CHAPTER 2

LITERATURE REVIEWS

2.1 Definition

Pesticides, a very broad definition, are chemicals that are used to control pests, such as insects, rats, weeds and moulds. In most cases, these chemicals are poisons and kill pests, but in some cases they act as a repellent, or they stop the pest from growing and reproducing.

2.2 Background of synthetic pyrethroids

Pyrethroids were manufactured in the 1970's after the removal of organochlorine, organophosphorus and carbamate insecticides from the consumer market. Formulations that are commercially available include aerosols, dips, emulsifiable concentrates, wettable powders, granules, and concentrates for ultra low volume applications targeting mosquitoes. The commercially synthetic pyrethroids that have been common used include permethrin, cypermethrin, fenvalerate and deltamethrin (Heudorf et al., 2006).

Synthetic pyrethroids are synthesized derivatives of naturally occuring pyrethrins, which are taken from pyrethrum, its extracts from *Chrysanthemum* flower having insecticidal activity (Elliot. 1976). The insecticidal properties of pyrethrins are derived from ketoalcoholic esters of chrysanthemic and pyrethroic acids, the structure shown in Table 2.1. These acids are strongly liphophilic and rapidly penetrate many insects and paralyze their nervous system (Reigart et al, 1999). Elliot(1976) also reported that synthetic pyrethroids provide a quick knockdown of insects at low dose, relatively low mammalian toxicity and improved stability in outdoor environments. However, they were unstable and broke down rapidly upon exposure to air and sunlight.

All pyrethroids contain several common features: an acid moiety, a central ester bond, and an alcohol moiety. The acid moiety contains two chiral carbons and a total of eight different stereoenantiomer (Lui et al., 2005, Shafer et al., 2005). Due to a complex chemical structure the individual pyrethroid substances are often composed of two, four, or eight isomers and their commercially manufactured products routinely contain a mixture of these various isomers. Thus, the production of individual pyrethroids with slightly varying isomeric ratios can often be the reason for the differences in the reported toxicities of the same compound. Some pyrethroids are mixed with piperonyl butoxide, a synergist, which increase the effect of the active ingredient (Amweg, 2006).

Table 2.1 Historical of synthetic pyrethroid insecticides

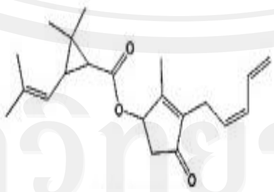
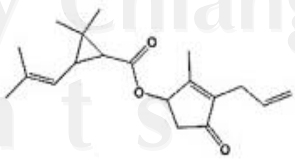
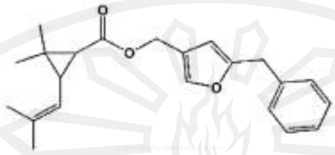
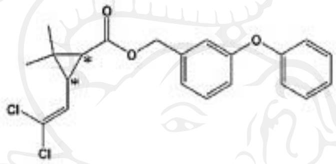
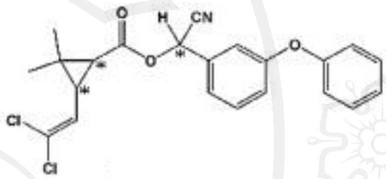
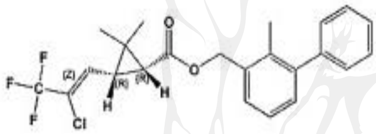
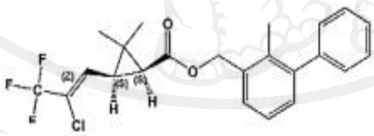
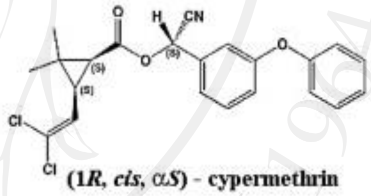
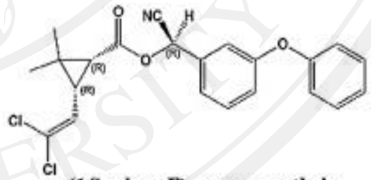
	Type I	Type II
Natural compounds	 pyrethrin	
1st synthetic analogs	 allethrin	

Table 2.1 Historical of synthetic pyrethroid insecticides (Continue)

	Type I	Type II
2nd aromatic alchols	 remethrin	
3rd halogenation and α-cyano addition	 permethrin	 cypermethrin
4th isomeric enrichment	 (1*R*, 3*R*) - bifenthrin  (1*S*, 3*S*) - bifenthrin	 (1*R*, *cis*, α*S*) - cypermethrin  (1*S*, *cis*, α*R*) - cypermethrin

For a breakdown of the Synthetic pyrethroid insecticide is degraded faster than the chemical insecticide organochlorine. The substance decomposes quickly when it was light. In plants, the breakdown in the range of 4-28 days for the water in the range of 20-50 days and in sediment in the range of 50-90 days is shown in Table 2.2.

Table 2.2 Breakdown of synthetic pyrethroid insecticide in vegetation, water, and sediment

Synthetic pyrethroid insecticide	vegetation (days)	Water (days)	Sediment (days)
Lambda cyhalothrin	9	7	28-44
Permethrin	10	51-71	5-42
Cyfluthrin	14	4	13.5-23.8
Cypermethrin	4-12	>50	<14
Fenvalerate	14-28	21	15-90
Deltamethrin	5.9-17	2	31-36

2.3 Toxicity of synthetic pyrethroids

The individual pyrethroids are typically grouped into two general classes, called Type I and Type II, based on a combination of toxicological and physical properties. The pyrethroid toxic action is similar in both insects and mammals. The toxicity is depending on dosing of vehicle used, the environment condition, the strain and sex, and dietary status. Toxic action takes place at the nervous system but there are some differences in the mode of action depending on their compound. Type I pyrethroids are non-α-cyano compounds while type II pyrethroids contain α-cyano compound (Perry et al., 1998). Pyrethroids with an α-cyano group can also assume different isomeric configuration based on the spatial orientation of this group. The isomer contents of pyrethroids are important since different isomer ratio having different toxicity. For the chrysanthemic acid, the ester of cis- isomer is more toxic than those of the trans-isomer. In elimination step, the *trans*- isomer is much faster than the *cis*- isomer. Insects have slowly rate of metabolite than mammals therefore they are more adversely affected with about 6 hours. In human, pyrethroids are rapidly metabolized by esterase, mainly in the liver and half-life is about 6 hours (Leng., 1996; Heudrof et al., 2001).

The acute toxicity of pyrethroid is dominated by pharmacological actions upon the central nervous system (CNS), predominantly mediated by prolongation of the kinetics of voltage-gated sodium channels, although other mechanisms operated (Ray et al, 2006). Type I symptoms are characterized by tremor, aggressive sparring, and increased sensitivity to external stimuli, whereas cyano-pyrethroids develop mainly salivation and choreoathetotic movement abbreviated as CS-syndrome. Furthermore, synthetic pyrethroids have been linked to disruption of the endrocrin system, which can adversely affect reproduction and sexual development, interfere with the immune system and increase chance of breast cancer (Xia et al., 2007; McCarthy et al., 2006; Han et al., 2008; Go et al., 1999).

The German Federal Environment Agency (2005) reported that the pyrethroid toxicity to mammal is relative low where the lethal dose values (LD_{50}) between 20 to > 5000 mg per kg body weight. The toxic classification of synthetic pyrethroid insecticides established by WHO are in class unlike the present acute (U) and slightly hazardous (III). In Table 2.3 shows the LD_{50} of the synthetic pyrethroid insecticide, highly toxic to bees in contact with it will die instantly. Toxicity in fish, the high toxic levels in fish have died after exposure to 0.1-1 ppm into the body. In addition, some substances are very high toxic levels is going to die when it gets lower than 0.1. ppm into the body. For the mice are in the range 56-1200 ppm.

Table 2.3 Toxic classification and LD_{50} of synthetic pyrethroid insecticides

Synthetic Pyrethroid insecticide	Toxic classification (a.i.)		LD_{50} (mg/kg)		
	WHO	US EPA	Bee	Fish	Rat (ppm)
Type I					
permethrin	-	II	HT	VHT	1200
Type II					
Cypermethrin	U	II	HT	VHT	250
Deltamethrin	U	II	HT	VHT	135
Fenvalerate	-	II	HT	HT	450
Lambda-cyhalothrin	III	II	HT	HT	56
Cyfluthrin	-	II	HT	VHT	250

Note: a.i: active ingredient

Class III: slightly hazardous U: unlike the present acute; (World Health Organization: WHO)

Class II: moderately hazardous (U.S. Environmental Protection Agency: US EPA)

Fish: very high toxic (VHT) = < 0.1, high toxic (HT) = 0.1-1 ppm

Bee: Highly toxic (HT); kill upon contact as well as residue

The acceptable daily intake (ADI) of synthetic pyrethroid insecticides established by Food and Agriculture Organization (FAO) and the World Health Organization (WHO) are in range 0.003 to 0.05 mg per kg body weight (mg/kg bw) per day (Solecki et al. 2005). The acute reference dose (ARfD value) of synthetic pyrethroid insecticides are in range 0.0075 to 1.5 mg per kg body weight. All shown in Table 2.4

Table 2.4 The acceptable daily intake (ADI value) and acute reference dose (ARfD value) of synthetic pyrethroid insecticides

Pyrethroid	ADI (mg/kg bw)	ARfD (mg/kg bw)
Type I		
permethrin	0.05	1.5
Type II		
Cypermethrin	0.05	0.2
Deltamethrin	0.02	-
Fenvalerate	0.01	0.01
λ-cyhalothrin	0.005	0.02
Cyfluthrin	0.003	0.0075

2.4 Parent synthetic pyrethroid insecticides

Synthetic pyrethroid pesticides are the most frequently used in Thailand had six compounds are summarized in Table2.5:

Table 2.5 CAS names, formular, and chemical structure of synthetic pyrethroid insecticides

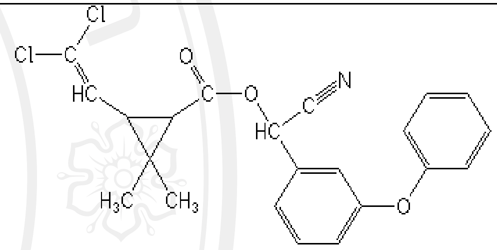
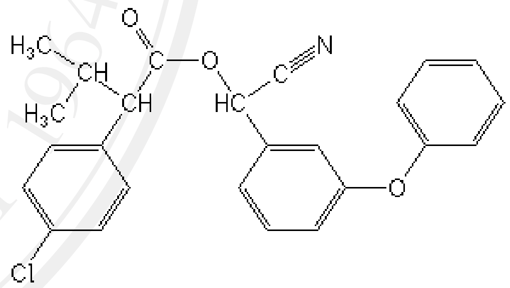
Synthetic pyrethroid	CAS name	CAS number	Formular	Chemical structure
Cypermethrin	cyano(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate	52315-07-8	$C_{22}H_{19}ClNO_3$	
Fenvalerate	cyano(3-phenoxyphenyl)methyl 4-chloro-*alpha*-(1-methylethyl) benzeneacetate	51630-58-1	$C_{25}H_{22}ClNO_3$	

Table 2.5 CAS names, formular, and chemical structure of synthetic pyrethroid insecticides (Continue)

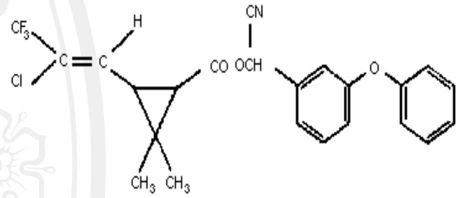
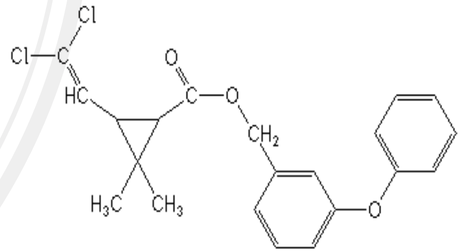
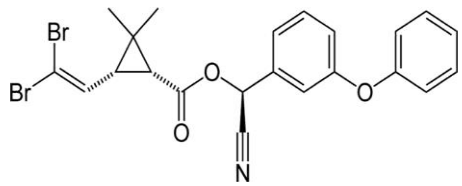
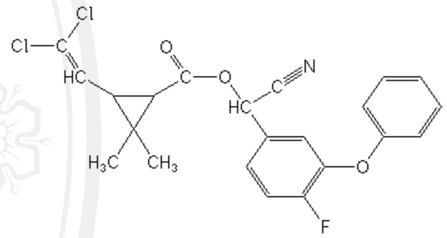
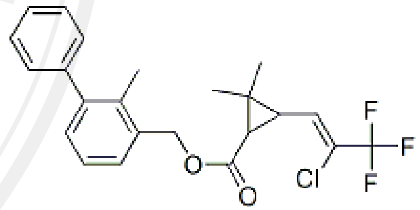
Synthetic pyrethroid	CAS name	CAS number	Formular	Chemical structure
Lambda cyhalothrin	(*R*)-cyano(3-phenoxyphenyl) methyl (1*S*,3*S*)-*rel*-3-[(1*Z*)-2-chloro-3,3,3-trifluoro-1-propenyl]-2,2-dimethylcyclopropane carboxylate	91465-08-6	$C_{23}H_{19}ClF_3NO_3$	
Permethrin	(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate	52645-53-1	$C_{21}H_{20}Cl_2O_3$	
Deltamethrin	(*S*)-cyano(3-phenoxyphenyl) methyl (1*R*,3*R*)-3-(2,2-dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate	52918-63-5	$C_{22}H_{19}Br_2NO_3$	

Table 2.5 CAS names, formular, and chemical structure of synthetic pyrethroid insecticides (Continue)

Synthetic pyrethroid	CAS name	CAS number	Formular	Chemical structure
Cyfluthrin	cyano(4-fluoro-3-phenoxyphenyl)methyl3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate	68359-37-5	$C_{22}H_{18}Cl_2lFNO_3$	
Bifenthrin	(2-methyl[1,1-biphenyl]-3-yl)methyl 3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate	82657-04-3	$C_{23}H_{22}ClF_3O_3$	

2.4.1 Cypermethrin

Cypermethrin is a synthetic compound primarily used as an insecticide. It acts as a fast-acting neurotoxin in insects. It is easily degraded in soil and plants but can be effective for weeks when applied to indoor inert surfaces. Exposure to sunlight, water and oxygen will accelerate its decomposition. It is a synthetic pyrethroid. Cypermethrin is highly toxic to fish, bees and aquatic insects, according to the National Pesticides Telecommunications Network (NPTN). Cypermethrin is found in many household ant and cockroach killers, including Raid and ant chalk.

2.4.2 Fenvalerate

Fenvalerate is a pyrethroid insecticide of moderate mammalian toxicity. In laboratory animals central nervous system toxicity is observed following acute or short-term exposure. The stability of fenvalerate in sunlight allows its application against a wide range of pests. Residue levels are minimized by low application rates and poor translocation characteristics in plants and in soil. Fenvalerate is highly toxic to fish and bees.

2.4.3 Lambda cyhalothrin

Lambda cyhalothrin is a synthetic pyrethroid insecticide used to control a wide range of pests in a variety of applications. Pests controlled include aphids, Colorado beetles and butterfly larvae (Kidd, 1991). Crops on which it may be applied include cotton, cereals, hops, ornamentals, potatoes, vegetables or others. It may also be used for structural pest management or in public health applications to control insects such as cockroaches, mosquitoes, ticks and flies which may act as disease vectors. Lambda cyhalothrin is available as an emulsifiable concentrate, wettable powder or ULV liquid (Meister 1992 and Kidd, 1991) and is commonly mixed with buprofezin, pirimicarb, dimethoate or tetramethrin. It is compatible with most other insecticides and fungicides. Unless otherwise stated, data presented herein refer to the technical product.

2.4.4 Permethrin (INCHE, 1994)

Permethrin is a synthetic pyrethroid insecticide. It is an ester of the dichloro analogue of chrysanthemic acid, chemically identified as (3-phenoxyphenyl) methyl-(±)-*cis-trans*-3(2,2-dichloroethyenyl)-2,2-dimethylcyclopro panecarboxylate. The technical-grade materials are mixtures of four stereoisomers, although the 1 *R*, *cis* isomer is the most active insecticide. Permethrin is effective against a wide range of insect pests in agriculture, animal husbandry, and public health and is used to control residential insects and dust mites. The insecticidal action of synthetic pyrethroids such as permethrin is due to interaction with ion channels on axons of the nervous systems of target species.

Permethrin was evaluated toxicologically by the Meeting in 1979, 1981, and 1982 (Annex 1, references 32, 36, and 38). The 1982 Meeting established an ADI of 0-0.05 mg/kg bw for the 40:60 *cis:trans* mixture of permethrin stereoisomers, since it recognized that mixtures with different isomeric ratios would require independent evaluation. The 1987 Meeting (Annex 1, reference 50) included permethrin mixtures in which the *cis:trans* ratio is nominally 25:75 in the ADI of 0-0.05 g/kg bw. Permethrin was reviewed by the present meeting within the periodic review programme of the Codex Committee on Pesticide Residues.

2.4.5 Deltamethrin

Deltamethrin is a pyrethroid ester insecticide. A Deltamethrin product is among some of the most popular and widely used insecticides in the world and has become very popular with pest control operators and individuals in the United States in the past five years. This material is a member of one of the safest classes of pesticides: synthetic pyrethroids.

There are many uses for deltamethrin, ranging from agricultural uses to home pest control. Deltamethrin has been instrumental in preventing the spread of diseases carried by tick-infested prairie dogs, rodents and other burrowing animals. It is helpful in eliminating and preventing a wide variety of household pests, especially spiders, fleas, ticks, carpenter ants, carpenter bees and cockroaches. Deltamethrin is also one of the primary ingredients in ant chalk.Deltamethrin almost killed a blind couple in 1998. They were not notified of the pesticide's application and had large quantities inside their dryer and furnace.

2.4.6 Cyfluthrin (Thomson, 1992)

Cyfluthrin is a synthetic pyrethroid insecticide that has both contact and stomach poison action. It is a non-systemic chemical used to control cutworms, ants, silverfish, cockroaches, termites, grain beetles, weevils, mosquitoes, fleas, flies, corn earworms, tobacco budworm, codling moth, European corn borer, cabbageworm, loopers, armyworms, boll weevil, alfalfa weevil, Colorado potato beetle, and many others. Its primary agricultural uses have been for control of chewing and sucking insects on crops such as cotton, turf, ornamentals, hops, cereal, corn, deciduous fruit, peanuts, potatoes, and other vegetables. Cyfluthrin is also used in public health situations and for structural pest control.

2.5 Synthetic pyrethroid metabolites

The urinary excretion of synthetic pyrethroid metabolites include 3-phenoxybenzoic acid (3-PBA), cis-3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclopropane-1-carbocylic acid(cis-DCCA), trans-3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclopropane-1-carbocylic acid (trans-DCCA), 3-(2,2-dibromovinyl)-2,2-dimethyl-cyclopropane-1-carboxylic acid (DBCA) and 4-fluoro-3-phenoxybenzoic acid (F-PBA) as shown in Table 2.6.

Table 2.6 Synthetic pyrethroid insecticide metabolites in urine

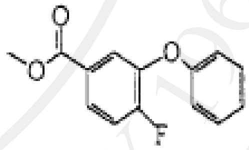
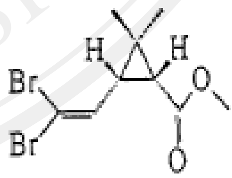
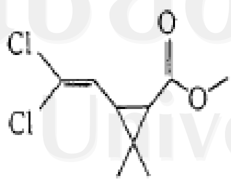
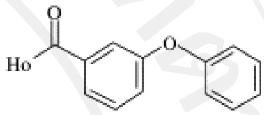
Synthetic pyrethroid insecticides	Synthetic pyrethroid insecticide metabolites	Structure of metabolites
Cyfluthrin	Fluorophenoxybenzoic acid (FPBA)	
Deltamethrin	*cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid (DBCA)	
Cypermethrin Permethrin Cyfluhrin	*cis*- and *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (*cis*- and *trans* DCCA)	

Table 2.6 Synthetic pyrethroid insecticide metabolites in urine (Continue)

Synthetic pyrethroid insecticides	Synthetic pyrethroid insecticide metabolites	Structure of metabolites
Cypermethrin Permethrin Deltamethrin	3-phenoxybenzoic acid (3-PBA)	

2.6 Exposure to synthetic pyrethroids and their metabolites

Synthetic pyrethroids can be found elsewhere because of their widely used in home, public health, agriculture, forestry, and horticulture (Morgan et al., 2007). The main route for pyrethroid exposure among the general public is apparently via residue in foods. The general population is potentially chronically exposed by food consumption (Fortin et al., 1997). According to, Chensheng et al., (2006) children were exposed to pyrethroids through their conventional diets. Heudrof et al. (2006) reported that exposure of pyrethroids from household dust at home or at work were found lower than expected. However, children ages appear to have an effect on pyrethroids exposure, younger childen is likely attributed to the use of pyrethroids around the premises or in the facilities where older children engaged in the outdoor activities.

In the diet study of Torres et al., (1996), dietary intake of pesticides is determined by analysis of fruit and vegetables as consumed. The levels of pesticide residues are controlled by the Maximum Residue Levels (MRLs), which are established by each country. In Thailand, the maximum residue level has been set for 36 pesticides in agricultural commodity and food. In 2006, Department of Agriculture (2007b) provides the MRLs of synthetic pyrethroid active ingredients comprises lambda-cyhalothrin, cypermethrin, fenvalerate, and deltamethrin.

Pyrethroids in blood are measurable but they are metabolized very fast and can be determined in plasma only a few hour after exposure (Leng et al., 1997). The half-life of pyrethroids in human is about 48 hours, the urinary excretion of synthetic pyrethroid metabolites include 3-phenoxybenzoic acid (3-PBA), cis-3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclopropane-1-carbocylic acid(cis-DCCA), trans-3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclopropane-1-carbocylic acid (trans-DCCA), 3-(2,2-dibromovinyl)-2,2-dimethyl-cyclopropane-1-carboxylic acid (DBCA) and 4-fluoro-3-phenoxybenzoic acid (F-PBA). The hydrolysis of ester bond of permethrin, cypermethrin, deltamethrin, cyfluthrin, and fenvalerate produces acid metabolites and 3- phenoxy benzyl (4-fluoro-3-phenoxybenzyl for cyfluthrin) alcohol. The acid metabolites are cis- and trans- DCCA (permethrin, cypermethrin, cyfluthrin), and DBCA (deltamethrin). The phenoxybenzoic compounds (3-PBA) derived from the alcohol group and metabolites from permethrin, cypermethrin, deltamethrin, and fenvalerate.

2.7 Measurement of synthetic pyrethroids and their metabolites

The analytical procedures of exposure to pesticide include sample collection and storage, sample preparation, analysis and validation of the method. The pesticide residue analysis of interest has to be simple and minimal, sample extraction and cleans up. In the extraction step i.e. liquid-liquid partition has been used various organic solvents such as acetonitrile, acetone, hexane, ethyl acetate, methanol, and dichloromethane (Pang et al., 1994, Sannino et al., 2003, Bempelou et al., 2006, Lesueur et al., 2008). Furthermore, there is increased efficiency of partition by elimination of water in the sample. In clean up step, solid phase extraction (SPE) effectively removed many polar matrix components and pigments (Zawiyah et al., 2007; Anastassiades, 2003; Masahiro et al., 2005). Because the matrix enhancement effect is related to the blocking of active sites on the injector liner by matrix compound, thereby increasing signal in the present of matrix versus standards in solvent in which the pesticide themselves interact with the active site is needed (Schenck et al., 2000).

Anastassiades (2003) reported a rapid method for analysis of pesticide residues in fruits and vegetables, name “QuEChERS” which comes from “Quick, Easy, Cheap, Effective, Rugged, and Safe”. The method employed a small volume liquid-liquid partitioning, and clean up with the extract by mixing with primary secondary amine (PSA). Nevertheless, “QuEChERS” method was found weak extraction potency and insufficient clean up (Masahiro et al., 2005; Lesueur et al., 2008).

Gas chromatography with electron capture detection (GC-ECD) has been used for determination of synthetic pyrethroid insecticides because ECD is sensitive to halogenated compounds. ECD is a selective and sensitive detector that provides good response even at very low concentration (Zawiyah et al., 2007). Gas chromatography with mass spectrometry (GC-MS) has been employed to verify identities of synthetic pyrethroid insecticides in various crops (Pang et al., 1998) as shown in Table 2.7.

Table 2.7 Synthetic pyrethroid residues detected in vegetable and fruit samples

Matrices	Sample weight	Synthetic pyrethroid	Instrument	LOD (mg/kg)	Recovery	Ref
Tomato puree, peach nectar, orange juice, and conned peas	20 g	Tefluthrin, bifenthrin, fenpropathrin, cyhalothrin, permethrin,cyfluthrin, cypermethrin, flucythrinate, fenvalerate,fluvalinate, and deltamethrin	GC-MS GC-ECD	0.010-0.100 <0.010	70.2-96.0	(Sannino et al. 2003)
Tobacco	10 g	Fenpropathrin, cyhalothrin, cypermethrin, fenvalerate and deltamethrin	GC-ECD	<0.01	76.2–111.2	(Sannino et al. 2004)
grape, lemon, onion, and tomatoes	10 g	bifenthrin, permethrin,cyfluthrin, deltamethrin cypermethrin, fenpropathrin, and fenvalerate	GC/SQ-MS	0..4-48.2	63- 120	(Lesueur et al. 2008)
Grapes	20 g	Permethrin, cypermethrin, and fenvalerate	GC-ECD	0.003-0.015	92.7-103.1	(Pang et al. 1997)
Grapes	25 g	Alpha cypermethrin,and Fenvalerate	GC-ECD	-	73.5-83.5	(Seyed Esmaeil Mahdavian 2010)
Vegetable oil	5 g	Tetramethrin, bifenthrin, phenothrin, cyhalothrin, permethrin,cyfluthrin, cypermethrin, flucythrinate, Esfenvalerate,fluvalinate, and deltamethrin	GC-MS-MS	0.01-0.02	82-105	(Fernandez-Alvarez et al. 2009)

The determination of pesticide metabolites in biological fluids such as urine, blood is for detecting an internal dose of over all exposure. A number of synthetic pyrethroids can be metabolized to 3-phenoxybenzoic acid (3-PBA) in human. Therefore, this metaboliteis commonly used as a common urinary biomarker of exposure to synthetic pyrethroids insecticides. These include synthetic pyrethroids such as cypermethrin, deltamethrin, permethrin, fenvalerate and possibly other synthetic pyrethroids. Thus, the detection of this metabolite in the urine may reflect multiple sources of environmental exposure to different synthetic pyrethroids (Han et al., 2008; Morgan et al., 2007). The analytical determination of pyrethroid metabolites in urine can be described briefly as acidic hydrolysis of urine sample following by liquid-liquid extraction or solid phase extraction and derivatization. For derivatization, by 1,1,1,3,3,3-hexafluoroisopropanol (HFIP), and N,N-diisopropylcarbodiamide (DIC) (Fortin et al., 2008; Leng et al., 2005;), pentafluorobenzyl bromide (PFBBr) (Aprea et al., 1997). Analytes are derivertized, and then quantified by gas chromatography with mass spectrometry (GC-MS) (Fortin et al., 2008; Leng et al., 1997; Chensheng et al., 2006; Marsha et al., 2007; Aprea et al. 2000) and gas chromatography with electron capture detection (GC-ECD) (Aprea et al., 1997) and high-performance liquid chromatography with UV-Vis detector (HPLC-UV) (Smith et al., 2002)

Recently, measureable levels of 3-PBA in the urine of non-occupationally expose have been detected in Germany, the United State, and Thailand adults and children (Heudrof et al., 2001; Baker et al., 2000; Panuwet et al., 2009). The reference values reported by Heudorf et al.(2006) in urinary metabolites of pyrethroids in general population group, which are not a strictly representative reference sample included trans- DCCA in urine 2 μg/L, cis- DCCA in urine 1 μg/L, and 3-PBA in urine 2 μg/L Exposure assessment: determine the amount, duration, and pattern of exposure to the chemical. There are 3 types of exposure assessment biomarker: 1) biomarkers of exposure 2) biomarkers of susceptibility and 3) biomarkers of effect.

2.8 Pesticide exposure assessment

Pesticide exposure assessment is the critical connection between potentially harmful factors of substances like pesticides (as determined in the hazard identification phase of risk assessment, and human health effects)

Exposure assessment requires estimating the concentration of a substance to which humans are exposed, the size of the population exposed, the nature of the exposed population (e.g., activity, age, occupation, special risk characteristics), and the duration and frequency (continuous or varied) of exposure.

Assessments estimate exposures for various sub population groups, including pesticide handlers, field workers, consumers exposed to pesticides in the home and garden, and bystanders, particularly infants, children and other susceptible subgroups.

2.8.1 The contamination of synthetic pyrethroid insecticides in Thailand

Studies of contamination of the insecticides in the environment (Nipon, 2005) found in surface water, 25 watersheds are synthetic pyrethroid insecticides 1.12% of the total sample, concentration in range 0.04 - 0.05 μg/L. The study identified areas, In the lower central area of the most compound is cypermethrin, the Northeast is the substance found that the lambda cyhalothrin.

2.8.2 Exposure level of 3 PBA in urine

Study of the synthetic pyrethroid insecticides exposure to the chemical analysis of urinary metabolite 3PBA, which has researchers in many country has been studied in several age ranges. Found in the urine sample of a population of 3 PBA, which is an indicator that there is a synthetic pyrethroid insecticide exposure were positive sample in the range 47-97 % and the average in the range of 0.9-1.2 μg/L is shown in the Table 2.8.

Table 2.8 compared the exposure of 3 PBA

Country	Age (years)	N	%detected	Mean (μg/L)	Max (μg/L)	Ref
Germany	6-12	30	97	1.2	25.6	Leng, 2005
USA	Preschool	127	67	0.9	33.8	Morgan, 2006
Canada	22-63	120	94	nd	nd	Fortin,2008
Thailand	12-13	207	47	1.0	74	Panuwet, 2009

Note: nd is no data