	20 (5%)
Organophosphate	10 (3%)
Glueboard/Mouse traps	7 (2%)
Carbamates	6 (2%)
Juvenile hormone mimic insecticide	6 (2%)
Coumarin rodenticides	5 (1%)
Herbicides	3 (1%)
Insecticides	3 (1%)
Unclassified acaricide	3 (1%)
Unclassified insecticide	3 (1%)
Biopesticides	2 (1%)
Pheromone	1 (<1%)
Phosphoramidothioate acaricide	1 (<1%)
Rodenticides	1 (<1%)

Table 2.7 Pesticides inventoried and used in 308 households in Minnesota (MNCPES) in summer 1997 (adapted from Adgate *et al.*, 2000).

Active Ingredient	Pesticide Class	Homes Where Found (Weighted Percent)	Homes Where Used in the Past Year (Weighted Percent)
DEET	Repellent	196 (58%)	162 (47%)
Piperonyl butoxide	Synergist	152 (45%)	91 (25%)
Pyrethrins	Pyrethrins/Pyrethroids	147 (43%)	88 (25%)
MCPA	Chlorphenoxy herbicide	107 (35%)	55 (17%)
Permethrin	Pyrethrins/Pyrethroids	93 (35%)	65 (15%)
Chlorpyrifos	Organophosphate	89 (29%)	55 (17%)
Propoxur	Carbamate	84 (25%)	53 (17%)
MGK 264 [a]	Synergist	83 (25%)	43 (12%)
Allethrin	Pyrethrins/Pyrethroids	81 (24%)	49 (13%)
2,4-D	Chlorphenoxy herbicide	74 (23%)	37 (11%)
Diazinon	Organophosphate	65 (18%)	37 (11%)
Glyphosoate	Aminophosphate	62 (18%)	37 (12%)
Tetramethrin	Pyrethrins/Pyrethroids	62 (18%)	32 (8.5%)
Resmethrin	Pyrethrins/Pyrethroids	60 (20%)	24 (8.1%)
Carbaryl	Carbamate	50 (14%)	24 (5.4%)

[a] N-octyl bicycloheptene dicarboximide

Table 2.8 Detection frequencies of target analytes in soil and wipe samples in the CCC study (weighted) and in screening wipe samples collected in JAX (unweighted).

Compound	CCC			JAX
	% Detect in Soil Samples	% Detect in Floor Wipes	% Detect in Surface Wipes	% Detect in Surface Wipes
PYRETHROIDS				
cis-Allethrin	5	2	0	22
trans-Allethrin	5	2	0	22
Bifenthrin	14	5	4	20
Cyfluthrin	7	7	1	20
lambda-Cyhalothrin	6	7	5	9
Cypermethrin	8	23	9	80
Delta/Tralomethrin	5	2	0	15
Esfenvalerate	9	6	0	30
cis-Permethrin	12	63	48	89
trans-Permethrin	15	64	64	87
Resmethrin	5	3	6	0
Sumithrin	5	2	1	4
Tetramethrin	5	2	0	13
ORGANOPHOSPHATES				
Acephate	50	3	0	7
Azinphos methyl	15	1	0	2
Chlorpyrifos	21	67	76	89
Chlorpyrifos oxon	11	1	1	0
Demeton S	11	0	0	0
Diazinon	19	53	43	91
Diazinon oxon	13	17	8	17
Dichlorvos	11	0	0	2
Dimethoate	11	1	0	0
Disulfoton	11	0	0	0
Ethion	11	1	0	2
Ethyl parathion	11	1	0	0
Fonofos	12	0	0	0
Malathion	12	18	5	20
Malathion oxon	11	0	0	0
Methamidophos	11	2	1	0
Methidathion	11	1	1	0
Methyl parathion	11	0	0	0
cis-Mevinphos	11	21	7	7
trans-Mevinphos	11	5	0	4
Naled	11	0	0	0
Phosmet	11	2	0	4
OTHER PRODUCTS				
Fipronil	11	8	10	7
Piperonyl butoxide	12	23	11	50