CHAPTER IV

RESULTS AND DISCUSSION

The results are presented in six parts:

4.1) General information of study population from baseline questionnaire
4.2) Children's daily behaviors from questionnaire and activity dairy
4.3) Biological monitoring results
4.4) Environmental and personal monitoring results
4.5) Correlation among potential exposure variables
4.6) Dose and risk estimation

4.1 General Information of the Study Population

The general information (e.g. age, gender, household location, parental occupation, etc.) of preschool participating children is presented in Table 4.1. The participating children in this study consisted of 37 farm children living in or near the Bang Rieng vegetable farm area and 17 reference children living outside the farm area in the same sub-district. Among the farm children were children who resided with vegetable farm families inside the farm area (n=27), and children who lived within non-farm families inside or nearby the farm area, approximately 30-50 meters away (n=10). Children living in a rubber plantation region, 7-8 km away from the vegetable farm area, were selected as the reference children (n=17). The average ages of all participating children were 3.4 years including 3.27 years for female (n=26) and 3.57 years for male (n=28). The data, however, was not available from four of the children during the wet season since they moved out of the area. Three of them were the farm children and the other one was the reference.

Table 4.1 General information for the study population

General Information	Farm Children		Reference		Total	
	n	%	n	%	n	%
1. Participant						
- Children	37	69	17	31	54	100
- Families	33	66	17	34	50	100
2. Gender						
- Male	20	37	8	15	28	52
- Female	17	32	9	17	26	48
						100
3. Age						
- 2 years	5	9	6	11	11	20
- 3 years	11	20	8	15	19	35
- 4 years	12	22	2	4	14	26
- 5 years	9	17	1	2	10	9
						100
4. Parental Occupation						
- Vegetable farmer	27	50	-	-	27	50
- Rubber plantation worker	8	15	15	27	23	42
- Sale	1	2	-	-	1	2
- Employee	1	2	2	4	3	7
						100
5. Parental Education Background						
-First primary school (Grade 1-4)	7	13	3	5	10	18
- Second primary school (Grade 5-6)	15	28	5	9	20	37
- Junior high school (Grade 7-9)	9	17	1	2	10	19
- Senior high school (Grade 10-12)	3	6	5	9	8	15
- Diploma	3	5	1	2	4	7
- Bachelor's degree	-	-	2	4	2	4
						100

Table 4.1 Cont.

General Information	Farm Children n	Farm Children %	Reference n	Reference %	Total n	Total %
6. Family Income (per month)						
- less than 3,000 bath	1	2	2	4	3	6
- 3,001- 5,000 bath	9	17	9	17	18	34
- 5,001-7,000 bath	9	17	4	7	13	24
- 7,001-10,000 bath	14	25	1	2	15	27
- more than 10,000 bath	4	7	1	2	5	9
						100
7. Original Family						
- Local people	10	19	17	31	27	50
- Migrant people	27	50	-	-	27	50
						100
8. Household Location						
- Inside the farm area	27	50	-	-	27	50
- Near the farm area	10	18	-	-	10	18
- Outside the farm area	-	-	17	32	17	32
						100
9. Structure of House						
- Temporary house	26	48	-	-	26	48
- Permanent house	11	20	17	32	28	52
						100
10. Type of Floor						
- Cement floor	21	38	12	22	33	61
- Wood floor	3	6	1	2	4	8
- Porcelain floor	2	4	4	7	6	11
- Dirt floor	11	20	-	-	11	20
						100
11. Household Pesticide Use						
- Yes	13	24	4	7	17	31
- No	24	44	13	24	37	68
						100

Table 4.1 Cont.

General Information	Farm Children n	%	Reference n	%	Total n	%
12. OP Pesticide Use in Farm						
- Chlorpyrifos	6	15	-	-	6	15
- Dicrotophos	18	44	-	-	18	44
- Methyl parathion	4	10	-	-	4	10
- Profenofos	13	32	-	-	13	32

The most common parental occupation was found to be vegetable farming (50%) followed by working for the rubber plantation (41%). All of the vegetable farmers were people who moved from central of Thailand such as Nakornsawan, Petchaboon, Uthaitani, and Chainat provinces. They moved into Bang Rieng community to be employee in the vegetable farms and lived there in average more than 6-7 years. The farm families (50%) as mentioned above also lived in household located inside the field whereas all of the reference children living with non-farm families located outside the farmland (32%). Moreover, the structure of house for the farm families mostly was temporary construction with partially opened house, or built with simple materials. Dirt floor was found in some houses of farm family (20%). This type of floor is the floor which is not constructed by any material, it is just a hard-pressed ground in the field. Accordingly, these housing conditions may increase the possibility of pesticide exposure by which pesticide spray drift or soil and dust outdoors can be easily settled indoors. This information initially indicated that children who lived with the farm family inside the field could be exposed to pesticide more than the children living with non-farm family or outside the farmland.

Regarding the information of pesticide application, it indicated that dicrotophos and profenofos were the predominant OP pesticides used by farmworkers within six months before the study began. The most commonly used OP pesticide was dicrotophos; 44% reported its use. The next most commonly used OP pesticides was profenofos; with 32% reporting its use. More than a half of participants (68%) reported that they did not use indoor pesticides to control insect or pests in their home.

The remaining respondents (31%), however reported using only light ingredient of insecticides with less frequent application, such as using incense burning.

4.2 Children Activity Information

In assessing children's exposure, a much wider distribution of activities need to be considered because children engage in more contact behaviors than do adults (Cohen Hubal *et al.* 2000a). In addition, certain activities and behaviors specific to children may place them at higher risk to certain environment agents (Chance and Harmsen, 1998). This study, therefore, provided the information of children's activities relevant to pesticide exposure which obtained from their parent as described in the following sections.

4.2.1 Children's Activity Pattern

Participating children's parents were asked questions concerning their children's activities. The data using four age categories was evaluated by χ^2-test of homogeneity and Spearman's correlation. Daily behaviors for the participating children are presented as percents of children who exhibited such activities which reported by their parents (Table 4.2). The children's behaviors categorized by ages are illustrated in Figure 4.1.

Both types of mouthing behaviors (placing hands in the mouth and placing nonfood objects in the mouth), were reported mostly at 2 years of age. A significant decrease in reported behavior with increasing age was exhibited for both hand mouthing ($R_s = -0.390$, $p = 0.004$) and object mouthing ($R_s = -0.554$, $p < 0.001$). For playing dirt or soil behavior, the 4 and 5 years old children were most likely to exhibit this activity rather than the younger ($R_s = 0.337$, $p = 0.013$), whereas no significant relationship was found for other behaviors.

Table 4.2 Percentages of reported daily behaviors for the participating children

Behavior	Percent reported by age 2 yrs (n=11)	3 yrs (n=19)	4 yrs (n=14)	5 yrs (n=10)	R_s [a]	p
Put hand to mouth	73	42	28	30	-.430	0.001
Put object to mouth	67	37	21	20	-.412	0.002
Play dirt or soil	73	74	100	100	.337	0.013
Walk barefeet inside home	100	100	86	80	-.302	0.026
Walk barefeet outside home	64	63	79	70	-.094	0.497
Eat outside home	54	32	43	40	.050	0.718
Eat on the floor	82	89	86	90	-.052	0.711

[a] R_s = Spearman's correlation

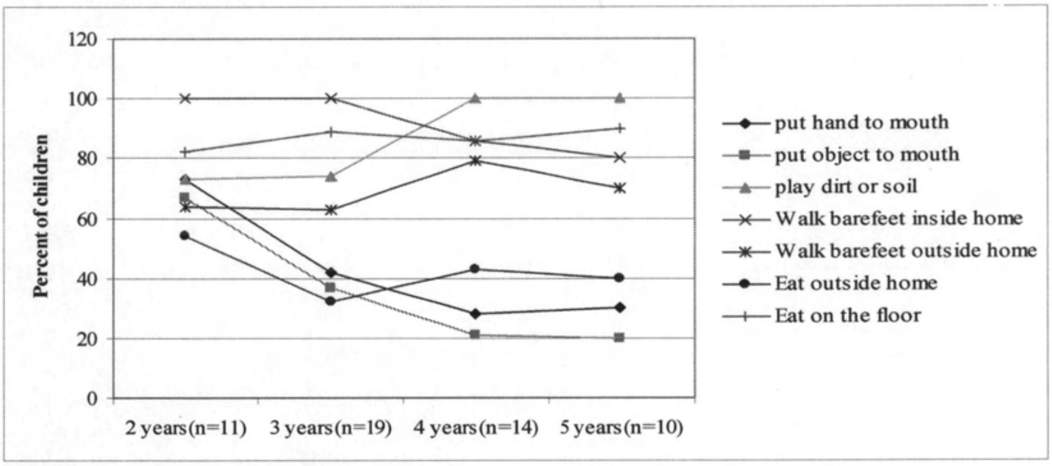


Figure 4.1 Daily behaviors for the participating children categorized by age

The mouthing behavior data from this study was consistent with the fact that hand-to-mouth is common behavior observed for 1-3 year old children (Needham and Sexton, 2000). Black *et al.* (2005) also found that mouthing behaviors decreased with increasing age. They reported the most observed mouthing behavior in the infant and 1 year old, and decreasing the behavior in preschool age (3-5 years). The hand-to-mouth or object-to-mouth behaviors may result in the ingestion of soil and dust, and may present a risk for children (Moya, Bearer, and Etzel., 2004). However, no reporting was found for soil ingestion behavior in the preschool age from the study of Black *et al* (2005). Data also shows that a large percentage of children contacted with dirt and soil, and walk barefeet inside home. These behaviors may be related to children's dermal exposures (Zartarian *et al.*, 1997a and Cohen Hubal *et al.*, 2000a).

Focusing on the farm children, their parents were asked additional potential exposure questions regarding the specific behaviors relevant to pesticide exposures in the farm area (Table 4.3 and Figure 4.2). The parental reports indicated that the behaviors were not significantly related among ages. However, most of the 3-5 year old children reportedly exhibited high percentage of pesticide exposure-specific behaviors for the farm children such as walking or playing in the farm, walk barefeet on the farm, or accompanying with parents into the field.

Table 4.3 Percentages of reported exposure-specific behaviors for the farm children

Behavior	Percent reported by age					
	2 yrs (n=5)	3 yrs (n=11)	4 yrs (n=12)	5 yrs (n=9)	R_s[a]	p
Play and walk in the farm	20	90	66	77	.173	0.306
Walk barefeet in the farm	40	64	33	33	.170	0.314
Play in the farm during pesticide spraying	0	27	16	22	.074	0.663
Accompany with parents into the field	40	63	66	56	.035	0.839
Contact contaminated pesticide containers	33	20	0	33	.034	0.860

[a] R_s = Spearman's correlation

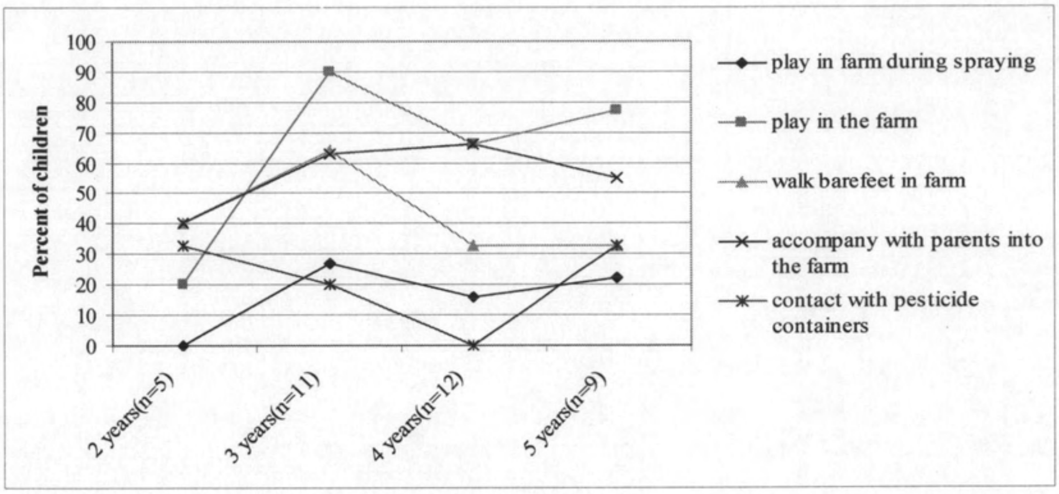


Figure 4.2 Exposure-specific behaviors for the farm children categorized by age

However, some of these farm children's behaviors had significant difference between male and female. Walking or playing in farmland and accompanied with parents into the farm were activities observed for the boys than the girls (Mann-Whitney test, p = 0.023 and p = 0.021, respectively). Therefore, the boys living in the farm could be contacted with outdoor environmental contaminants more than the girls.

4.2.2 Time Spent Indoors and Outdoors

The information of the amount of time which children spend indoors versus outdoors was required in the exposure assessment (US EPA., 2002). This study also presented data on time spent indoors and outdoors within a day for the participating children (Table 4.4).

On average, times spent indoors and outdoors during the dry season for farm children were 5 hrs/day and 6 hrs/day, respectively, whereas times spent indoors and outdoors during the wet season were 6 hrs/day and 5 hrs/day, respectively. The data also shows that the average times spent indoors and outdoors for the reference children during the dry season as well as the wet season were 6 hrs/day and 4 hrs/day, respectively.

Table 4.4 Mean time spent indoors and outdoors (hrs/day) for the participating children [a]

	Dry Season		Wet Season	
	Time Indoors	Time Outdoors	Time Indoors	Time Outdoors
Farm children	4.8	5.7	6.0	4.6
Reference	5.8	4.5	6.1	4.3

[a] Recording only waking time

The additional result revealed that the 95th percentile of time spent indoors and outdoors of the participating children was 7 hrs/day during both seasons. Nevertheless, a number of previous studies involving children's activity pattern survey indicated that the mean time spent indoors (included sleeping time) for 3-5 year old children was 19 hrs/day (Timmer *et al.*, 1985); 18.8 hrs/day (Wiley *et al.*,1991). As a result of these findings, the times spent indoors are likely much higher than the time indoors which reported in this current study.

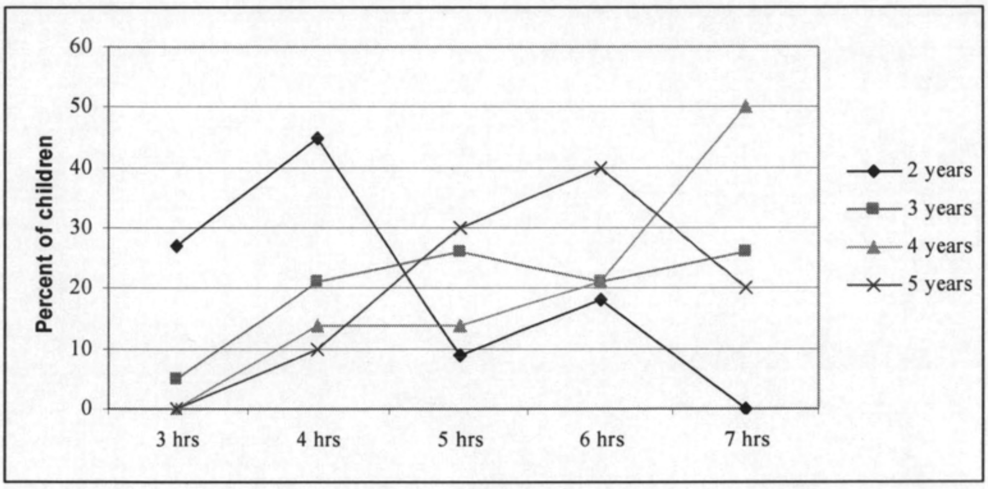
However, the activity recording in this study focused on waking time or the day time of children by excluding the night time which typically is 12 hrs. Thus, the average times spent indoors would have been raised to 18 hrs/day which consistent with the previous findings. Those studies also indicated that the mean time spent outdoors for 3-5 year old children was 2.8 hrs/day (Timmer *et al.*, 1985); 5.2 hrs/day (Wiley *et al.*,1991). An additional study found that the mean time spent outdoors for 1-5 years children was 6.0 hrs/day (Tsang and Klepeis, 1996). Some of these results are consistent with this current study. However, the limitation compared children's activities to other studies could be due to the difference in various factors that may influence to activity performing such as geography, weather, demography, or social culture of each study location.

It also was found that the average time spent outdoors for the farm children during the dry season was significantly higher than that of the reference (independent sample t-test, $p=0.003$). On the other hand, the reference children spent more times indoors compared to the farm children ($p=0.001$). Increasing time spend outside home of children can result in contacting with environmental contaminants including contaminated soil surface (Needham and Sexton, 2000). However, the significant difference for time spent indoors and outdoors between the two groups of the children did not occur during the wet season.

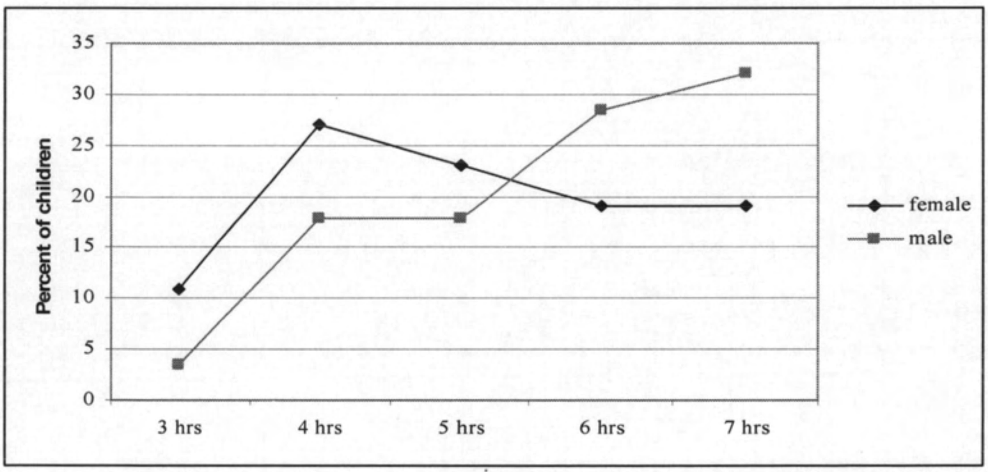
As indicated in the paired sample t-test results, the farm children spent time outdoors during the dry season significantly higher than they did during the wet season ($p<0.0001$). Conversely, they spent time indoors during the wet season significantly higher than they did during the dry season ($p<0.0001$). This finding indicated that the farm children spent a relatively high amount of time outdoors during the dry season and a lesser amount of time in the wet season, as consistent with the study of Wong *et al.* (2000) which found that children spent high percentage of time outdoors during warmer months compared to cold weather. For the reference children, however, there was no significant difference across seasons for their time spent indoors and outdoors.

Categorizing by age and sex, the observed time spent indoors and outdoors of the participants are presented in Figure 4.3 and Figure 4.4, respectively. The observations showed that the youngest children (2 years of age) were likely to spend time indoors longer than they did outdoors whereas the older children spent more time outdoors than they did indoors. In addition, boys were more likely than girls to spend time outdoors. However, the differences by age and sex category were not significant. Although the difference by sex was not quite clear for preschool age children, it could be noted that location in which children spend time may vary by sex as indicated by Cohen Hubal *et al.* (2000a).

However, some studies suggested that difference in duration and frequency of periods spent in particular locations result in different exposures and risks to children that vary with age and developmental stage (Cohen Hubal *et al.*, 2000a). Preschool children can be also located anywhere from private home to day-care facilities and may spend a significant period of time in outdoor environments such as playground and backyard (Bearer, 1995).

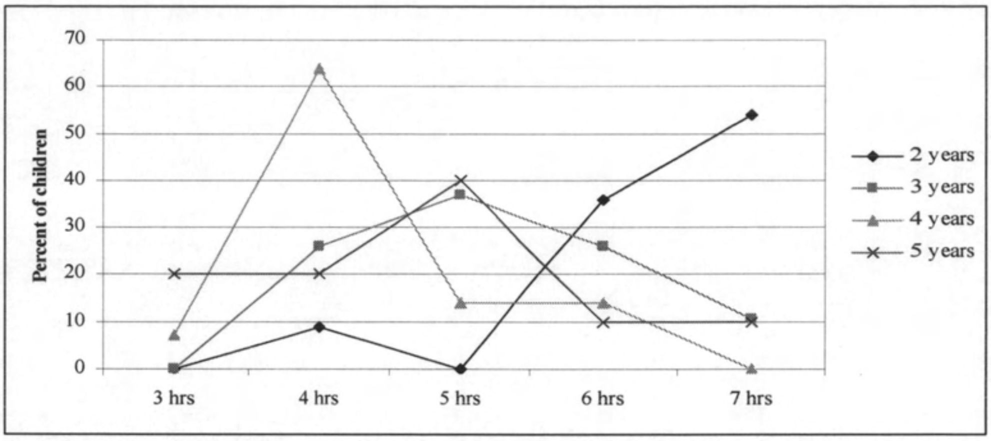


(a)

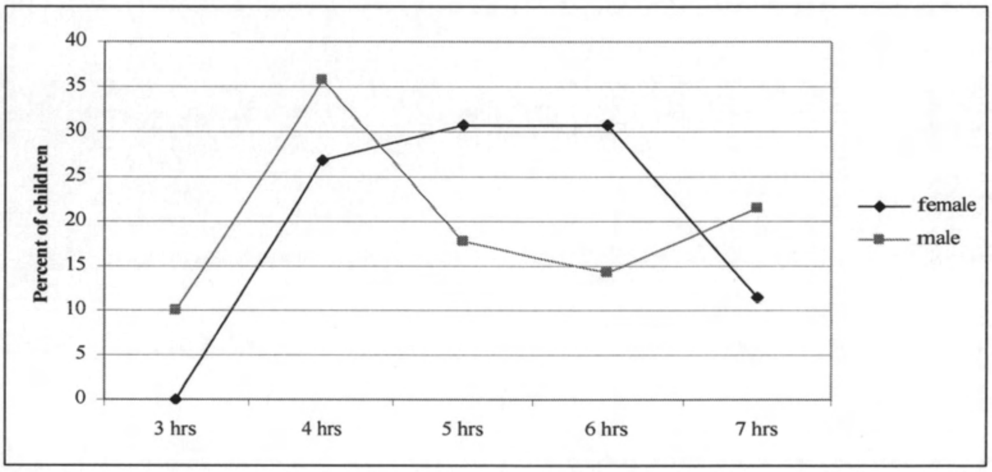


(b)

Figure 4.3 Time spent outdoor for the participating children (a) categorized by age; (b) categorized by gender



(a)



(b)

Figure 4.4 Time spent indoor for the participating children (a) categorized by age; (b) categorized by gender

4.2.3 Children Personal Hygiene Behaviors

The parents also reported the questions related to children's personal hygiene as how many times per day their child washed his/her hands and how many times the child bathed or showered per day during the dry season and the wet season. This information provided an estimate of the time between skin contact with soil and removal of soil by washing (Wong *et al.*, 2000). In this study, the parental reporting for the farm children indicated that hand washing was found to occur an average of 4 times/day during both the dry and the wet seasons. The mean frequency for bathing or showering was 3 times/day during both seasons. The reference children were found to exhibit hand washing activity as a mean of frequency 4 times/day during both seasons. The mean frequency for bathing or showering was 3 times/day during both seasons. No significant difference of frequency exhibiting of both behaviors was found between the farm and the reference. Based on this behavioral information, it can be assumed that hand washing and bathing behaviors may not influence on comparison of the OP pesticide residue on children's hands or feet between the farm children and the reference children, also across the season.

However, only the information from the questionnaire or activity diary can not be used to predict the OP pesticide exposure. Questionnaire data alone would provide a reliable dosimeter for the environmental chemicals of concern and may need to be supplemented with other direct measures (Özkaynak *et al.*, 2005). Therefore, this study needed additional direct environmental or personal measurement together with biological monitoring so that the data from these measurements combined with the questionnaire information could explain a whole picture of children's pesticide exposure in the study site.

4.3 Biological Monitoring

4.3.1 Direct Measurement of Urinary DAP Metabolites

The method for urinary DAP metabolite measurement used in this study consisted of three steps; lyophilization technique, derivatization with pentafluorobenzyl bromide (PFBBr), and analysis by GC-FPD, respectively as shows in Figure 4.5. These procedures were developed for the purpose of urinary DAP metabolite analysis in children non-occupationally exposed to OP pesticides in an agricultural community. The optimal procedures for analyzing the DAP urinary metabolite in this study were adapted based on some previously published procedures described by Oglobline *et al.* (2001a, b) and Brava *et al.* (2004).

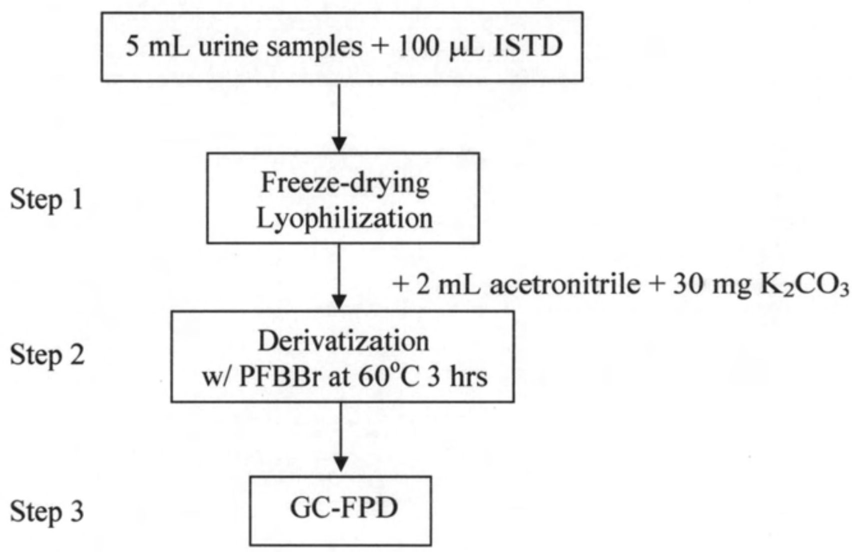
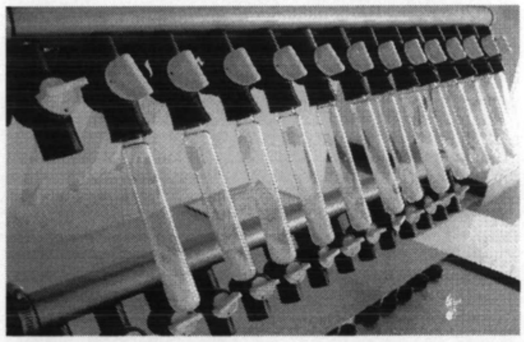


Figure 4.5 Summarized procedures for the urinary DAP metabolite analysis

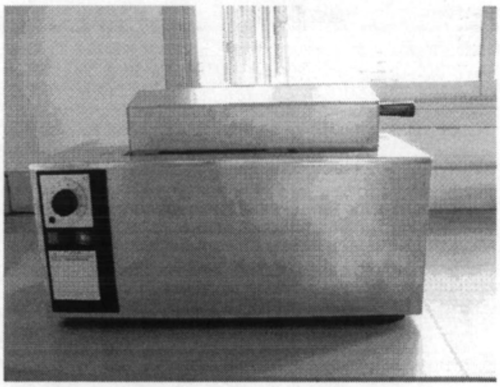
The lyophilization of urine sample was used because it was available technique for removing water from urine samples of DAP analysis, and it was the simplest method to prepare samples with less labor-intensive. The derivatizing recoveries were also greater by using lyophilization technique. In this study, the freeze drying process was taken only 6-7 hours for urine dryness after sufficiently sample frozen. The PFBBr derivatization coupled with solvent, acetronitrile, was selected in order to isolate the metabolites from urine because the PFBBr reagent formed only one reaction product with individual metabolite, and was accepted to use with freeze dry technique (Ogloblin *et al.*, 2001a).

The materials and instruments involved with the DAP measurement are illustrated in Figure 4.6

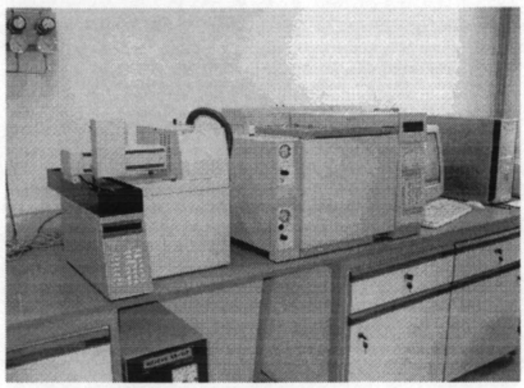
(a) Children's urine samples



(b) Lyophilization



(c) Derivatization



(d) GC-FPD analysis

Figure 4.6 The materials and instruments involved with the DAP metabolite measurement

The reaction temperature and time also play an important role in the extraction of DAP metabolites since the alkylation of DAP metabolites is a thermosensitive reaction and high temperature degradation of the sulfur-containing DAP metabolite;

DMTP, DMDTP, DETP, and DEDTP (Moate *et al.*, 1999; Oglobline *et al.*, 2001a, b). This method presented here performing the derivatization under the reaction conditions of 60°C for 3 hours as suggested by Bravo *et al* (2004). This condition was the best to yield all of DAP metabolites in one derivatization step without the loss of sulfur-containing compounds.

According to the instrument conditions, the DAP metabolites had retention times of DMP 7.14 min, DEP 7.96 min, DMTP 8.28 min, DMDTP 8.77 min, DETP 8.9 min, DEDTP 9.35 min and DBP 9.97 min. The limits of detection (LOD), the derivatization recoveries, the coefficient of variation (%CV), and r value from calibration plot were given in Table 4.5.

Table 4.5 Summary of the method specifications

Analyte	LOD (μg/L)	%CV (n=12)	%Recovery	r
DMP	5	12.0	60.0	0.999
DEP	3	11.0	67.5	0.999
DMTP	1	10.0	107.5	0.999
DETP	1	5.0	98.6	0.996
DEDTP	3	6.0	90.3	0.998

The method shows good linearity for each metabolite with a correlation coefficient (r) of 0.996 or higher. It also found high recoveries for DMTP, DETP, and DEDTP whereas low recoveries were occurred for DMP and DEP. The limits of detection are higher than those of previously reported by using lyophilization and GC/MS-MS technique which range from 0.02-0.5 μg/L (Oglobline *et al.*,2001b) and 0.1-0.6 μg/L (Barvo *et al.*, 2004). It could be due to difference in using a detector of the analysis. Compared to the same analysis detection, the detection limits are lower than the reported in the method using freezing dry process and GC-FPD analysis which range from 5-50μg/L (Oglobline *et al.*, 2001a). The chromatograms of DAP standard spiked urine, and the example chromatogram of children's urine sample in this study are presented in the Appendix C.

4.3.2 Biological Monitoring Results

At least one of five common DAP metabolites was measured in urine samples of participating children. Individual DAP metabolite concentrations adjusted by creatinine (µg/g creatinine) are presented in Table 4.6.

Table 4.6 Concentration of urinary DAP metabolites in participating children's urine

	Dialkylphosphate (µg/ g creatinine)				
	DMP	DEP	DMTP	DETP	DEDTP
Farm children (n=37)			*Dry Season*		
Mean±SD	2.14±2.5	6.13±5.7	8.09±10.2	4.02±7.8	5.8±9.7
Median	1.06 [a, b]	4.75 [b]	4.68 [a,b]	2.57 [a,b]	1.74 [a,b]
Range	0-8.63	0-21.07	0-37.86	0-48.57	0-36.43
Frequency (%)	57	92	81	92	70
Reference children (n=17)					
Mean±SD	0.85±1.5	3.95±2.4	2.73±2.6	1.21±2.2	0.52±0.4
Median	0.0 [a]	3.8	2.9 [a]	0.3 [a]	0.4 [a]
Range	0-5.5	0-8.12	0-9.50	0-8.28	0-1.48
Frequency (%)	29	94	65	47	65
Farm children (n=34)			*Wet Season*		
Mean±SD	0.71±2.0	3.26±2.2	3.15±4.9	1.62±2.6	2.84±7.5
Median	0.0 [b]	2.5 [b]	1.3 [b]	0.9 [b]	0.3 [b]
Range	0-11.16	0-6.45	0-22.87	0-14.12	0-37.24
Frequency (%)	47	88	74	85	59
Reference children (n=16)					
Mean±SD	0.77±0.9	3.26±2.2	3.39±6.1	1.19±2.1	1.26±1.8
Median	0.4	3.8	1.0	0.2	0.5
Range	0-2.66	0-6.63	0-22.76	0-6.56	0-6.53
Frequency (%)	56	94	75	50	56

[a] Significantly different between farm and reference children ($p<0.05$)

[b] Significantly different across seasons ($p<0.05$)

Comparison of the dry season data indicated that the farm children had higher levels of DAP metabolites in their urine compared to the reference children, the significant differences for DMP, DMTP, DETP and DEDTP were p=0.04, p=0.04, p=0.001 and p=0.01, respectively (Mann-Whitney U-Test). During the wet season, a significant difference was not apparent for all DAP metabolites between the farm children and the reference children (p >0.05). The comparisons of the average concentration of five urinary DAP metabolites between the farm and the reference children during the dry and the wet seasons are presented in Figures 4.7.

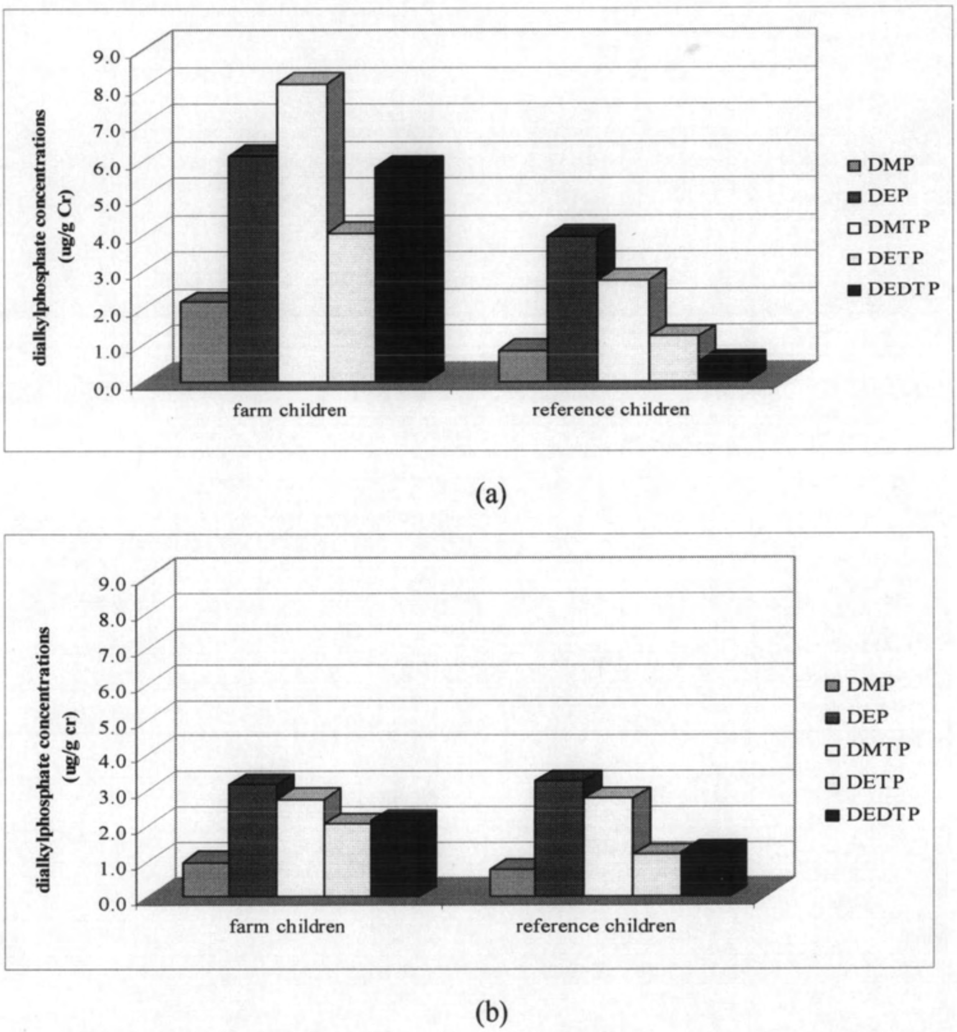


Figure 4.7 Concentrations of urinary DAP metabolites in the participating children (a) the dry season; (b) the wet season

As indicated by Wilcoxon Signed Rank test, the farm children had significantly higher levels of DMP, DEP, DMTP, DETP and DEDTP metabolites in their urine during the dry season compared to the wet season ($p=0.007$, $p=0.001$, $p=0.008$, $p=0.002$, $p=0.009$, respectively). Among the reference children, there was no significant difference observed for DAP metabolites between the dry season and the wet season ($p>0.05$).

Total Urinary OP Metabolites

Considering in term of total urinary OP metabolites, the average concentrations of total DAP metabolites in farm children's urine during the dry and the wet season were 26.2 and 9.6 μg/g creatinine, respectively. The average concentrations of total DAP metabolites in urine of the reference children during the dry and the wet season were 9.3 and 9.8 μg/g creatinine, respectively. The distribution of total OP metabolites in all participating children compared between the dry and the wet seasons are presented as box plot in Figures 4.8. The distribution indicated that the farm children had significantly higher total urinary OP metabolite concentrations compared to the reference during the dry season ($p<0.0001$). During the wet season, the levels of total urinary metabolites in farm children were significantly lower than those of the children during the dry season ($p<0.0001$) whereas there was no significant difference observed for total OP metabolites between the farm and reference children during the wet season.

Figure 4.9 illustrates total OP metabolites in children's urine grouped by proximity to vegetable farm between the dry season and the wet season. The levels of total OP metabolites in urine of the farm children who lived in household located inside the farm area were significantly higher than the farm children living nearby the field, whereas the reference children living outside the farmland had the lowest levels of total OP metabolites (Kruskal-Wallis test, $p<0.0001$). It can be noted that the levels of OP metabolites increased in children who lived more distance from the farmland.

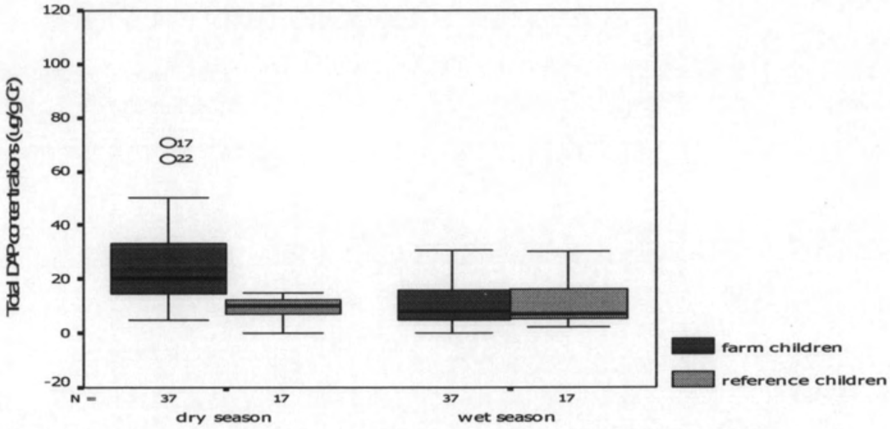


Figure 4.8 Levels of total OP pesticide metabolites categorized by the study population between the dry and the wet seasons

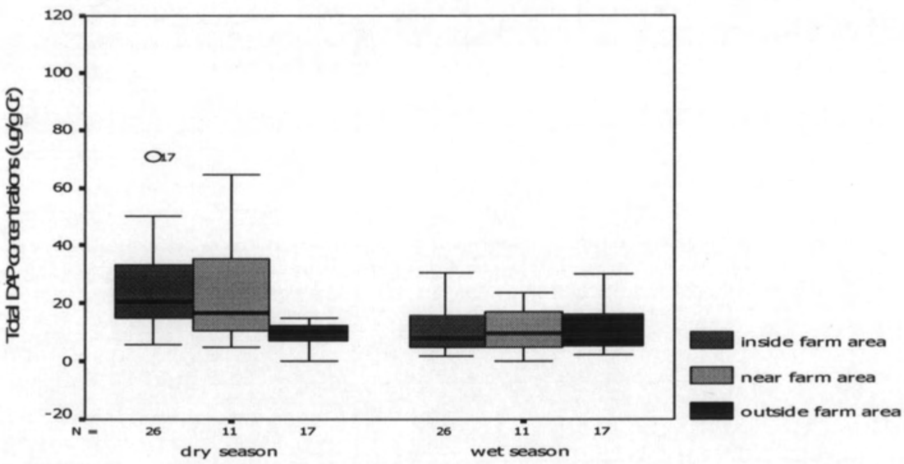


Figure 4.9 Levels of total OP pesticide metabolites in children's urine grouped by household location between the dry and the wet seasons

However, the sample analysis indicated that there was no significant difference of total OP metabolite concentrations across gender of farm children during the dry season and the wet season (Mann-Whitney U-Test; $p>0.05$), as shown in

Figure 4.10. The result also indicated that the metabolite concentration trend with age was not significantly different (Kruskal-Wallis Test, p>0.05) as shows in Figure 4.11.

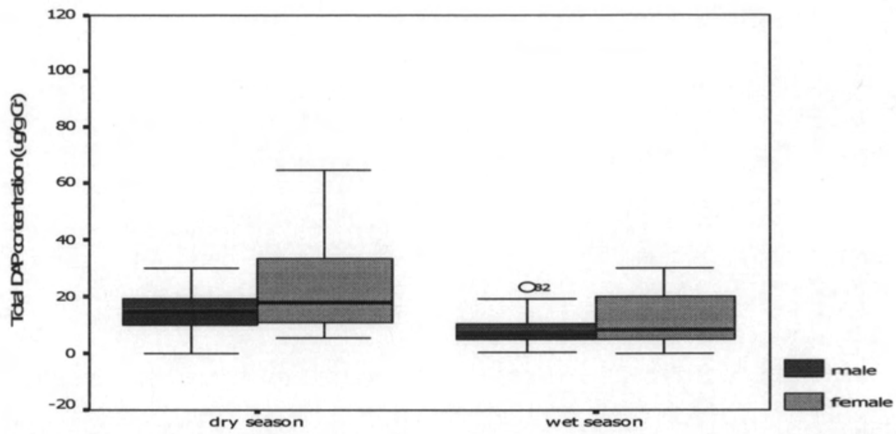


Figure 4.10 Total OP urinary metabolites in the farm children grouped by gender between the dry and the wet seasons

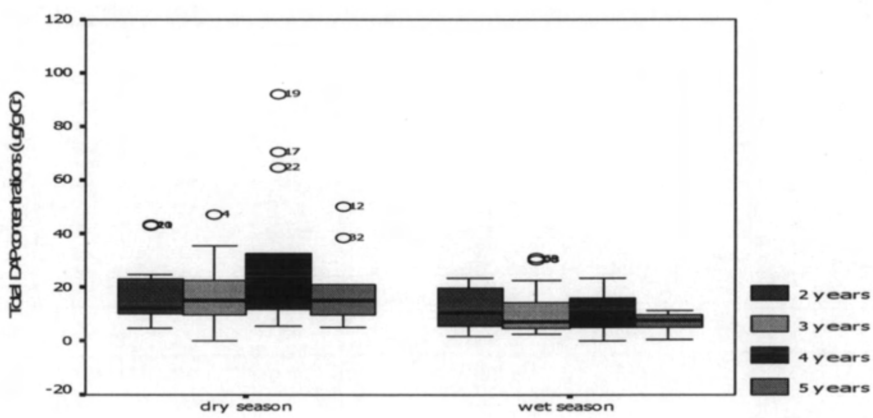


Figure 4.11 Total OP urinary metabolites in the farm children grouped by age between the dry and the wet seasons

Based on this biomonitoring study, the clear differences in the levels of DAP urinary metabolites between the farm children and the reference children during the dry season, and the differences across seasons and farmland proximity supports the assumption that the farm children who lived inside or nearby the vegetable farm areas have elevated pesticide exposures compared to the reference who lived outside the farmland even in the same sub-district.

Normally, vegetable farmers in the study area frequently spray OP pesticides, 3-4 times per crop cycle during the dry season (April-May). During the wet season (September-October), since the weather does not support insect growth, there is considerably less insecticide spraying, 1-2 times per crop. As a result of spraying pattern, the farm children could be exposed to a larger amount of pesticide during the dry season compared to the wet season. A study of Koch *et al.* (2002) supports this finding that elevated levels of OP pesticide metabolite levels associated with agricultural spraying of OP pesticides. They found that DAP metabolite levels during spray months were higher than those during non-spray months.

Measurement of dialkylphosphate (DAP) compounds in urine has been used to assess exposure to organophosphate pesticides in children living in agricultural settings (Loewenherz *et al.* 1997; Azaroff, 1999; Fenske *et al.* 2000a; Lu *et al.* 2000, 2001; Curl *et al.* 2002; Shalat *et al*, 2003). The literatures indicated that children who lived near farmland or had a parent working with agricultural pesticides had higher DAP concentrations compared to the reference children. Decreased levels of OP metabolites were found in children who lived farther away from the farmland. Urinary DAP metabolites measured in the children were also found to be significantly higher during the spraying season.

The findings of this study are consistent with those recent studies that found significant difference of the common urinary OP metabolite levels across agricultural and reference children. Although this study did not exactly identify proximity to treated vegetable farmland, the children who lived with non-farm family located near the farm area tended to have significantly higher OP metabolite levels than did children living with non- farm family outside the farm area.

In addition, neither age nor sex was associated with children's exposure to pesticide in this study. It was reported previously that there was no association between age of the child and DAP concentrations (Lu *et al.* 2001 and Koch *et al.* 2002), and found that gender was not significantly predictive for OP metabolite levels (Shalat *et al.* 2003). However, some studies found that a marginally significant trend of decreasing concentration with increasing age, and younger children had higher exposures than their older siblings, indicated that age appeared to play a role in exposure (Loewenherz *et al.* 1997). Shalat *et al.* (2003) also established that age was inversely associated with urinary levels of OP metabolites. Because the current study focused only on preschool ages, it did not categorize in various age groups of children, the difference among ages may not be quite obvious. In further study, a comparison between young children and older children could help reveal such age difference.

4.3.3 Biologically Based Pesticide Dose Estimates

The dose estimates based on attribution of dialkylphosphate metabolites related to each parent OP pesticides were presented here. Only the relevant metabolites for each compound were considered in the dose calculation (Fenske *et al.*, 2000). The OP pesticides of interest normally produce DEP, DETP, DMTP, or DMDTP, thus the dose estimation was limited to these four common DAP metabolites. In this study, however, profenofos was excluded in the dose estimation because there is no applicable information for its metabolite reported in US EPA's document (US EPA.,2003). Concentrations of dialkylphosphate metabolites and total molar concentrations in the urine which involved with the biologically based pesticide dose calculation are presented in Table 4.7. Total dimethyl DAP levels for dicrotophos and methyl parathion were not significantly different between the farm and the reference children, neither significant difference across seasons. Only total diethyl DAP concentration for chlorpyrifos was found to be significant difference between study groups, and also difference across seasons (p=0.005 and p=0.019, respectively).

Table 4.7 Total molar concentrations (μmol/L) in participating children's urine

	Dialkylphosphate Metabolites (μg/L)				Total Molar Concentrations (μmol/L)		
	DMP	DEP	DMTP	DETP	Dimethyl[a]	Dimethyl[b]	Diethyl[c]
Dry Season							
Farm Children							
Mean±SD	1.65±2.1	3.43±3.8	3.13±4.7	1.75±1.9	0.025±0.04	0.04±0.03	0.033±0.03
Median	2.5	1.5	1.5	1.4	0.12	0.03	0.021
Maximum	10.29	15.84	21.49	8.61	0.17	0.15	0.153
Reference Children							
Mean±SD	0.74±1.2	1.61±0.9	1.89±2.7	0.77±1.8	0.015±0.5	0.02±0.02	0.015±0.01
Median	0.0	1.5	1.5	0.0	0.012	0.011	0.013
Maximum	2.5	4.93	9.37	7.61	0.07	0.06	0.05
Wet Season							
Farm Children							
Mean±SD	1.29±1.5	2.45±1.8	2.20±3.6	1.47±1.5	0.017±0.3	0.03±0.03	0.03±0.01
Median	0.0	1.5	1.5	1.1	0.012	0.02	0.024
Maximum	6.39	8.21	20.33	6.04	0.16	0.16	0.053
Reference Children							
Mean±SD	1.40±1.3	2.0±2.0	1.31±0.7	0.97±1.5	0.01±0.003	0.02±0.01	0.02±0.02
Median	0.0	1.5	1.5	0.0	0.012	0.03	0.012
Maximum	2.5	4.93	9.37	7.61	0.023	0.04	0.07

[a] Dimethyl molar for dicrotophos (DMP metabolite)

[b] Dimethyl molar for methyl parathion (DMP and DMTP metabolites)

[a] Diethyl molar for chlorpyrifos (DEP metabolite)

Table 4.8 Dose estimates (μg/kg/day) for each OP pesticides based on attribution of dialkylphosphate metabolites

	Farm Children						Reference Children					
Pesticide (RfD[a])	Mean	25th	50th	75th	90th	Max	Mean	25th	50th	75th	90th	Max
Dry Season												
Dicrotophos (0.1)	0.17	0.08	0.08	0.13	0.51	1.16	0.11	0.00	0.08	0.08	0.44	0.50
Chlorpyrifos (0.3)	0.33	0.13	0.21	0.45	0.66	1.54	0.17	0.11	0.14	0.17	0.43	0.60
Methyl parathion (0.25)	0.28	0.08	0.24	0.35	0.71	1.20	0.17	0.09	0.13	0. 24	0.50	0.57
Wet season												
Dicrotophos (0.1)	0.12	0.00	0.08	0.08	0.32	1.09	0.09	0.08	0.08	0.08	0.10	0.16
Chlorpyrifos (0.3)	0.26	0.13	0.29	0.38	0.43	0.53	0.2	0.10	0.13	0.22	0.63	0.69
Methyl parathion (0.25)	0.20	0.08	0.19	0.24	0.42	1.29	0.17	0.08	0.24	0.24	0.26	0.32

[a] Chronic oral reference dose in units of μg/kg/day (US EPA., 1994)

The individual dimethyl or diethyl OP pesticide doses for participating children are presented in Table 4.8. The average of the estimated daily absorbed doses of dicrotophos, chlorpyrifos, and methyl parathion for the farm children during the dry season were 0.17, 0.33, and 0.28 μg/kg/day which exceeded the US EPA reference dose (RfD). During the wet season, only the absorbed dose of dicrotophos was apparent to be above the RfD value. On the other hand, the average of the dose estimates of nearly all the pesticides, excluding dicrotophos, were found to be less than the RfD during the dry and the wet seasons for the reference children. The dose estimate of dicrotophos almost equals to the RfD value, it was assumed to be not hazard in concern for the reference children. The result indicated that during the dry season, the farm children had higher potential hazard from OP pesticide exposure than they had during the wet season. This finding related to the occurrence of the total OP metabolites in the children's urine which was previously presented in this study.

This study also indicated that the fraction of the daily absorbed doses that exceeded the RfD values for the OP pesticides in the full population. During the dry season, 24% of the farm children's doses and 18% of the reference children's doses exceeded the dicrotophos RfD; 38% of the farm children's doses and 12 % of the reference children's doses were above the RfD for chlorpyrifos; 27% of the farm children's doses and 23 % of the reference children's doses exceeded the RfD for methyl parathion. During the wet season, the percentage of children exceeding the RfD for dicrotophos was 13% for the farm children and 6% for the reference children; 35% of the farm children's doses and 12 % of the reference children's doses were above the RfD for chlorpyrifos; 16% of the farm children's doses and 6 % of the reference children's doses were above the RfD for methyl parathion.

This finding supported the assumption of the study that the farm children were likely to have potential hazard of OP pesticide exposure higher than the reference children. The percentage of the farm children who have absorbed doses exceeding the US EPA reference doses was higher than those of the reference children even during the less spraying season. Nevertheless, the potential hazard estimated from the biomarker data did not identify the specific exposure pathways.

Based on biological monitoring, it demonstrates that biomarkers may play a role in understanding of the pesticide exposure in children. They are also important in children as their absorbed dose for a given external exposure levels (Weaver *et al.*, 1998). Biomarkers, however, can only provide the information that a person has been exposed to contaminants and can possibly present some quantitative data concerning when an exposure occurred (Lioy, 1995). In addition, the attribution of DAP metabolite measurements to specific pesticides is difficult without detailed knowledge of sources and exposure pathways (Fenske *et al.* 2000a). Therefore, there is a need for continued performing of external markers through environmental and personal monitoring.

4.4 Environmental and Personal Monitoring

Four OP pesticides of interest including chlorpyrifos, dicrotophos, methyl parathion, and profenofos were detected from surface soil samples, surface floordust collected from children's household. Because approximately more than 50% of exposure values were less than LOD, these values were assigned to be one half of LOD. A number of detectable samples (frequency of detection) were presented for comparison among the different media.

4.4.1 Soil Samples

The mean concentrations for each target OP pesticide in composite soil samples collected from home of farm children and reference children during the dry season and the wet season are presented in Table 4.9. A comparison of mean OP pesticide concentrations in soil between the farm children and the reference children during the dry season indicated that the farm children had significantly higher concentrations of dicrotophos, chlorpyrifos, and profenofos (Mann-Whitney U test; p = 0.002, 0.019, and 0.027, respectively). Dicrotophos and profenofos were the most frequently detected pesticides, 40% and 32%, respectively. Seasonal comparison also indicated that the households of the farm children had significantly higher levels of dicrotophos and profenofos residue in soil during the dry season than those during the wet season (Wilcoxon Signed-rank test; $p=0.015$ and $p<0.001$, respectively). During the wet season, profenofos was found only 12% of soil samples collected from the farm children's households, whereas the reference's household had non-detectable level of all OP pesticides of interest during the wet season.

A significant difference of OP pesticide levels in soil samples from household of the farm children and the reference children was apparent only for dicrotophos during the wet season ($p = 0.012$). Profenofos levels also appeared to be elevated ($p = 0.054$). A significant difference was not found for methyl parathion during both the dry season and the wet season. Dicrotophos and profenofos were also the most frequency detected pesticides during the wet season.

Table 4.9 OP pesticide concentrations in soil (μg/g soil) collected from children's household

	Dry Season		Wet Season	
	Farm Children	Ref. Children	Farm Children	Ref. Children
Dicrotophos				
Mean	0.26	<LOD	0.16	<LOD
Range	<LOD-1.20	<LOD	<LOD-0.36	<LOD
% detectable [a]	40.5	0	26.5	0
Chlorpyrifos				
Mean	0.18	<LOD	0.15	<LOD
Range	<LOD-0.55	<LOD	<LOD-0.42	<LOD
% detectable	24.3	0	17.6	0
Methyl parathion				
Mean	0.16	<LOD	0.15	<LOD
Range	<LOD-0.67	<LOD	<LOD-0.35	<LOD
% detectable	13.5	0	17.6	0
Profenofos				
Mean	0.25	0.14	0.16	<LOD
Range	<LOD-0.83	<LOD-0.27	<LOD-0.47	<LOD
% detectable	32.4	11.8	20.6	0

[a] % detectable = Percentage of samples with detectable concentrations (> LOD)

LOD for each OP pesticides = 0.24 μg/g soil

4.4.2 Surface Floor Dust Samples

The mean pesticide loadings for each target OP pesticides residue in housedust samples collected from household of farm children and reference children during the dry season and the wet season are presented in Table 4.10.

Table 4.10 OP pesticide loadings in surface floor dust samples (μg/cm^2) collected from children's household

	Dry Season		Wet Season	
	Farm Children	Ref. Children	Farm Children	Ref. Children
Dicrotophos				
Mean	0.00053	<LOD	0.00027	<LOD
Range	<LOD-0.003	<LOD-0.0004	<LOD-0.0006	<LOD-0.0004
% detectable [a]	46	12	21	6
Chlorpyrifos				
Mean	0.00037	<LOD	0.00025	<LOD
Range	<LOD-0.0015	<LOD-0.0004	<LOD-0.0008	<LOD-0.0004
% detectable	27	12	12	6
Methyl parathion				
Mean	0.00038	<LOD	0.00025	<LOD
Range	<LOD-0.0016	<LOD	<LOD-0.0006	<LOD
% detectable	24	0	21	0
Profenofos				
Mean	0.00049	<LOD	0.00026	<LOD
Range	<LOD-0.004	<LOD-0.0005	<LOD-0.0009	<LOD-0.0004
% detectable	35	6	15	6

[a] % detectable = Percentage of samples with detectable concentrations (>LOD)

LOD for each OP pesticides = 0.004 μg/cm^2

A comparison of mean OP pesticide loadings in housedust for participating children household during the dry season indicated that the farm children's household had significantly higher concentrations of dicrotophos, chlorpyrifos, methyl parathion, and profenofos than those of the reference (Mann-Whitney U test; $p = 0.001, 0.028, 0.019$, and 0.024, respectively). However, a significant difference was not apparent for all of four OP pesticides during the wet season (Mann-Whitney U test; $p > 0.05$). Compared to the same method by using the surface wipe sampling, the mean levels of chlorpyrifos in this study was not much different from that in the study of Fenske *et al.* (2002) which were 0.0006 $\mu g/cm^2$ of chlorpyrifos measured on non-carpeted floor. Lu *et al.* (2000) found that the mean of some OP pesticides (azinphos methyl and phosmet) residue on non-carpeted floor ranged from 0.001to 0.002 $\mu g/cm^2$.

Seasonal comparison of OP pesticide levels in surface floor dust samples indicated that the households of the farm children had significantly higher levels of dicrotophos, chlorpyrifos and profenofos residue in the floor dust during the dry season compared to the wet season (Wilcoxon Signed-rank test; $p=0.005$, 0.007 and 0.22, respectively). The analytical results also found that dicrotophos and profenofos were the most frequently detected pesticide in floor dust of the farm children's household during the dry season (46% and 35%, respectively) whereas those of the reference children had non-detectable level of all OP pesticides.

4.4.3 Dermal Wipe samples

Dermal wipe samples were collected from both hands and feet of the participating children. The mean concentration of each target OP pesticide in dermal wipe samples collected from the farm children and the reference children are presented in Table 4.11 and Table 4.12, respectively. The levels of dicrotophos and profenofos were apparent in hands and feet wipe samples of farm children significantly higher than those of reference children during the dry season (Mann-Whitney Test, $p=0.006$ and $p=0.002$ for hand wipe; $p=0.005$ and 0.019 for feet wipe, respectively). The significant differences were found only dicrotophos both on children's hands and feet during the wet season.

Table 4.11 OP pesticide concentrations on children's hands (μg/two hands)

	Dry Season		Wet Season	
	Farm Children	Ref. Children	Farm Children	Ref. Children
Dicrotophos				
Mean	0.24	0.12	0.15	<LOD
Range	<LOD-0.68	<LOD-0.26	<LOD-0.46	<LOD
% detectable [a]	43	12	18	0
Chlorpyrifos				
Mean	0.14	<LOD	<LOD	<LOD
Range	<LOD-0.58	<LOD	<LOD	<LOD
% detectable	11	0	0	0
Methyl parathion				
Mean	0.12	<LOD	0.11	<LOD
Range	<LOD-0.31	<LOD	<LOD-0.33	<LOD
% detectable	16	0	9	0
Profenofos				
Mean	0.19	<LOD	0.11	<LOD
Range	<LOD-0.58	<LOD	<LOD-0.26	<LOD
% detectable	41	0	6	0

[a] % detectable = Percentage of samples with detectable concentrations (>LOD)

LOD for each OP pesticides = 0.2 μg/two hands

Focusing on the farm children, there were significant differences observed for dicrotophos and profenofos on their hands and feet between the dry season and the wet season. The levels of dicrotophos residue on hands and feet during the dry season were significantly higher than those during the wet season (Wilcoxon Signed-rank test; p=0.007 and p=0.022, respectively). The levels of profenofos residue on hands and feet during the dry season were significantly higher than those during the wet season (Wilcoxon Signed-rank test; p=0.002 and p=0.004, respectively).

Table 4.12 OP pesticide concentrations on children's feet (μg/two feet)

	Dry Season		Wet Season	
	Farm Children	Ref. Children	Farm Children	Ref. Children
Dicrotophos				
Mean	0.25	0.11	0.14	<LOD
Range	<LOD-1.48	<LOD-0.23	<LOD-0.56	<LOD
% detectable [a]	41	12	21	0
Chlorpyrifos				
Mean	0.14	<LOD	0.11	<LOD
Range	<LOD-0.51	<LOD	<LOD-0.39	<LOD
% detectable	16	0	6	0
Methyl parathion				
Mean	0.14	<LOD	<LOD	<LOD
Range	<LOD-0.48	<LOD	<LOD	<LOD
% detectable	16	0	0	0
Profenofos				
Mean	0.18	<LOD	0.11	0.11
Range	<LOD-0.87	<LOD	<LOD-0.31	<LOD-0.23
% detectable	27	0	6	12

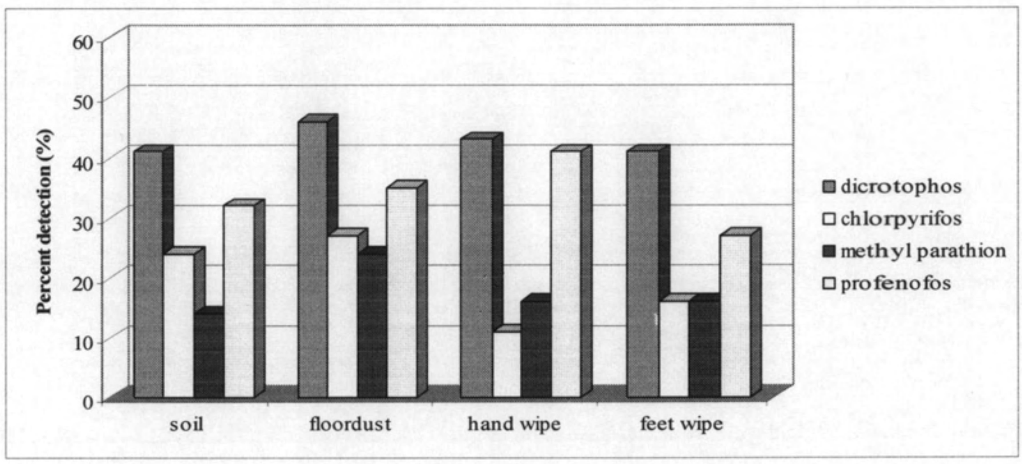
[a] % detectable = Percentage of samples with detectable concentrations (>LOD)

LOD for each OP pesticides = 0.2 μg/two feet

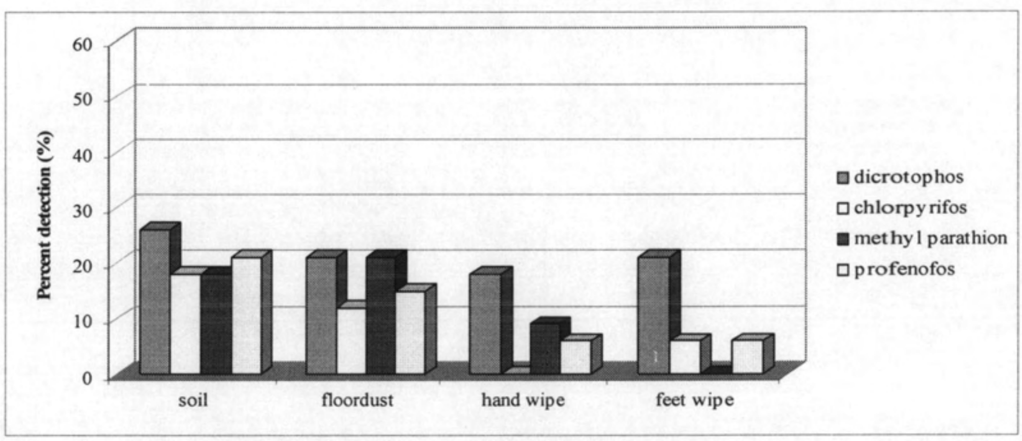
Considering in term of percent of detection, dicrotophos and profenofos were the most frequently detected pesticides on the farm children's hands during the dry season (43% and 41%, respectively). The frequencies of detection of four target OP pesticides residue in both hands and feet wipes were higher than those of the reference during the dry season.

4.4.4 OP Pesticide Residues among Different Exposure Media

The comparison of OP pesticides of interest residues among various exposure media (soil, housedust, children's hand and feet) in form of frequencies of detection, focusing on the farm children during the dry season and the wet season, are illustrated in Figure 4.12.



(a)



(b)

Figure 4.12 Frequency of detection of OP pesticides in soil, floor dust, hand wipe and feet wipe samples of the farm children (a) the dry season; (b) the wet season

A number of detectable samples of four OP pesticides in all environmental and personal media were likely to decrease in the wet season compared to the dry season.

This finding indicated that spraying season is an important factor for occurring of the pesticides in exposure media for the farm children. It was consistent with the evidence of biological monitoring as previously discussed in this study. High pesticide spraying in the dry season resulted in high frequency detectable of four OP residues in soil and floordust, whereas the frequency detectable of pesticide residues in such environmental media was appeared to be low during the wet season. Consequently, the children would be exposed to a larger amount of pesticide during the dry season by either coming into direct and/or indirect contact with contaminated soil or surface dust both indoors and outdoors than they would be during the wet season, as found that the frequency detectable of the pesticides in dermal wipes of the children during the dry season was higher than it was during the wet season.

Dicrotophos was found to be the most frequently detected OP pesticide in soil, floor dust, and dermal wipe samples followed by profenofos, chlorpyrifos and methyl parathion, respectively. This finding was supported by the information of pesticide usage in the farm area during six months before the time of sample collection. It was revealed that the most applied OP pesticide was dicrotophos (44%), followed by 32% profenofos, 15% chlorpyrifos, and 10% methyl parathion as given in the general information (Table 4.1). As a result, the levels of dicrotophos and profenofos were appeared to be mostly detected compounds in each sampling media. In addition, dicrotophos degradation normally is not induced by exposure to light. Laboratory studies found that dicrotophos was stable to photolysis in soil surface (EXTOXNET, 1995) resulted in an apparently high residue in soil.

Additionally, dicrotophos and profenofos presented as the number of detection (non-detected=0; detected=1) in floordust were significantly correlated with the house construction (temporary =1; permanent =2). Dicrotophos and profenofos in floordust were appeared to be high frequent detectable for the temporary construction ($R_s = -0.60$, $p < 0.0001$ and $R_s = -0.355$, $p = 0.031$, respectively). However, this finding was established only during the dry season, and other factors including type of floor, indoor pesticide use, and house cleaning did not have a significant relationship with the apparent of any OP pesticide in floordust during both seasons. All of the temporary houses in this study were located inside the farmland and belong to the farm family.

Besides the house construction, residences nearby the fields can be contaminated by subsequent wind circulation of dust from the fields, particularly during the dry season which was high ventilation of the wind. A study of Lewis *et al.* (2001) has demonstrated that pesticides applied outside dwellings are re-deposited inside the house within hours. Therefore, high levels of non-occupational pesticide exposure might be expected in the children living in the temporary house construction located close to the fields. In addition, because pesticide spray drift, or soil and dust can be settled indoors, the children can be exposed to pesticides indirectly through dust in their home or by entering from sprayed fields.

This study also found that the measured levels of OP pesticides in indoor floor dust of the farm children's household were lower than those in outdoor soil. This finding was not consistent with some previous studies (Lewis *et al.*, 1994; Simcox *et al*, 1995; and Whitmore *et al.*, 1994). They reported that the levels of OP pesticides residue in housedust were higher than those in soil, and implied that some pesticide residues can persist in indoor environments. Conversely, there was a different reason given that many pesticides can be hydrolyzed under the moisture condition which was likely found in indoor environments rather than the dry condition in outdoor environments (Schmidt, 1999).

The different result of the studies could be due to a difference in the method used for housedust sampling. Surface floordust wipe technique was carried out for housedust collection in this study, whereas those previous studies used a high volume surface sampler. The difference in the sampling and analysis protocols may limit comparisons. There is no uniform standard for settled dust sampling methods (IPCS, 2000), making it impossible to compare one study with another. Although the levels of OP pesticides in floordust appeared to be low in this study, floordust still was an important source because it provides an opportunity for children exposure since presence of pesticides on a floor predicted pesticides on hands (Quandt *et al.*, 2004).

Dust can be transfered to children's hands which is of particular concern for children who exhibit mouthing behaviors (Lioy *et al.*, 2002).

The presence of pesticides on hands and feet of the farm children from this study supported the assumption that the children can be exposed to the pesticides through the outdoor soil or indoor dust via dermal contact. It was also consistent with the parental report that the children mostly exhibited the activities involved with soil or dirt contact and walk barefeet outside home. Furthermore, hand mouthing was a significant behavior exhibited by the children. This behavior can be contributor to soil or dust ingestion exposure as addressed from US EPA guidelines (1998) that soil and dust may be ingested by children as a result of normal mouthing behaviors.

4.5 The Relationship among Potential Exposure Variables

4.5.1 Correlation among OP Pesticide Residues in Different Exposure Media

Spearman correlation coefficients were calculated to examine the relationship between levels of target OP pesticides in different environmental and personal samples of the farm children during the dry season and the wet season. In spite of the high numbers of non-detectable residues in soil, floordust, and dermal wipe samples, each of paired variables (e.g. outdoor soil and indoor floordust) of the farm children were found significant correlation for some OP pesticides of interest as presented in Table 4.13, 4.14, 4.15, and 4.16.

Table 4.13 Spearman rank correlation coefficients (r) between OP levels in outdoor soil and indoor floordust of the farm children's household

	Dry Season		Wet Season	
Pesticide	*r*	*p*	*r*	*p*
Dicrotophos	0.51	0.001	0.18	0.31
Chlorpyrifos	0.27	0.11	0.17	0.34
Methyl parathion	0.23	0.17	0.29	0.09
Profenofos	0.40	0.015	0.23	0.18

Table 4.13 shows that there were moderate significantly correlated between outdoor soil and floor dust for dicrotophos and profenofos during the dry season, with Spearman correlation coefficients of 0.51 and 0.40, respectively. It appears that the indoor levels of those compounds were derived from outdoor application. In addition, the contaminants presenting in indoor dust may originate from outdoor soil, road dust, or work site by tracking into home (IPCS, 2000). Pesticide can be also contaminated indoors through spray drift spreading by wind (Quandt *et al.*, 2001)

Table 4.14 Spearman rank correlation coefficients (r) between OP pesticides on hands and feet of the farm children

	Dry Season		Wet Season	
Pesticide	*r*	*p*	*r*	*p*
Dicrotophos	0.67	<0.0001	0.61	<0.0001
Chlorpyrifos	0.38	0.02	-	-
Methyl parathion	0.56	<0.0001	-	-
Profenofos	0.25	0.14	0.48	0.004

Table 4.14 shows that the moderately significant correlations between hands and feet wipe were found for dicrotophos and methyl parathion during the dry season. However, the correlations between hand and feet wipes were found only for dicrotophos and profenofos during the wet season. The correlation between pesticide on hands and on feet could be explained with the children's behaviors as reported that the children often play and contact soil, and walk barefeet outside home, thus the pesticide can residue on children's skin, both hands and feet simultaneously.

Table 4.15 Spearman rank correlation coefficients (r) between OP concentration in surface floor dust and dermal wipes of farm children's household

	Dry Season		Wet Season	
Pesticide	*r*	*p*	*r*	*p*
Floordust and Hand wipes				
Dicrotophos	0.37	0.026	0.19	0.47
Chlorpyrifos	0.02	0.92	-	-
Methyl parathion	0.07	0.68	0.15	0.43
Profenofos	0.53	0.001	0.12	0.52
Floordust and Feet wipes				
Dicrotophos	0.19	0.25	0.08	0.66
Chlorpyrifos	0.05	0.75	0.09	0.61
Methyl parathion	0.13	0.43	-	-
Profenofos	0.44	0.007	0.12	0.52

Table 4.15 shows that there were the significant correlations between floordust and dermal wipes (both hands and feet) for profenofos during the dry season, with Spearman correlation coefficients of 0.53 for hands and 0.44 for feet, respectively. Dicrotophos was found only for the correlation between floordust and hand wipe. Although, the correlation between floordust levels and dermal loadings was not quite strong, it suggests that floordust is an important media for children's OP exposure through dermal contact.

Table 4.16 Spearman rank correlation coefficients (r) between OP concentration in soil and dermal wipes of the farm children's household

	Dry Season		Wet Season	
Pesticide	*r*	*p*	*r*	*p*
Soil and Hand wipes				
Dicrotophos	0.42	0.009	0.13	0.47
Chlorpyrifos	0.04	0.81	-	-
Methyl parathion	0.04	0.82	0.14	0.42
Profenofos	0.29	0.07	0.23	0.18
Soil and Feet wipes				
Dicrotophos	0.20	0.24	0.08	0.29
Chlorpyrifos	0.15	0.39	0.12	0.60
Methyl parathion	0.03	0.87	-	-
Profenofos	0.22	0.18	0.50	0.003

Table 4.16 indicated that there was a significant correlation between soil and hand wipe for dicrotophos during the dry season with the Spearman correlation coefficients of 0.42. For the wet season, a significant correlation was observed only for profenofos with paired outdoor soil and feet wipe values. Surprisingly that there were poor correlations between soil levels and dermal loadings despite the two media were closely linked as the exposure media relevant to children's activities such as contact dirt or soil, walk barefeet outside home.

4.5.2 Relationship between Children's Behavioral Variables and OP Exposure

The results of multiple regression modeling to identify activities of the farm children associated with pesticide exposure (as a total urinary OP metabolite) are presented in Table 4.17. Demographic information (e.g. age, gender, weight, family's income, family's education) and children's behavior data were included in the regression model as independent variables. Total urinary OP metabolite concentration (log transformed) was a dependent variable of the model.

Table 4.17 Linear regression model estimating the association of farm children's activities and total urinary OP metabolites [a]

Variable [b]	Parameter Estimate	Standard Error	Standard Coeffecient	*P* Value	Partial R^2
Intercept	1.014	0.178		<0.0001	
Walk barefeet outside	0.297	0.112	0.406	0.013	0.457
Put hand to mouth	0.098	0.042	0.356	0.027	0.411
Play in the farm	0.099	0.040	0.373	0.020	0.429

[a] Correlation of model; $R = 0.619$, $R^2=0.383$, adjusted $R^2=0.315$; p-Value = 0.004

[b] Categorized variables; 1= never, 2=almost never, 3=sometimes, 4=often

The model best fit the farm children's activities to OP exposure was elaborated as the following equation:

$$\log(\text{DAP metabolites}) = 1.01 + 0.297(\text{walk barefeet outside home}) + 0.098(\text{put hand to mouth}) + 0.099(\text{play in the farm})$$

The regression model indicated that there was no significant association among children's demographic variables with urinary DAP metabolites. The output found only the association of children's behavioral variables and the urinary metabolites (Table 4.17). It showed that three specific behaviors of the farm children were significant positively associated with the DAP metabolites including walking barefeet outside home, putting hand into mouth, and playing in the field. The more exhibit these activities, the higher levels of DAP metabolite in the farm children's urine. Consequently, such children's activities were significant predictors for OP pesticide exposure in this model, and used to be initial concern in reducing exposure strategies. Although, these behavioral variables were consistently identified in the statistical analysis as factors that affected the levels of total DAP metabolites for the farm children, such behaviors explained only 31.5 % of the variation in the OP exposure. Data collected by self-reporting may explain the moderate predictive value of the model. Attempts were made to distinguish the categorized variables for children's activities, this may have led to fill-in some inexact data.

4.5.3 Relationship between OP Residue Variables and OP Exposure

The results of multiple regression model to examine the association of OP pesticides in environmental and personal samples with the total of DAP metabolites for the farm children are presented in Table 4.18.

Table 4.18 Linear regression model estimating the correlation of OP residues and total urinary DAP metabolites [a]

Variable	Parameter Estimate	Standard Error	Standard Coeffecient	*P* Value	Partial R^2
Intercept	1.909	0.186		<0.0001	
Dicrotophos in hands	0.403	0.144	0.414	0.008	0.433
Profenofos in feet	0.352	0.171	0.304	0.047	0.333

[a] Correlation of Model; R=0.509, R^2=0.259, adjusted R^2=0.215; p-Value =0.006

The model for the OP exposure in the farm children was elaborated as follows:

log (DAP metabolites) = 1.9 + 0.403 (dicrotophos on hands)
+ 0.352 (profenofos on feet)

This model indicated that the levels of dicrotophos in hand wipes and the levels of profenofos in feet wipes were significantly associated with increasing of urinary DAP metabolites in the farm children. It can be seen that the predictors in the model involved dermal contact which measured through the personal media. The regression model explained only 21.5 % of the variability in exposure. It can be noted that there was a wide variability in OP pesticide measurements within subjects. In particular, OP pesticide levels in environmental media (e.g. soil and floordust) were not a significant predictor in the model. One reason can be consistent this finding is that all data input in the model were derived from cross-sectional investigation, results in lack of the correlation between environmental and biologic measurement (Rappaport *et al.*, 1995).

Some researches, even studied on pesticide exposure for adult farmworkers, are consistent with partial of this finding. A study investigating pesticide exposure for farm family in Iowa has found significant association between urinary and hand wipe levels of atrazine (Curwin *et al.*, 2005). Others have found positive correlations between pesticide hand exposure and urinary levels among greenhouse pesticide applicators and agricultural workers (Aprea *et al.*, 1994; Tuomainen *et al.*, 2002).

4.6 Dose and Risk Estimates

This study focuses on the dermal and non-dietary ingestion exposure pathways which are the potential pathways for non-occupational pesticide exposure for young children (US EPA, 1999). To assess exposure for each pathway, the route-specific mathematical algorithms were used and expressed as functions of pesticide concentration in the exposure medium, intake or contact rate, rate of transfer from the exposure medium to the portal of entry, and exposure duration (Cohen Hubal *et al.*, 2000).

The average daily dose (ADD) was used to estimate the exposure for non-carcinogenic exposure as described in each exposure pathway. The recommended values for 2-5 year old children obtained from EPA's information were used as some exposure factors in the dose estimation. Some factors were estimated according to site specific values such as pesticide concentrations in each exposure media and children's characteristic data in the study site. Site specific values of children's characteristic for the dose calculation are summarized in Table 4.19.

Table 4.19 Site specific values of children's characteristic [e]

Characteristic	Participating Children
Average BW	14 kg
Total BSA[a]	6,019 cm^2
Exposed SA[b]	1,505 cm^2
Hands SA[c]	343 cm^2
SA Mouthed, 1-3 fingers[d]	17 cm^2

[a] The average of total body surface area of male and female children based on a formula, BSA = (BW+4)/30 (Current, 1998)

[b] Recommended 25% of the total skin area is exposed to soil or dust (US EPA, 1992)

[c] Recommended 5.7% (the mean of percentage) of the total skin area is the surface areas of two hands for children 2-5 years of age (US EPA,1992)

[d] Assumed 0.05 fraction of skin mouthed surface area, 1-3 fingers (EPA, 2001 and Zartarian *et al.*, 2000)

[e] Estimates based on the default values for Thai children as given in Appendix A (Table A-2 and A-3)

The dose estimates were expressed as the mean and median for describing the distribution of exposure for the study population. The values at the extreme upper-end were presented for describing the most individual exposed persons in the population. The statistical 95% confidence interval (CI) was also presented.

4.6.1 Soil Ingestion Exposure

Soil ingestion exposure was calculated by the following algorithm.

$$ADD = (C_s \times IR \times CF \times FI \times EF \times ED) / (BW \times AT) \qquad (4.1)$$

Where:

ADD = average daily dose for soil ingestion (mg/kg/day)

C_s = concentrations of pesticide in soil (mg/kg)

IR = soil ingestion rate (mg/day)

CF = conversion factor (10^{-6} kg/mg)

FI = fraction of intake from contaminated soil (unitless)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

The dose estimates generated using the algorithms presented above were based on site specific values (i.e., chemical concentrations in soil, body weight, and exposure frequency) and some US EPA's default values (i.e., soil ingestion rate, exposure duration). The values of the exposure factors for estimating soil ingestion exposure in this study are given as follow.

C_s : pesticide concentrations in soil (chemical specific field data)

IR : 200 mg/day (US EPA, 1991)

FI : 1 (assumed value)

EF : 365 days (represent full time resident)

ED : 6 years (default value for children; US EPA, 1991)

BW : 14 kg (average body weight for participating children)

AT: $6 \times 365 = 2,190$ days (default value for children, US EPA, 1991)

The average daily doses and hazard quotient for soil ingestion exposure among the participating children during the dry season and the wet season are presented in Table 4.20 and Table 4.21, respectively. The finding found that none of the average daily doses for all OP pesticides of interest were above the US EPA oral reference dose (RfD) niether for the farm children nor the reference. However, the mean daily doses of dicrotophos and profenofos were found to be the most highly levels for soil ingestion exposure of the farm children during the dry season, and were significantly higher than those of the reference children (Mann-Whitney U test, $p<0.05$). A significant difference was not found for all four OP pesticides between the farm and the reference children during the wet season (Mann-Whitney U test, $p>0.05$).

Table 4.20 Average daily dose and hazard quotient for soil ingestion exposure for participating children during the dry season

		Farm Children			Reference Children		
	Oral RfD[a] (mg/kg/day)	Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)	Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.0001						
Mean		0.26	3.73E-06	0.037	0.12	1.70E-06	0.017
Median		0.12	1.71E-06	0.017	0.12	1.70E-06	0.017
Maximum		1.20	1.71E-05	0.171	0.12	1.70E-06	0.017
95% CI				0.25-0.45			-
Chlorpyrifos	0.003						
Mean		0.18	2.53E-06	0.001	0.12	1.70E-06	0.001
Median		0.12	1.71E-06	0.0006	0.12	1.70E-06	0.001
Maximum		0.55	7.86E-06	0.003	0.12	1.70E-06	0.001
95% CI				0.0007-0.001			-
Methyl parathion	0.00025						
Mean		0.16	2.30E-06	0.009	0.12	1.70E-06	0.007
Median		0.12	1.71E-06	0.007	0.12	1.70E-06	0.007
Maximum		0.67	9.57E-06	0.038	0.12	1.70E-06	0.007
95% CI				0.007-0.011			-
Profenofos	0.0001						
Mean		0.25	3.50E-06	0.035	0.14	1.90E-06	0.019
Median		0.12	1.71E-06	0.017	0.12	1.70E-06	0.017
Maximum		0.83	1.19E-05	0.119	0.27	3.90E-06	0.039
95% CI				0.026-0.044			0.016-0.023

[a] Oral chronic reference dose (from Integrated Risk Information System Database, IRIS EPA 1994; Toxicity & Chemical-Specific Factors Database (http://risk.lsd.ornl.gov/cgi)

Table 4.21 Average daily dose and hazard quotient for soil ingestion exposure for participating children during the wet season

		Farm Children			Reference Children		
	Oral RfD[a] (mg/kg/day)	Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)	Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.0001						
Mean		0.16	2.31E-06	0.023	0.12	1.70E-06	0.017
Median		0.12	1.71E-06	0.017	0.12	1.70E-06	0.017
Maximum		0.36	5.14E-06	0.051	0.12	1.70E-06	0.017
95% CI				0.019-0.027			-
Chlorpyrifos	0.003						
Mean		0.15	2.14E-06	0.001	0.12	1.70E-06	0.001
Median		0.12	1.71E-06	0.0006	0.12	1.70E-06	0.001
Maximum		0.42	6.00E-06	0.002	0.12	1.70E-06	0.001
95% CI				0.0006-0.008			-
Methyl parathion	0.00025						
Mean		0.15	2.14E-06	0.009	0.12	1.70E-06	0.007
Median		0.12	1.71E-06	0.007	0.12	1.70E-06	0.007
Maximum		0.35	5.00E-06	0.02	0.12	1.70E-06	0.007
95% CI				0.007-0.01			-
Profenofos	0.0001						
Mean		0.16	2.31E-06	0.023	0.12	1.70E-06	0.017
Median		0.12	1.71E-06	0.017	0.12	1.70E-06	0.017
Maximum		0.47	6.7E-05	0.067	0.12	1.70E-06	0.017
95% CI				0.018-0.027			-

[a] Oral chronic reference dose (from Integrated Risk Information System Database, IRIS EPA 1994; Toxicity & Chemical-Specific Factors Database (http://risk.lsd.ornl.gov/cgi)

4.6.2 Hand-To-Mouth Exposure

Non-dietary exposure from hand-to-mouth transfer (hand mouthing) was estimated from which hand-to mouth activity occurs. The hand-to-mouth exposure was calculated by the following algorithm.

$$ADD = (C_x \times TE_{xm} \times SA_x \times EF) / BW \qquad (4.2)$$

Where: ADD = average daily dose for hand to mouth contact (mg/kg/day)

C_x = contaminant loading on hands ($\mu g/cm^2$)

TE_{xm} = transfer efficiency, fraction transferred from hand to mouth (unitless)

SA_x = hand surface area that is mouthed (cm^2/event)

EF = frequency of mouthing event over a 24-h period (events/24-h)

BW = body weight (kg)

The dose estimates generated using the algorithms presented above were based on site specific values (i.e., pesticide hand loadings, hand surface area and average body weight) mouthing frequency) and some of US EPA's default values (i.e., hand to mouth transfer efficiency and mouthing frequency). The values of the exposure factors for estimating soil ingestion exposure in this study are given as follow.

C_x : pesticide loadings on hands (chemical specific field data)

TE : 0.5 (50 % transfer efficiency from hand to mount for children; EPA, 2001)

SA_{hand} : 17 cm^2 (1-3 fingers which is mouthed; as given in Table 4.12)

EF : 9 events/hr (EPA, 2002); assumed 12 hrs for amount of day time for participating children ($9 \times 12 = 108$ events/day)

BW : 14 kg (average body weight for participating children)

The Average daily doses and hazard quotient for hand to mouth exposure among the participating children during the dry season and the wet season are presented in Table 4.22 and Table 4.23, respectively. The mean daily doses for dicrotophos and profenofos of the farm children were significantly higher than those of the reference children during the dry season (Mann-Whitney U test, $p<0.05$). The daily doses of all four OP pesticides were not different between the farm and the reference children during the wet season (Mann-Whitney U test, $p>0.05$).

Table 4.22 Average daily dose and hazard quotient for hand mouthing exposure for participating children during the dry season

		Farm Children			Reference Children		
	Oral RfD[a] (mg/kg/day)	Cx ($\mu g/cm^2$)	ADD (mg/kg/d)	HQ (ADD/RfD)	Cx ($\mu g/cm^2$)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.0001						
Mean		0.0007	4.58E-05	0.458	0.0003	1.94E-05	0.194
Median		0.0003	2.16E-05	0.216	0.00029	1.92E-05	0.192
Maximum		0.002	1.47E-04	1.467	0.00033	2.16E-05	0.216
95% CI				0.342-0.575			0.186-0.202
Chlorpyrifos	0.003						
Mean		0.0004	2.61E-05	0.009	0.0003	1.94E-05	0.0065
Median		0.0003	1.92E-05	0.006	0.00029	1.92E-05	0.0064
Maximum		0.002	1.25E-04	0.042	0.00033	2.16E-05	0.0072
95% CI				0.006-0.01			0.006-0.007
Methyl parathion	0.00025						
Mean		0.0004	2.38E-05	0.095	0.0003	1.94E-05	0.077
Median		0.0003	2.03E-05	0.081	0.00029	1.92E-05	0.077
Maximum		0.001	6.29E-05	0.252	0.00033	2.16E-05	0.086
95% CI				0.081-0.109			0.074-0.081
Profenofos	0.0001						
Mean		0.0005	3.64E-05	0.364	0.0003	1.94E-05	0.194
Median		0.0003	2.16E-05	0.216	0.00029	1.92E-05	0.192
Maximum		0.002	1.17E-04	1.177	0.00033	2.16E-05	0.216
95% CI				0.279-0.448			0.186-0.202

[a] Oral chronic reference dose (from Integrated Risk Information System Database, IRIS EPA 1994; Toxicity & Chemical-Specific Factors Database (http://risk.lsd.ornl.gov/cgi)

Table 4.23 Average daily dose and hazard quotient for hand mouthing exposure for participating children during the wet season

	Oral RfD[a] (mg/kg/day)	Farm Children			Reference Children		
		Cx ($\mu g/cm^2$)	ADD (mg/kg/d)	HQ (ADD/RfD)	Cx ($\mu g/cm^2$)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.0001						
Mean		0.00045	2.93E-05	0.293	0.00029	1.95E-05	0.195
Median		0.0003	2.03E-05	0.203	0.00030	1.97E-05	0.197
Maximum		0.0013	8.82E-05	0.883	0.00033	2.16E-05	0.216
95% CI				0.220-0.366			0.188-0.201
Chlorpyrifos	0.003						
Mean		0.00029	1.93E-05	0.006	0.00029	1.95E-05	0.0065
Median		0.00029	1.92E-05	0.006	0.00030	1.97E-05	0.0066
Maximum		0.002	2.16E-05	0.007	0.00033	2.16E-05	0.0072
95% CI				0.006-0.0066			0.006-0.007
Methyl parathion	0.00025						
Mean		0.00033	2.18E-05	0.087	0.00029	1.95E-05	0.078
Median		0.00031	2.03E-05	0.081	0.00030	1.97E-05	0.079
Maximum		0.0009	5.99E-05	0.240	0.00033	2.16E-05	0.086
95% CI				0.075-0.098			0.075-0.08
Profenofos	0.0001						
Mean		0.00032	2.12E-05	0.212	0.00029	1.95E-05	0.195
Median		0.00029	1.92E-05	0.192	0.00030	1.97E-05	0.197
Maximum		0.0003	5.28E-05	0.528	0.00033	2.16E-05	0.216
95% CI				0.183-0.241			0.188-0.201

[a] Oral chronic reference dose (from Integrated Risk Information System Database, IRIS EPA 1994; Toxicity & Chemical-Specific Factors Database (http://risk.lsd.ornl.gov/cgi)

4.6.3 Dermal Exposure

4.6.3.1 Soil Contact Exposure

$$ADD = (C_s \times CF \times SA \times AF \times ABS \times EF \times ED) / (BW \times AT) \qquad (4.3)$$

Where:
- ADD = average daily dose for dermal contact (mg/kg/day)
- C_s = concentration of pesticide in soil (mg/kg)
- CF = conversion factor (10^{-6} kg/mg)
- SA = skin surface area available for contact (cm^2/day)
- AF = soil to skin adherence factor (1 mg/cm^2)
- ABS = absorption factor (unitless)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- BW = body weight (kg)
- AT = averaging time (days)

The dose estimates generated using the algorithms presented above are based on site specific values (i.e., chemical concentrations in soil, skin surface area, body weight, and exposure frequency) and some US EPA's default values (i.e., soil adherence, exposure duration). The values of the exposure factors for estimating dermal exposure from soil contact in this study are given as follow.

C_s : pesticide concentration in soil (chemical specific field data)

SA : 1,505 cm^2/day (25% of the total body surface areas; as given in Table 4.12)

AF : 1 mg/cm^2 (the high end of soil to skin adherence factor; US EPA, 1991)

ABS : 0.01 for each OP pesticide of interest (cited from Toxicity & Chemical-Specific Factors Data Base Search Result; http://risk.lsd.ornl.gov/cgi)

EF : 365 days (represent full time resident)

ED : 6 years (default value for children; US EPA,1991)

BW : 14 kg BW : 14 kg (average body weight for participating children)

AT : 6×365 = 2,190 days (default values for children, US EPA, 1991)

The Average daily doses and hazard quotient for dermal exposure from soil contact among the participating children during the dry season and the wet season are presented in Table 4.24 and Table 4.25, respectively. The finding found that none of the average daily doses for all OP pesticides of interest was above the dermal RfD niether for the farm children nor the reference children. However, the mean of the daily doses for dicrotophos and profenofos were found to be the most highly levels for soil contact of the farm children during the dry season, and were significantly higher than those of the reference children (Mann-Whitney U test, $p<0.05$). A significant difference was not apparent for all four OP pesticides between the farm and the reference children during the wet season (Mann-Whitney U test, $p>0.05$).

Table 4.24 Average daily dose and hazard quotient for soil contact exposure for participating children during the dry season

		Farm Children			Reference Children		
	Dermal RfD [a] (mg/kg/day)	Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)	Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.00005						
Mean		0.26	2.8E-07	0.006	0.12	1.3E-07	0.0027
Median		0.12	1.3E-07	0.003	0.12	1.3E-07	0.0027
Maximum		1.20	1.29E-06	0.026	0.12	1.3E-07	0.0027
95% CI				0.004-0.007			-
Chlorpyrifos	0.0015						
Mean		0.18	1.9E-07	0.0001	0.12	1.3E-07	0.0001
Median		0.12	1.3E-07	0.0001	0.12	1.3E-07	0.0001
Maximum		0.55	5.9E-07	0.0004	0.12	1.3E-07	0.0001
95% CI				0.0001-0.0002			-
Methyl parathion	0.000125						
Mean		0.16	2.0E-07	0.0001	0.12	1.3E-07	0.001
Median		0.12	1.3E-07	0.0001	0.12	1.3E-07	0.001
Maximum		0.67	7.0E-07	0.006	0.12	1.3E-07	0.001
95% CI				0.001-0.002			-
Profenofos	0.00005						
Mean		0.25	2.6E-07	0.005	0.14	1.5E-07	0.0031
Median		0.12	1.3E-07	0.003	0.12	1.3E-07	0.0027
Maximum		0.83	8.9E-07	0.018	0.27	3.0E-07	0.0061
95% CI				0.004-0.007			0.025-0.036

[a] Dermal chronic reference dose (from : Toxicity & Chemical- Specific Factors Database; http://risk.lsd.ornl.gov/cgi)

Table 4.25 Average daily dose and hazard quotient for soil contact exposure for participating children during the wet season

	Dermal RfD [a] (mg/kg/day)	Farm Children			Reference Children		
		Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)	Cs (mg/kg)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.00005						
Mean		0.16	1.7E-07	0.0035	0.12	1.3E-07	0.0027
Median		0.12	1.3E-07	0.0026	0.12	1.3E-07	0.0027
Maximum		0.36	3.9E-07	0.008	0.12	1.3E-07	0.0027
95% CI				0.003-0.004			-
Chlorpyrifos	0.0015						
Mean		0.15	1.6E-07	0.0001	0.12	1.3E-07	0.0001
Median		0.12	1.3E-07	0.0001	0.12	1.3E-07	0.0001
Maximum		0.42	4.5E-07	0.0003	0.12	1.3E-07	0.0001
95% CI				0.00009-0.0001			-
Methyl parathion	0.000125						
Mean		0.15	2.0E-07	0.00013	0.12	1.0E-07	0.001
Median		0.12	1.3E-07	0.0001	0.12	1.0E-07	0.001
Maximum		0.35	7.0E-07	0.003	0.12	1.0E-07	0.001
95% CI				0.001-0.002			-
Profenofos	0.00005						
Mean		0.16	2.6E-07	0.0034	0.12	1.3E-07	0.0026
Median		0.12	1.3E-07	0.0026	0.12	1.3E-07	0.0026
Maximum		0.47	8.9E-07	0.010	0.12	1.3E-07	0.0026
95% CI				0.003-0.004			-

[a] Dermal chronic reference dose (from : Toxicity & Chemical- Specific Factors Database; http://risk.lsd.ornl.gov/cgi)

4.6.3.2 Surface Residue Contact

Dermal exposure from surface residue contact was calculated by the following equation.

$$ADD = (C_{surf} \times TC_{der} \times ED) / BW \qquad (4.4)$$

Where:
- ADD = average daily dose for surface residue contact (mg/kg/day)
- C_{surf} = indoor surface residue concentration at home ($\mu g/cm^2$)
- CF = conversion factor (10^{-3} mg/μg)
- TC_{der} = dermal transfer coefficient (cm^2/hr)
- ED = time spent indoor at home (hr/24-h)
- BW = body weight (kg)

The dose estimates generated using the algorithms presented above were based on site specific values (i.e., surface residue concentrations, time spent indoor, and average body weight) and dermal transfer coefficient which is based on the value reported by Cohen Hubal *et al.* (2006). The values of the exposure factors for estimating dermal exposure from surface residue contact in this study are given as follow.

C_{surf} : average surface wipe loadings ($\mu g/cm^2$)

TC_{der} : 56 cm^2/hr (the lower end value of dermal transfer coefficient, Cohen Hubal *et al.*, 2006)

ED : the average site specific time spent indoor for children,

- farm children: 5 hrs/day for dry season; 6 hrs/day for wet season
- reference: 6 hrs/day for both dry and wet season

BW : 14 kg (average body weight for participating children)

The Average daily doses and hazard quotient for surface residue contact among the participating children during the dry season and the wet season are presented in Table 4.26 and Table 4.27, respectively. The mean daily doses of dicrotophos and profenofos of the farm children were found to be significantly higher than those of the reference children during the dry season (Mann-Whitney U test, $p<0.05$). The daily doses for all four OP pesticides were not significantly different between the farm and the reference children during the wet season (Mann-Whitney U test, $p>0.05$).

Table 4.26 Average daily dose and hazard quotient for surface residue contact for participating children during the dry season

		Farm Children			Reference Children		
	Dermal RfD [a] (mg/kg/day)	Csurf ($\mu g/cm^2$)	ADD (mg/kg/d)	HQ (ADD/RfD)	Csurf ($\mu g/cm^2$)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.00005						
Mean		0.0057	1.14E-05	0.228	0.0002	5.4E-06	0.108
Median		0.0002	4.69E-06	0.094	0.0002	4.8E-06	0.096
Maximum		0.003	6.0E-05	1.20	0.0004	9.7E-06	0.194
95% CI				0.152-0.228			0.091-0.124
Chlorpyrifos	0.0015						
Mean		0.0004	7.4E-06	0.005	0.0002	5.4E-06	0.004
Median		0.0002	4.0E-06	0.003	0.0002	4.5E-06	0.003
Maximum		0.002	3.0E-05	0.02	0.0004	9.7E-06	0.006
95% CI				0.003-0.005			0.003-0.004
Methyl parathion	0.000125						
Mean		0.0004	7.7E-06	0.061	0.0003	4.8E-06	0.038
Median		0.0002	4.0E-06	0.032	0.00029	4.8E-06	0.038
Maximum		0.002	3.2E-05	0.257	0.00033	4.8E-06	0.038
95% CI				0.041-0.061			-
Profenofos	0.00005						
Mean		0.0005	9.8E-06	0.197	0.0003	5.4E-06	0.108
Median		0.0002	4.0E-06	0.080	0.00029	4.1E-06	0.082
Maximum		0.004	8.2E-05	1.642	0.00033	1.14E-05	0.229
95% CI				0.131-0.196			0.09-0.126

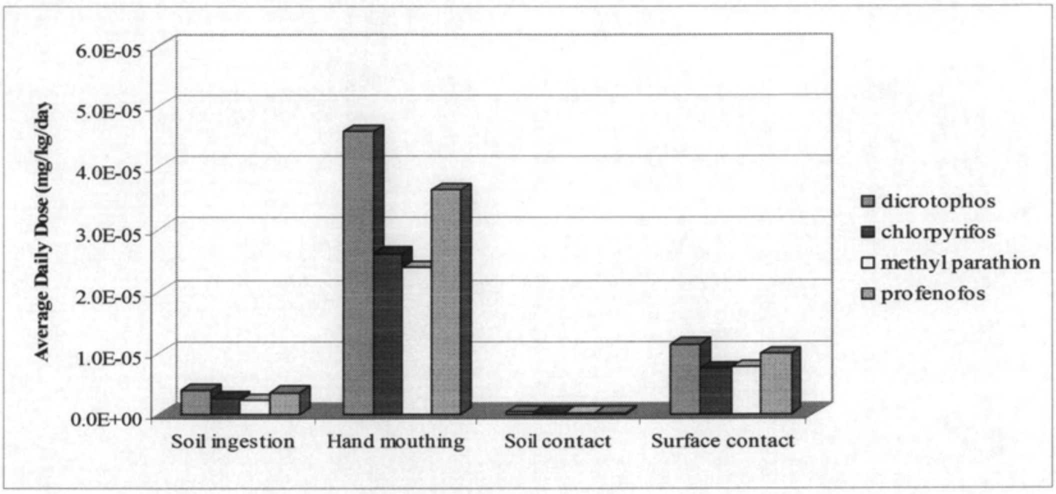
[a] Dermal chronic reference dose (from : Toxicity & Chemical- Specific Factors Database; http://risk.lsd.ornl.gov/cgi)

Table 4.27 Average daily dose and hazard quotient for surface residue contact for participating children during the wet season

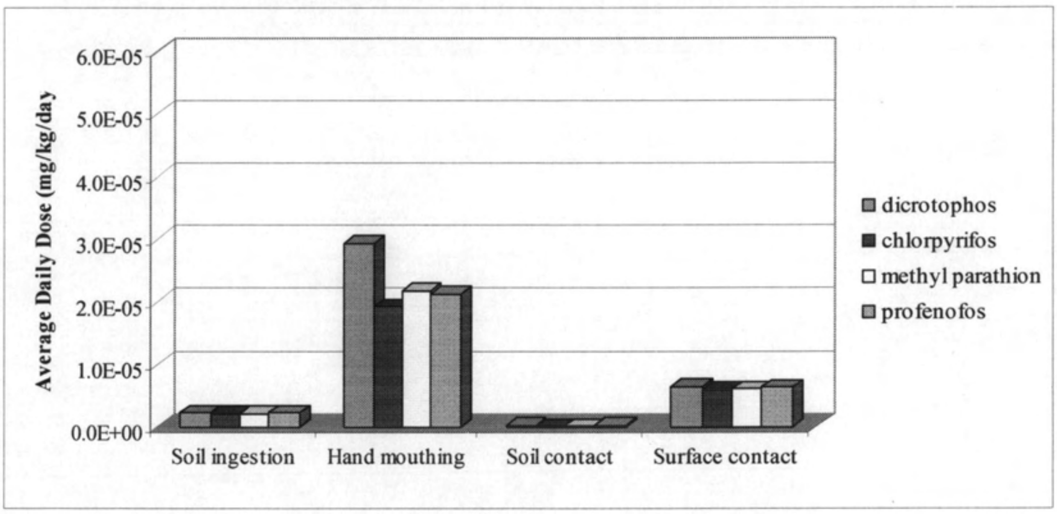
		Farm Children			Reference Children		
	Dermal RfD [a] (mg/kg/day)	Csurf (µg/cm^2)	ADD (mg/kg/d)	HQ (ADD/RfD)	Csurf (µg/cm^2)	ADD (mg/kg/d)	HQ (ADD/RfD)
Dicrotophos	0.00005						
Mean		0.00027	6.38E-06	0.128	0.0002	5.1E-06	0.102
Median		0.0002	4.80E-06	0.096	0.0002	4.8E-06	0.096
Maximum		0.0006	1.45E-05	0.291	0.0004	9.5E-06	0.189
95% CI				0.105-0.150			0.092-0.112
Chlorpyrifos	0.0015						
Mean		0.00025	5.94E-06	0.004	0.0002	5.1E-06	0.003
Median		0.0002	4.80E-06	0.003	0.0002	4.8E-06	0.002
Maximum		0.0008	1.92E-05	0.013	0.0004	9.4E-06	0.006
95% CI				0.003-0.005			0.003-0.004
Methyl parathion	0.000125						
Mean		0.00025	6.09E-06	0.049	0.0002	4.5E-06	0.038
Median		0.0002	4.80E-06	0.038	0.0002	4.5E-06	0.038
Maximum		0.0006	1.46E-05	0.117	0.0002	4.5E-06	0.038
95% CI				0.041-0.056			-
Profenofos	0.00005						
Mean		0.00026	6.40E-06	0.127	0.00021	5.1E-06	0.102
Median		0.0002	5.00E-06	0.096	0.0002	4.8E-06	0.096
Maximum		0.0009	2.16E-05	0.432	0.00039	9.4E-06	0.188
95% CI				0.098-0.156			0.09-0.112

[a] Dermal chronic reference dose (from : Toxicity & Chemical- Specific Factors Database; http://risk.lsd.ornl.gov/cgi)

Comparisons of mean of the average daily doses among the exposure pathways for farm children are illustrated in Figure 4.13.



(a)



(b)

Figure 4.13 Mean of average daily dose of four OP pesticides from all exposure pathways of concern for farm children (a) dry season; (b) wet season

The finding indicated that the exposure from hand-to-mouth was higher than other exposure pathways in comparison for all four OP pesticides of interest, following by surface dust contact, soil ingestion, and soil contact, respectively.

Pesticide exposure through hand mouthing pathway can exceed other ingestion routes and dermal exposure because non-dietary ingestion may result in higher ingestion rates of contaminated material (Weaver *et al.* 1998; Moya, Bearer, and Etzel., 2004).

However, the hand mouthing exposure in this study might not represent the exposure of the local condition because the dose calculation for this route using the value of hand mouthing frequency based on data recommended from US EPA (2002) which referred to the data from the videotaped observations of Zatarian *et al.* (1998) and Reed *et al.* (1999). Site specific values of the frequency of hand-to-mouth were not available for the dose calculation due to limited observation by the parents and limited information from the questionnaire. Detailed information about this behavior is difficult to obtain from the questionnaire (Freeman *et al.*, 2001). Therefore, the default value of hand mouthing frequency was selected to use in the estimation instead. Nevertheless, the US EPA default value defined as conservative value which is considered to be representative of high-end exposure (US EPA., 2002).

Even though the average daily doses in some pathways were very low levels of estimates, significant Spearman correlations of total average daily doses among exposure pathways of concern were apparent, particularly for the farm children during the dry season. The Spearman correlation coefficients indicated some findings for the daily dose comparisons among the different exposure pathways. There were significant correlations among exposure through surface dust contact with other pathways. The correlations between total dose for surface dust contact and hand mouthing exposure was observed with the Spearman coefficient of 0.484 ($p = 0.002$). A significant correlation between surface dust contact and soil ingestion exposure was observed with the coefficient of 0.672 ($p < 0.0001$), as well as the correlation between surface dust contact and soil contact with the same coefficient. The latter was consistent with the relationship of OP pesticides in different exposure media as presented previously that OP pesticide residues in soil were significant correlated to OP pesticide levels in floordust. It could be noted that soil and settled dust can be a significant source of exposure to pesticides, as addressed by IPCS (2000).

4.6.4 Non-Carcinogenic Hazard Index Estimates

The sum of the hazard quotients for all the pesticides of interest gives the hazard index for a given exposure pathway particular for the farm children is presented as the population distribution in Table 4.28. During the dry season, the risk estimates indicated that the non-carcinogenic hazards as the average of total exposure HI of 1.51 was above the acceptable level of 1. It found to be concern for non-carcinogenic hazard of total exposure to OP pesticide of the farm children. Considering the individual risk, the total exposure HI at high-end levels which above 90th percentile of the population distribution was much above the acceptable index in range of 2.83 to 3.44, indicating a great potential for adverse non-carcinogenic health impact to the farm children.

Although exposure through each pathway of concern was not significant contributor to the mean of HI, hand mouthing and surface residue contact were significant contributors to the potential health effect of the individual persons for the farm children. The high-end HI range for hand mouthing exposure were 1.85 to 2.24 for the individuals who were highly exposed (n=3). High-end risk estimates for surface residue contact were range of 1.08 to 2.05 for most exposed individuals (n=3). Exposures through soil ingestion and soil contact did not appear to be significant contributors to the HI for the individual farm children. Based on the individual data of the farm children, it can be seen that there was only one child (T21) who had the high-end risk estimate through both hand mouthing and surface dust contact. The data of OP measurement showed that this child had the highest levels of dicrotophos on his hands which resulted in high distributor for hand mouthing exposure. Based on activity information, it reported that this child exhibited frequent hand mouthing behavior, and often playing in the farm and companying with his parents into the field. These activities could be also contributor to the pesticide exposure and high risk. In addition, there was another child (T19) who had high risk from hand mouthing. The biomonitoring data revealed that the highest level of urinary OP metabolite was found in his urine. This child also had the highest HI values among the high-end individual persons.

In view of hazard index for each OP pesticide of interest during the dry season (Table 4.29), it was found that the single greatest contributor to the high-end HI for the individual resulted from profenofos with HI of 1.21 to 2.44. The following contributor to high-end HI was dicrotophos with HI of 1.11 to 1.53. The remaining OP pesticides, chlorpyrifos and methyl parathion, were not significant contributors to the mean of total HI.

During the wet season, neither exposure pathways nor pesticides of concern were significant contributor to the mean of total HI for the farm children. However, the value of 0.97 is almost nearly the acceptable index of unity (Table 4.28). Considering the conservative assumptions used in the dose estimation, it can be concluded that the children did not exposed any risk due to the presence of all pesticides of interest through any exposure routes during the wet season which is the less pesticide spraying period. However, exposure through hand-to-mouth activity still appeared to be significant contributor to the high-end risk estimate for some individual persons (n=3) with the range 1.00 to 1.16. The values, however, were not very much above the acceptable index of unity. These individuals could be more susceptible to the adverse health effect than others in the population (US EPA, 1992). Considering the hazard index for each OP pesticide of interest, it was found that the single greatest contributor to the high-end HI for the individual resulted from profenofos with HI of 1.21 to 2.44. The finding of the risk estimates also indicated that the farm children were likely to have non-carcinogenic hazards significantly higher than those of the reference children both during the dry season and the wet season. (Mann-Whitney U test; $p<0.001$).

However, data on the distribution of non-carcinogenic hazards was not available for the reference children. It presented only for the average value which found that total exposure HI of 0.78 was less than the acceptable level of 1. Exposure through soil ingestion, hand mouthing, soil contact, and surface residue contact did not appear to be a problem for the reference group.

Table 4.28 The distribution of hazard index for a given exposure pathway among the farm children

	Mean	Percentiles				Max	% above 90th Percentile (n)[a]
		25th	50th	75th	90th		
Dry Season							
Soil Ingestion	0.082	0.042	0.079	0.094	0.175	0.200	-
Hand Mouthing	0.925	0.509	0.765	1.204	1.850	2.240	8 (3)
Soil Contact	0.012	0.006	0.012	0.015	0.026	0.030	-
Surface Residue Contact	0.491	0.199	0.354	0.497	1.082	2.054	8 (3)
Total Exposure HI	1.511	0.824	1.240	1.960	2.835	3.444	8 (3)
Wet Season							
Soil Ingestion	0.055	0.042	0.042	0.069	0.083	0.105	-
Hand Mouthing	0.598	0.467	0.494	0.743	1.000	1.164	9 (3)
Soil Contact	0.008	0.006	0.006	0.010	0.013	0.016	-
Surface Residue Contact	0.307	0.234	0.234	0.338	0.474	0.843	-
Total Exposure HI	0.968	0.773	0.852	1.120	1.414	1.680	6 (2)

[a] Individuals at the high end of the risk distribution; n= number of children

Table 4.29 The distribution of aggregate hazard index for each OP pesticide of concern among the farm children

	Mean	Percentiles				Max	% above 90th Percentile (n)[a]
		25th	50th	75th	90th		
Dry Season (n=37)							
Dicrotophos	0.507	0.225	0.259	0.773	1.110	1.526	8 (3)
Chlorpyrifos	0.015	0.010	0.01	0.015	0.390	0.054	-
Methyl parathion	0.167	0.115	0.126	0.209	0.344	0.410	-
Profenofos	0.600	0.303	0.374	0.702	1.210	2.438	8 (3)
Total HI	1.289	0.716	1.025	1.540	3.027	3.048	8 (3)
Wet Season (n=34)							
Dicrotophos	0.447	0.318	0.330	0.517	0.837	1.102	3 (1)
Chlorpyrifos	0.011	0.010	0.011	0.011	0.014	0.021	-
Methyl parathion	0.146	0.123	0.127	0.175	0.197	0.286	-
Profenofos	0.365	0.307	0.319	0.366	0.614	0.701	-
Total HI	0.969	0.776	0.852	1.118	1.415	1.680	6 (2)

[a] Individuals at the high end of the risk distribution; n= number of children

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In summary, it can be noted that there are several exposure factors relevant to the non-occupational pesticide exposure for preschool children in Bang Rieng community (Figure 4.14). The main sources of the pesticide exposure were due to children's behaviors which coming into contact the pesticides, the spraying season for pesticide application, housing conditions (location and construction). Four OP pesticides of concern were measured as the parent compounds and their urinary metabolites from the exposure media including environmental, personal, and biological media in order to indicate the degree of the exposure occurred. There were significantly correlated among OP pesticide residues in the difference exposure media. Combination of biomonitoring, personal and environmental exposure measurements, and related exposure factors relatively contributed the exposures as internal dose (as average daily dose) through the different routes and exposure media. The potential exposure routes for the children in this study consist of non-dietary ingestion through hand mouthing and soil ingestion, and dermal exposure through soil contact and surface floor dust contact.

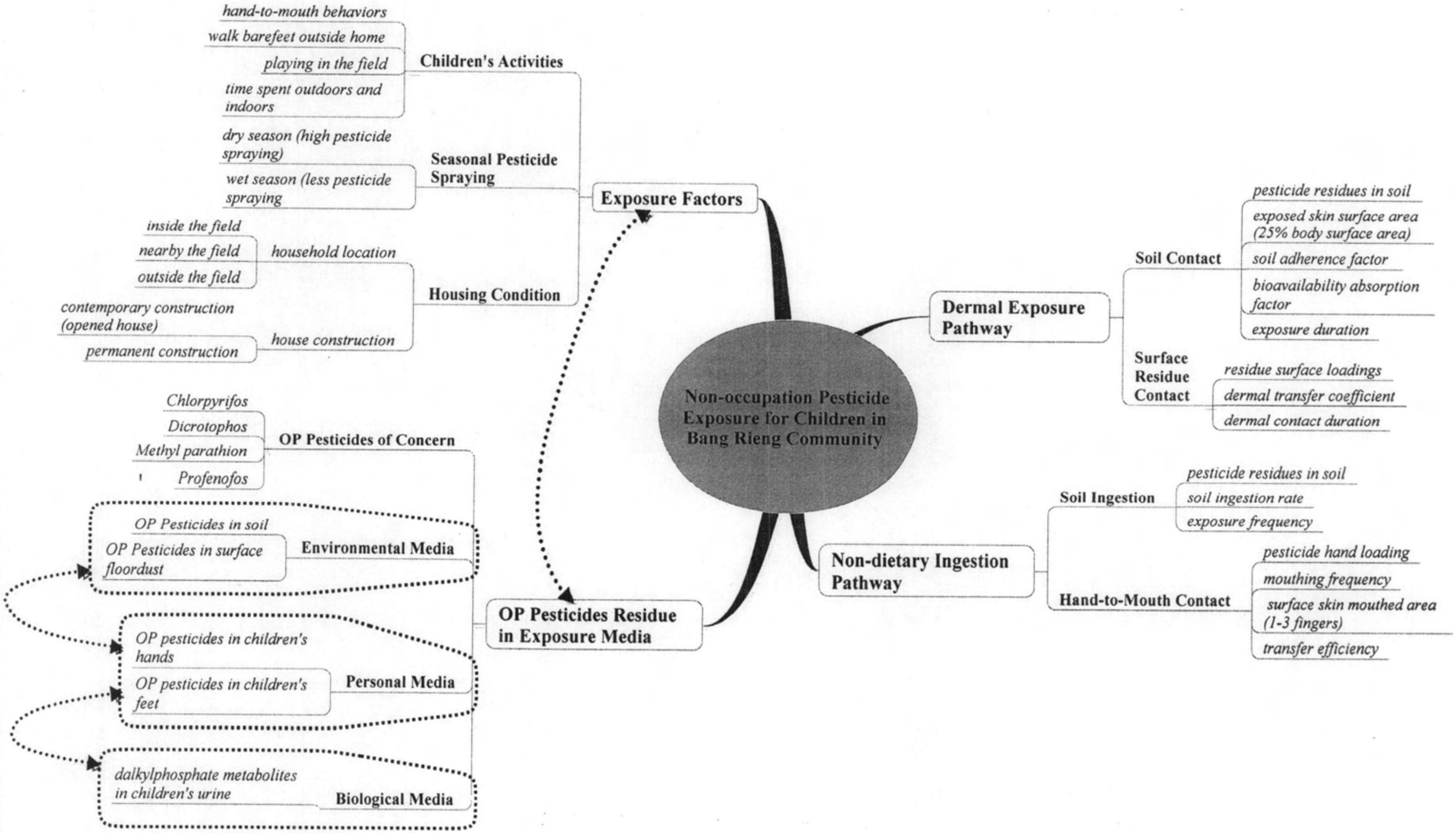

Figure 4.14 Schematic of non-occupational pesticide exposures for the farm children in Bang Rieng agricultural community

4.6.5 Uncertainty in the Dose Estimation

Exposure assessment is not exact science, and confidence in the results may vary enormously (US EPA.,1992). It is essential to address uncertainty in the assessment. The following items summarize sources of uncertainty in the exposure and risk estimation in this study.

1) Using surrogate data or professional judgment

This study attempted to use the site specific data for the dose calculation (e.g. pesticide concentrations in exposure media, time spent indoor, exposure duration, skin surface area and average body weight), but some factors were not available (e.g. soil ingestion, mouthing frequency, hand-to-mouth transfer efficiency, dermal transfer coefficient). The use of surrogate data is common when site-specific data are not available (US EPA.,1992). Therefore, this study required the use of available measurements in combination with actual data and surrogate data (or professional judgment). This is one of sources of uncertainty because the data may not represent the exposure scenario being analyzed.

2) Conservative risk estimates

Most measured OP pesticides in all exposure media of interest which reported as non-detected were assigned a haft of LOD. As a result, this source of uncertainty leads to overestimate exposure, dose, or risk where substituting values of detection limit were used. Use of high-end value for the exposure factors in dose calculation also leads to an overestimate. Despite professional judgment values were considered to upper-percentile assumptions, conservative approach can lead to unrealistically high exposure estimate if taken for all factors (US EPA.,2002). Using a lower-end value from the weight distribution in some cases was preferred. In this study, the minimum default value of dermal transfer coefficient was selected to enter into the algorithms for estimating the exposure from surface residue contact in order to reduce the very high uncertainty from this conservative value.

3) Excluded some exposure pathways

Exposure through object mouthing was not quantified even though this behavior was exhibited in the participating children. Measurement of object mouthed surface area and OP residue in such objects was impractical to be conducted. Inhalation exposure was neither evaluated, because of the limitation in personal air sampling from young children. Inclusion of these exposure pathways could result in higher risk estimates even though the individual estimated risk of the total exposure for the farm children already exceeded US EPA risk criteria.