ORIGINAL ARTICLE

Exposure assessment of traditional and IPM farmers on using pesticides: A case study at Bang Rieng Sub District, Khuan Nieng District, Songkhla Province

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Abstract

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A questionnaire was developed to quantitatively evaluate the exposure to pesticides and to gauge the concentration of organophosphate pesticides such as chlorpyrifos and methyl-parathion while the farmers of Bang Rieng were spraying these pesticides. The results were applied to the exposure assessment and to compare the quantity of exposure to these pesticides between 33 traditional and 40 integrated pest management (IPM) farmers of Bang Rieng. There was a significant difference in the level of exposure between the traditional farmers, who had the average pesticide exposure scores of 58.30 points and the IPM farmers, whose average scores were 53.50 points, ($p \leq 0.015$).

Concentrations of organophosphate pesticides chlorpyrifos and methyl-parathion were measured. Thirty-three air samples were collected by personal sampling during the period of pesticide spraying. Traditional farmers were exposed to higher levels of the pesticide(s) with a mean concentration of 0.1865 mg/m^3

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compared to the IPM farmers who were exposed to a mean pesticide concentration of 0.037 mg/m^3. It was estimated that the farmers of Bang Rieng would be exposed to 186-19,616.6 mg of the organophosphate pesticide(s) via inhalation throughout their lifetime (65 years). Moreover, according to the exposure assessment, the traditional farmers exposed to a greater amount of the pesticide(s) via inhalation compared to the IPM farmers.

Key words : exposure assessment, organophosphate pesticide exposure, IPM farmers, working air condition

บทคัดย่อ

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การประเมินการสัมผัสสารกำจัดศัตรูพืชและสัตว์ ของเกษตรกรที่ใช้วิธีดั้งเดิมกับเกษตรกรที่ใช้วิธีจัดการแบบผสมผสาน กรณีศึกษาตำบลบางเหรียง อำเภอควนเนียง จังหวัดสงขลา

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งานวิจัยนี้เป็นการพัฒนาแบบสัมภาษณ์เพื่อใช้เป็นเครื่องมือในการประเมินการสัมผัสจากสารกำจัดศัตรูพืชและสัตว์ในเชิงปริมาณ และทำการตรวจวัดความเข้มข้นของสารกำจัดแมลง กลุ่มออกาโนฟอสเฟต (คลอไพริฟอสและเมธิล-พาราไทออน) ในขณะที่ทำการฉีดพ่นของเกษตรกรในต.บางเหรียง อ.ควนเนียง จ.สงขลา ข้อมูลที่ได้จะนำมาใช้ในการประเมินหาระดับการสัมผัสสารกำจัดศัตรูพืชและสัตว์และหาปริมาณการสัมผัสสารกำจัดแมลงของเกษตรกร และนำมาเปรียบเทียบระหว่างเกษตรกลุ่มผู้ใช้สารกำจัดแมลงกับกลุ่มผู้ใช้วิธีผสมผสาน จากการเก็บข้อมูลแบบสัมภาษณ์จำนวน 73 ตัวอย่าง พบว่าเกษตรกรกลุ่มผู้ใช้สารกำจัดศัตรูพืชและสัตว์ มีคะแนนจากการประเมินเฉลี่ยเท่ากับ 58.30 คะแนน และมากกว่ากลุ่มผู้ใช้วิธีผสมผสาน ซึ่งมีคะแนนเฉลี่ยเท่ากับ 53.50 อย่างมีนัยสำคัญ ที่ระดับ .05

เมื่อวิเคราะห์ตัวอย่างที่เก็บได้ขณะที่เกษตรกรทำการฉีดพ่นสารกำจัดแมลง จำนวน 33 ตัวอย่าง พบว่า เกษตรกรกลุ่มผู้ใช้สารกำจัดแมลงมีความเข้มข้นของสารในอากาศขณะที่ทำการฉีดพ่น เฉลี่ยเท่ากับ 0.1865 มก./ลบ.ม. และมากกว่ากลุ่มผู้ใช้วิธีผสมผสาน ซึ่งมีความเข้มข้นเฉลี่ย 0.0370 มก./ลบ.ม. อย่างมีนัยสำคัญที่ระดับ .05 เมื่อนำผลการวิเคราะห์ตัวอย่างอากาศที่เก็บขณะที่เกษตรกรทำการฉีดพ่นสารกำจัดแมลง มาใช้คำนวณหาปริมาณการสัมผัสสารกำจัดศัตรูพืช พบว่าตลอดชั่วชีวิตของเกษตรกร จะได้รับสารกำจัดแมลง กลุ่มออกาโนฟอสเฟตจากการหายใจเข้าสู่ระบบทางเดินหายใจ เป็นจำนวน 186-19,616.6 มก. ตลอดชั่วชีวิตของเกษตรกร (65 ปี) และสามารถประเมินได้ว่าเกษตรกรกลุ่มผู้ใช้สารกำจัดแมลง ได้รับสารกำจัดแมลงเข้าสู่ร่างกายมากกว่า กลุ่มผู้ใช้วิธีการผสมผสาน

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The geographical location of Thailand and its climate not only encourage good harvests but also are favorable to insect populations. To increase agricultural production, therefore, Thai farmers have preferred to use large quantities of chemicals (chemical fertilizer, pesticide and synthetic hormone) to speed up and control their harvest, as well as to reduce and repel pests and epidemic plants.

As pesticides are efficient and readily available, a large quantity of pesticides, approximately 70,158 tons in 2003, (Department of Agriculture, 2003) have been imported by Thai farmers to control the pests.

Because of their ease of purchase and use and their high and rapid effectiveness, large quantities of pesticides have been applied by Thai farmers. Pesticides widely used in Thailand include those of the organophosphate group due to their high effectiveness for insect eradication, shorter lifetime, and high degradability under natural conditions. On the other hand, organophosphate compounds are hazardous chemicals, which can cause many adverse health effects to human being. For example, they can inhibit the function of nervous systemic enzymes, especially acetylcholinesterase (cholinesterase). The severity of their effects (Galo and Lawryk, 1991) depends on the exposure dose and duration. The severity ranges from pulmonary edema, muscle spasms, muscle weakness, blurred vision, respiratory difficulty, and eventually death due to respiratory failure (TOXNET). Furthermore, pesticide residues in the environment have caused toxic residue problems as well as posed a risk to human health associated with accumulation in the food chain.

Bang Rieng Sub district is the largest agricultural area in Songkhla Province, where vegetables are the main product. Farmers in the Bang Rieng region follow either traditional methods or Integrated Pest Management (IPM) methods to control for pests. Traditional farmers mainly use the pesticide for pest control whereas IPM farmers use a combination of pesticides and non-chemical methods such as crop rotation and plant growing in a netted area to protect their harvest (Postel, 1987). In general, IPM farmers use a smaller quantity of the pesticide than traditional farmers. It appears that organophosphates are the pesticides most commonly used in the Bang Rieng region where most farmers are subject to pesticide exposure (Department of Public Health, 2001).

These traditional and IPM farmers are expected to be directly and indirectly exposed to pesticide residues in the soil, ground water, surface water, food and ambient air. The objective of this study was to develop a questionnaire for assessing the exposure to organophates pesticides and compare the concentration of exposure between traditional farmers and farmers practising integrated pest management.

Methodology

Population and samples

The population in Bang Rieng Sub district, Khuan Nieng District, Songkhla Province, southern Thailand, are predominantly vegetable farmers, and organophosphates are commonly used type of pesticides. The Office of Agricultural Research and Development Zone 8, (1993) reported approximately 520 families, or more than 6,000 persons, potentially exposed to pesticide in Bang Rieng.

This study assessed the pesticide exposure by evaluating the exposure concentration of the organophosphate pesticide to which farmers are exposed during their spraying in 2 steps (Berglund. *et al*, 2001), as follows:

Step I: Indirect method: Farmers were interviewed using a structured questionnaire which was developed and adapted by the researcher team. The exposure questionnaire assessed the farmers' activities and their behaviors relating to pesticide usage. The exposure scores from the assessment need to estimate the pesticide exposure level in each farmer.

Step II: Direct method: The air contamination level from pesticide was determined by personal exposure monitoring while farmers applied the pesticide in their farms. This method evaluated the amount of pesticide and its concentration, to which farmers may be exposed via slim contact or by breathing in via the respiratory systems.

Step I: Indirect method

Materials and procedure for sampling interview questionnaire

The questionnaire for pesticide exposure assessment was adapted from the Agricultural Health Study Questionnaire, (1996), The Institute

of Environmental Medicine; WHO (2001), and New Jersey IPM Study (Robson *et al.*). The questionnaire and its content were reviewed by a psychology specialist, an occupational health and safety specialist, and a pesticide specialist. Questionnaires consisted of 4 parts as follows:-

Part 1: General Information: This was to obtain the necessary data from the farmers such as name and address, age, sex, educational background, house location, applying pesticide information, and etc.

Part 2: Health Information: This was to assess farmers' health problems which may arise from the exposure to organophosphate pesticide including some related signs and symptoms.

Part 3: Pesticide Exposure Assessment: This contained 26 questions to assess the farmer's behaviors and activities related to pesticide exposure, such as mixing and spraying method, storage and disposal. Each item consisted of a ranking score to evaluate each behavior's content with theoretical maximum total score of 92 points.

Part 4: IPM Information; this was to evaluate the alternative method that IPM farmers for pest control. Only IPM farmers were interviewed for this part.

Step II: Direct method

Materials and procedure for sampling pesticide concentration in the working air condition

Sampling method for study the pesticide concentration in the air followed NIOSH Manual of Analytical Methods Number 5600: Organophorus Pesticides, Issue 1: 15 August 1994, Fourth Edition. The concentration of organophosphate pesticide was analyzed by GC-NPD and the total organophosphate pesticide concentration in working air when the farmers spray the pesticide calculated. To determine the mass in μg of respective analyses, organophosphate pesticide was found in the sample front (W_f) and back (W_b) sorbent section, and in the media blank front (B_f) and back (B_b) sorbent section and calculated concentration, C, of analyte in the air volume sample, V(l):

$$C = (W_f + W_b - B_f - B_b)/V \quad (mg/m^3)$$

The results were calculated in order to determine organophosphate pesticide exposure concentration, life time exposure and intake dose between Traditional and IPM farmers.

Results and Discussion

1. Pesticide exposure assessment scores

The sample comprised 33 traditional farmers and 40 IPM farmers, 38 were males and 35 females. Almost 60% were in the age range 36 - 55 years and 26% were in age range 29 - 35 years.

The questions and values of the exposures of the pesticide exposure questionnaire from the traditional and IPM Farmer are described in Table 1.

Pesticide exposure scores

The theoretical range of total scores for the pesticide exposure was 22 - 92. However, the highest exposure score obtained was 83 points and the lowest score 36 points, while the mean score was 55. 7 with standard deviation 8.6. The numbers of persons in each score are shown in the Figure 1.

The researchers assigned and calculated the pesticide exposure score, and also categorized them into 5 levels as shown in Table 2. The results showed that 45 Bang Rieng farmers had medium pesticide exposure, and 18 farmers had moderately low exposure, while 9 farmers had moderately high and high exposure (Table 2).

The comparison (t-test) of mean pesticide exposure score showed that there were significant differences of pesticide exposure scores between traditional and IPM farmers. The traditional farmers (mean = 58.30, s.d. = 7.5, n = 33) had a higher exposure score than IPM farmers (mean = 53.50, s.d. 8.92, n = 40), ($p \leq 0.015$).

2. Organophosphate pesticide concentration in the working air condition

Thirty-three air samples were collected

Table 1. Description of question and results in the pesticide exposure assessment questionnaire from interviewing farmers in Bang Rieng Sub district (n = 73)

Item	No. of Answers	Description
1. Where do you mix pesticide?	28	In the farm and near the water source
2. What is the method that you select to apply pesticide?	50	Mixed with the individual creation
3. How do you mix the pesticide?	46	Bare hand and use stirring stick
4. When mixing or applying pesticides, which part of your body usually contact the pesticide?	59	Hand and arm
5. When do you spray pesticides?	58	Evening
6. What equipment do you use for spraying pesticides?	35	Hand pump
7. If you spill some of pesticide on your clothes, when do you change clothes?	56	Change after finishing spraying
8. If your last pesticide application is ineffective, what will you do with the firth pest control?	38	Change the new one
9. After applying pesticides, when do you usually change into clean clothes?	64	Immediately
10. How do you wash your clothes, which you were during applying pesticide?	64	Separate from family washed
11. After mixing and applying pesticides, where do you usually wash up or shower?	48	Bathroom at home
12. What is the method in disposing the pesticides container?	26	To dispose in the ground
13. How do you wash the pesticide equipment after used?	27	Frequently
14. What is the method for washing the pesticide equipment?	36	Rinse all equipment
15. Do you usually repair your own spraying or mixing equipment?	40	No
16. Where do you store the pesticides?	30	In the separate storage facility
17. Where is the source of the water used?	61	Artesian well or deep well
18. Normally, what kind of drinking water do you usually drink?	54	Artesian well (directly)
19. Whether the water source used for consuming is the same source for mixing pesticides?	39	Different source from farming
20. How far is your usage well from the nearest area where pesticides are mixed?	45	Less than 10 m.
21. Where do you have launch?	64	At home (out of the farm areas)
22. Do you drink in the farm or during lunch?	67	No

from traditional (18 samples) and IPM (15 samples) farmers, comprising 28 males and 5 females. Of all, 23% of the farmers applied chlorpyrifos in their farms, while 7% applied methyl parathion. However, 3 farmers applied both chlorpyrifos and methyl-parathion simultaneously. The reason for using chlorpyrifos was to eradicate worm and that for using methyl parathion was to control ant. However, during the collection of air samples (November 2002 - February 2003), the farmers used a high level of chloryrifos since it coincided with the worm-spreading period.

Table 3 shows the analyzed results in the highest, lowest, and mean pesticide concentrations

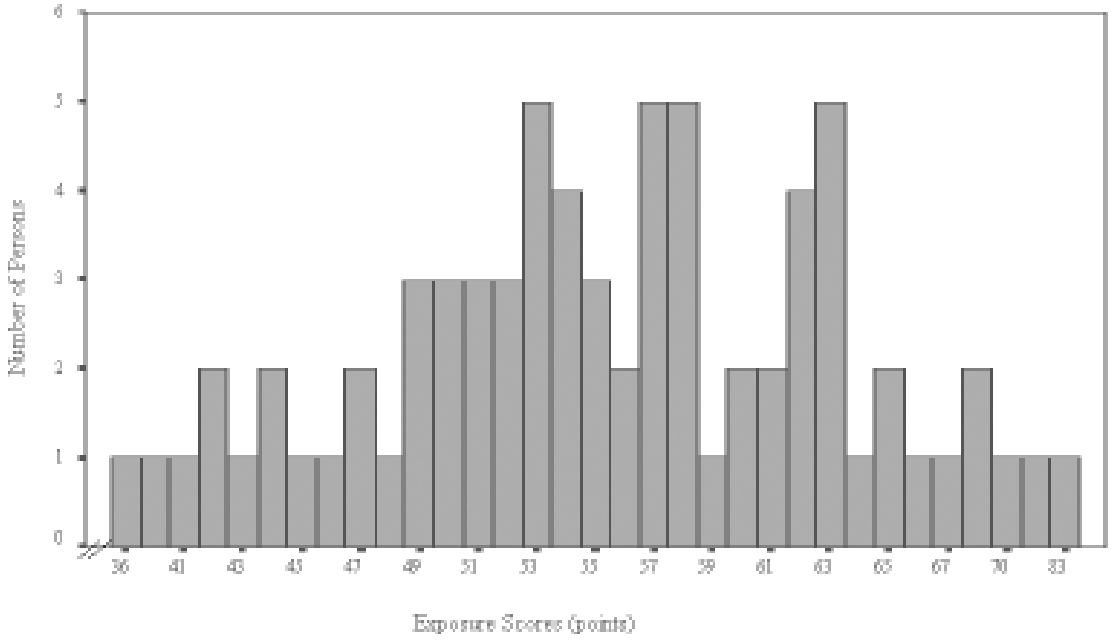

Figure 1. Pesticide exposure scores from interviewing questionnaire of Bang Rieng farmers

Table 2. Pesticide exposure level of Bang Rieng farmers

Level	Exposure Score (points)	Description	No. of farmer (s)	Percentage
1	22 - 36	Low Exposure	1	1.4
2	36 - 50	Moderately Low Exposure	18	24.7
3	50 - 64	Medium Exposure	45	61.6
4	64 - 78	Moderately High Exposure	8	11
5	78 - 92	High Exposure	1	1.4

Table 3. Organophosphate pesticide concentrations in working air condition which Bang Rieng farmers exposed

Pesticide Name	Farmer group	No. of Samples	Highest Conc. (mg/m³)	Lowest Conc. (mg/m³)	Mean Conc. (mg/m³)
chlorpyrifos	Trad.	9	0.6055	0.0307	0.2152
	IPM	14	0.1324	0.0204	0.0539
methyl parathion	Trad.	3	0.0695	0.0168	0.0434
	IPM	4	0.0133	0.0040	0.0088
Both (chlorpyrifos	Trad.	1	-	-	0.1284
& methyl parathion)	IPM	2	0.0257	0.0094	0.0176
Total		**33**	**0.6055**	**0.0040**	**0.1186**

to which the farmers were exposed; which were 0.6055, 0.0040 and 0.1186 mg/m^3, respectively.

The comparison of pesticide concentration results between traditional and IPM farmer with t-test analysis showed that traditional farmers (mean = 0.1865 mg/m^3) were exposed to a significantly higher concentration of each pesticide than IPM farmers (mean = 0.0370 mg/m^3), ($p \leq 0.000$).

3. Pesticide exposure assessment

3.1 Pesticide exposure concentration

Comparison between traditional and IPM farmers were made using the exposure equation (Lawrence, 1996):

$$E = C \times \Delta t \times CR$$

where C [mg/m^3] = Chemical concentration
Δt [time] = Duration of exposure
CR [m^3/time] = Contact Rate

To estimate the Traditional and IPM farmers' total inhalation exposure during pesticide spraying throughout their lifetime, the following factors were used: (in the frame below)

The results of the pesticide exposure are shown in Table 4.

Next, the amount of organophosphate the farmers were exposed to during working hours in their lifetime was calculated using the following equation:

$$E_{OPair} = C_{in\ farm} \times \text{Working Time}_{in\ farm} \times \text{Inhalation Rate}$$

The estimated lifetime exposure to organophosphate pesticides of farmers through in-

	Traditional Farmers	**IPM Farmers**
Working Hour:	Average 0.4 hrs/day	Average 0.58 hrs/day
Mean of Conc.:	0.1865 mg/m^3	0.0370 mg/m^3
Max. Conc.:	0.6055 mg/m^3	0.1324 mg/m^3
Min. Conc.:	0.0168 mg/m^3	0.0040 mg/m^3
Spraying Time:	24 min or 0.4 hr/day	34.8 min or 0.58 hr/day
Working Duration:	Starting from age 20 to 65 years old or 45 years	
Working Day:	Average 300 days/year	
Working Time$_{in\ farm}$:	(65 -20 yrs) × 300 workdays/yr × 0.4 hrs/day or equal 5,400 hrs	(65 -20 yrs) × 300 workdays/yr × 0.58 hrs/day or equal 7,830 hrs
Inhalation Rate:	For heavy activity = 6.0 m3/hr	

Table 4. Calculation of pesticide exposure in traditional and IPM farmers

Parameters	**Traditional Farmer:**	**IPM Farmer:**
Mean of pesticide concentration time	$E_{OPair\text{-}Mean}$ = (0.1865 mg/m^3 × 5,400 hrs.) = 1,007.38 mg.hr/m^3	$E_{OPair\text{-}Mean}$ = (0.0370 mg/m^3 × 7,830 hrs.) = 289.85 mg.hr/m^3
Maximum pesticide concentration time	$E_{OPair\text{-}Max}$ = (0.6055 mg/m^3 × 5,400 hrs.) = 3,269.43 mg.hr/m^3	$E_{OPair\text{-}Max}$ = (0.1324 mg/m^3 × 7,830 hrs.) = 1,036.32 mg.hr/m^3
Minimum pesticide concentration time	$E_{OPair\text{-}Min}$ = (0.0168 mg/m^3 × 5,400 hrs.) = 90.46 mg.hr/m^3	$E_{OPair\text{-}Min}$ = (0.0040 mg/m^3 × 7,830 hrs.) = 31.00 mg.hr/m^3

Table 5. Calculation of lifetime exposure to pesticide via inhalation in each farmer

Parameters	Traditional Farmer	IPM Farmer
Mean lifetime exposure	$E_{OPair\text{-}Mean}$ = (1,007.38 × 6) = 6,044.3 mg	$E_{OPair\text{-}Mean}$ = (289.85 × 6) = 1,739.1 mg
Maximum lifetime exposure	$E_{OPair\text{-}Max}$ = (3,269.43 × 6) = 19,616.6 mg	$E_{OPair\text{-}Max}$ = (1,036.32 × 6) = 6,217.9 mg
Minimum lifetime exposure	$E_{OPair\text{-}Min}$ = (90.46 × 6) = 542.8 mg	$E_{OPair\text{-}Min}$ = (31.00 × 6) = 186.0 mg

halation from spraying at the inhalation rate of 6.0 m^3/hr are shown in Table 5.

3.2 Comparison of pesticide intake dose: Comparison between traditional and IPM Farmers

A generalized equation used to calculation the intake dose (Galo *et al*., 2001) was:

$$I = (C \times CR \times EF \times ED) / (BW \times AT)$$

The researcher determined some factors to calculate intake concentration. Those factors were assumed as follows:

I = Intake Dose (mg/kg.day)

C = Chemical Concentrations at the exposure point (mg/m^3); assessed in 3 scenarios the mean maximum and minimum concentrations.

CR = Contact Rate (m^3/day); for Traditional farmer breathing rate = 2.4 m^3/day, calculated from breathing rate in heavy activity (spraying pesticide: 6.0 m^3/hr) and multiply by 0.4 hr/day for spraying pesticide period. For IPM farmer breathing rate = 3.48 m^3/day (from 6.0 m^3/hr × 0.58 hrs/day)

BW = Body Weight (average over exposure period: kg); = 65 kilogram for both male and female

EF = Exposure Frequency (days/year); for Traditional farmers = 52 days/year (average time for applying pesticide = 4.33 times/month). For IPM farmers = 35 days/year (average time for applying pesticide = 2.87 times/month)

ED = Exposure Duration (years); = farming period = 45 years

AT = Average Time (days); calculated from farming duration (45 years) multiply by the exposure frequency - 52 or 35 days/year

ADI = for Chlorpyrifos = 0.010 mg/kg·day, and for Methyl-parathion = 0.020 mg/kg·day

(Department of Pollution Control, 1996)

A comparison between the intake doses calculated for the Traditional and the IPM farmers and the recommended Acceptable Daily Intake (ADI) values is presented in Table 6.

Conclusion

The researcher applied this questionnaire by interviewing 33 Traditional and 40 IPM farmers in Bang Rieng Sub district, Khuan Nieng District, Songkhla Province. The results showed that farmers had the mediu pesticide exposure scores or representing the mean scores of 55.67 ± 8.58 points or 60.5%. About 67% of farmers had the medium exposure scores, and12% moderately high as high exposure scores. Moreover, traditional farmers had the mean scores of 58.3 points, which was higher than IPM farmers whose mean scores was 53.50 points.

Table 6. Organophosphate pesticide intake dose via the inhalation route: Traditional farmers vs. IPM farmers

Farmer Groups	Concentration (mg/m^3)		Intake dose (mg/kg.day)	%ADI of chlorpysifos	%ADI of methyl parathion
Traditional	Mean	0.1865	**0.0069**	68.9	34.5
	Max	0.6055	**0.0224**	223.6	111.8
	Min	0.0168	**0.0006**	6.2	3.1
IPM	Mean	0.0370	**0.0013**	13.3	6. 7
	Max	0.1324	**0.0048**	47.7	23.9
	Min	0.0040	**0.0001**	1.4	0.7

We applied NIOSH Manual of Analytical Methods Number 5600: Organophophorus Pesticides to collect 33 air samples, comprising 23 chlorpyrifos samples, 7 methyl-parathion, and 3 both of chlorpyrifos and methyl-parathion. The sample analysis results showed that farmers were exposed to organophosphate pesticide at the concentration ranging from 0.0040 - 0.6055 mg/m^3 and four farmers were exposed to the pesticide over the ACGIH (TWA) Recommendation (0.02 mg/m^3). In addition, traditional farmers had been exposed to the pesticide concentration of 0.1865 mg/m^3, which were higher than that of IPM farmers (0.0370 mg/m^3).

When compare the lifetime exposure through inhalation between Traditional and IPM Farmer, the result showed that the lifetime exposures of organophosphate pesticides were 542.8 - 19,616.6 mg by the Traditional farmers, and 186.0 - 6,217.9 mg by IPM farmers. For the comparison of the exposure concentrations between Traditional and IPM farmer, Traditional farmers intook the pesticide at the level of 0.0006 - 0.0224 mg/kg.day or 6.2 - 223.6% of the ADI chlorpyrifos or 3.1 - 111.8% of the ADI methyl-parathion whereas the IPM farmers intook the pesticides at the level of 0.0001 - 0.0048 mg/kg.day or 1.4 - 47.7% of the ADI chlorpyrifos or 0.7 - 23.9% of the ADI methyl-parathion.

In conclusion, the IPM farmers have lower risk from being exposed to organophosphate pesticide than traditional farmers. This was attributable to their exposure concentrations in ambient working air, which were lower than for traditional farmers.

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References

Agricultural Health Study. 1996. Final Questionnaire: Private Applicator, National Institutes of Health (NIH) and Office of Research and Development of the US Environmental Protection Agency (U.S.EPA).

Berglund, Marika, Carl-Gustaf Elinder, Lars Järup. 2001. Assessment of Respiratory Damages in Relation to Particulate Air Pollution Questionnaire, "Human Exposure Assessment An Introduction", World Health Organization, (The Institute of Environmental Medicine, Stockholm. Available from http://www.imm.ki.se [2002, May 30]. pp. 15-51.

Galo A. Micheal and Lawryk J. Nicholas. 1991. Organic Phophorus Pesticide. **In** Wayland J.Hayes and Edward R. Raws, Handbook of Pesticide Toxicology Volume 2: Classes of Pesticides. (California: Academic Press). pp. 917-1091.

LaGrega D. Micheal, Buckingham L. Phillip, Evans C. Jeffrey. 2001. Environmental Resources Management and Quantitative Risk Assessment,

Hazardous Waste Management. (Singapore, McGraw Hill, Inc., Series in Water Resources and Environmental Engineering, 2nd ed). pp. 264, 316-317, 865-911.

Lawrence B. Gratt. 1996. Air Toxic Risk Assessment and Management: Public Health Risks from Normal Operations, (USA, John Wiley & Sons, Inc.). pp.109-146.

National Institute of Occupational Safety and Health (NIOSH). 2002. NIOSH Manual of Analytical Methods (NMAM) 5600: Organophosphorus Pesticides, 4th ed,. Available from http://www.cdc.gov/niosh [2002, June 15].

Office of Agricultural Research and Development Zone 8 Changwat Songkhla. 1996. Vegetable Farmer Name in Amphoe Khuan Nieng, Changwat Songkhla, Songkhla". (in Thai)

Postel Sandra. 1987. Defusing the Toxics Threat: "Controlling Pesticides and Industrial Waste", Worldwatch Paper 79, Worldwatch Institute, Washington, D.C. USA.

Robson, Mark G., Hamilton, and George C., Samulis Raymond, and Prostko Eric. ..... Final Report An Assessment of Regulatory, Market and Financial Obstacles to Integrated Pest Management in New Jersey. (Pilot Project).

Thailand, Agricultural and Cooperative Ministry, Department of Agricultural. 2003. Available from http://www.oae.go.th/statistic/ import/inftz.xls [2003, Aug, 2]. (in Thai)

Thailand, Public Health Ministry, Department of Provincial Administration. 2001. Registered Population Notification, Bangkok. (in Thai)

Thailand, Science Technology and Environment Ministry, Pollution Control Department, Office of Toxic and Hazardous Waste Management. 1996. Safety Standard for Pesticide in Environment., pp.1 - 21. (in Thai)

TOXNET. 2003. National Library of Medicine Specialize Information Services. Available from http://toxnet.nlm.nih.gov/cgi-bin/sis/search [2003, Feb 28].