

ORIGINAL ARTICLE

ORGANOPHOSPHATE EXPOSURE, ASSOCIATED RISK FACTORS AND EXPOSURE RISK ASSESSMENT AMONG VEGETABLE FARMERS IN SABAH, MALAYSIA

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ABSTRACT

Uncontrolled use of pesticides in agriculture may result in increased health risks. Organophosphate (OP) pesticides are widely used among vegetable farmers to control pests and increase productivity. The aim is to determine the organophosphate exposure, associated risk factors, and exposure risk assessment among vegetable farmers in Sabah. A cross-sectional study design in Kundasang, Sabah, Malaysia. We took a blood sample from participants for blood cholinesterase concentration measurements of pesticide exposure using the rapid test kit model Lovibond AF267. A validated questionnaire was used to collect the associated risk factors of vegetable farmers. The Hazard Identification, Risk Assessment, Risk Control (HIRARC) guidelines were used for exposure risk assessment of OP exposure. The response rate was 91.1%. About 23.3% (38 out of 163) have abnormal blood cholinesterase. The significant associated risk factors were age [aOR=1.07, 95%CI (1.02,1.13)], Body Mass Index [aOR=8.60, 95%CI (2.80,26.51)], frequency of exposure a month [aOR=5.99, 95%CI (1.29,27.76)], had not attended pesticide safety training [aOR=9.08, 95%CI (2.97,27.74)], no designated pesticide storage [aOR=6.92, 95%CI (1.70,28.25)] and low practices scores on pesticide handling [aOR=6.01, 95%CI (1.97,18.36)]. The exposure risk assessment level for vegetable farmers was at low-medium risk. Organophosphate exposure among the vegetable farmers in Kundasang was higher than in other settings. The risk factors associated with organophosphate exposure were related to inadequate compliance to the standard occupational safety and health practices in agriculture. Exposure assessment revealed the opportunity for improvement by implementing the recommended control measures. Vegetable farmers need continuous support from relevant authorities. Further research is required to understand better the health risks among vegetable smallholder farmers in Sabah.

Keywords: Organophosphate pesticide exposure, associated risk factors, exposure risk assessment, vegetable farmers

INTRODUCTION

The agricultural industry remains an important sector in Malaysia, accounting for 7.3% of gross domestic product (GDP) in 2018¹. Pesticides are agricultural technologies that enable farmers to control pests and weeds and constitute an important input when producing crops². Food crops refer to vegetables, fruit, root crops, and grain crops associated with smallholdings managed by individual farmers. The average farm size in Malaysia is 1.45 ha³. Due to their toxicity and widespread use in agricultural settings, pesticides pose a severe threat to rural populations, particularly children and farmers in low-income countries⁴. The unsafe use of pesticides in agriculture represents a significant hazard to the environment and human health⁵. Many studies on pesticide residues have produced evidence of increased incidence of acute pesticide poisoning and long-term effects such as cancer⁶. However, poisoning cases due to pesticide exposure in

agriculture activities are not well documented in Malaysia.

A survey showed that poisoning had occurred in 14.5% of the 4,531 farmers growing vegetables, flowers, and fruit in the Cameron Highlands. At government health facilities in Malaysia between 1999 and 2001, 21714 hospital admissions and 779 deaths related to poisoning were recorded. The most significant number of fatalities was said to be due to pesticide poisoning⁷. Most of the communities in Kundasang are small-scale vegetable farmers. They are self-employed or owners of vegetable farms. They commonly used organophosphate pesticides for routine pest control activity. Currently, there is no system available to monitor pesticide usage by relevant agencies among this group of workers. Thus, there is no robust health surveillance program to assess the impact of pesticide exposure among family farmers. This study aims to determine organophosphate

exposure, associated risk factors, and exposure risk assessment among vegetable farmers in Sabah.

MATERIALS AND METHODS

We conducted a cross-sectional study in two selected villages in Kundasang Ranau, Sabah, East Malaysia. They have located about 93.1km from Kota Kinabalu City and are known as the largest vegetable producer in Sabah. The main economic activities among the villagers as a source of family income were related to vegetable cultivation. Approximately 80% of the community and 285 family farms in Kundasang were cultivating vegetables in areas covering 3020 acres, according to information from Federal Agricultural Marketing Authority (FAMA) Ranau District Office (2017). We identified 180 respondents for participation in this study after considering inclusion, exclusion criteria, and sample size determination⁸. The inclusion criteria were age above 18 years old and working in vegetable cultivation for at least 12 months. The exclusion criteria were farmers with mental health problems and chronic diseases before becoming involved in farming that uses pesticides. Data were collected from December 2018 to April 2019.

We took a blood sample from participants' fingertips for blood cholinesterase measurements of pesticide exposure. Steps for collecting the blood samples followed Cholinesterase Monitoring for Agricultural Pesticide Handler. Blood cholinesterase concentration was analyzed using the rapid test kit model Lovibond AF267. This method has been specified by World Health Organization Technical Sheet Report Series No. 356, item 4.4.1 since 1967⁹. The cholinesterase activity is expressed as the percentage of activity in normal blood. The reaction rate (and thus the enzyme activity of the sample) is measured by the range of color change of an indicator (bromothymol blue) present in the solution. Depending on the results obtained, the following action is recommended: 100-75% of normal (no action; retest in the near future); 74.9-50% of normal (overexposure probable; repeat test and if confirmed, suspend from further work with organic phosphorous insecticides for two weeks, then retest to assess recovery); 49-25% of normal (serious over-exposure; repeat test and if confirmed, suspend from all work with pesticides; if indisposed or ill, arrange for a medical examination); 24.9-% of normal (severe and dangerous over-exposure; repeat test and if confirmed, suspend from all work pending a medical examination).

We developed a questionnaire based on previously published studies^{10,11,12}. The validated questionnaire consisted of: i) sociodemographic information: age, gender, height, weight, education; ii) working history: the period of the

current job as full-time farmers, total farm size (acres), types of plants or vegetables cultivated, and income per month; iii) basic information on the use of pesticides: number of days per month working with pesticides, years of pesticide use, number of pesticide safety talks attended if any, the type of pesticide used most frequently, pesticide storage place, pesticide preparation technique, and disposal of empty pesticide containers; iv) knowledge, attitude, and practices on pesticide handling; v) medical history and self-reported symptoms of toxicity associated with pesticide use; vi) smoking. The questionnaires were administered face-to-face. Knowledge, attitude, and practices toward pesticide handling among vegetable farmers questionnaires, the maximum possible scores are 24, 34, and 26, respectively. The minimum score to be considered good knowledge, attitude, and practice is >75% of the correct response score¹² (knowledge=18, attitude=26, practice=20)¹³.

Hazard Identification, Risk Assessment, and Risk Control (HIRARC) were undertaken. A qualitative risk assessment using the Risk Matrix Scale was conducted to define hazards and health risks¹⁴. The HIRARC process involved: a) classifying work activities among vegetable farmers; b) identifying hazards through workers' activities done on a daily, weekly, or monthly basis and assessing what could pose significant risks to the health and safety of the workers; c) conducting a risk assessment by analyzing and estimating risks from each hazard involved by calculating or estimating the likelihood of occurrence and severity of the hazard; d) determining whether the outcome of each of the risks identified is acceptable or whether control measures need to be applied.

Data collected from the questionnaire, biological sampling, and observations were analyzed using the Statistical Package for the Social Sciences (SPSS) version 23. Data regarding the sociodemographic characteristics of the respondents were analyzed using descriptive statistics, including mean, standard deviation, frequencies, and percentages. Comparing abnormal cholinesterase and normal cholinesterase levels were performed using chi-square or Fisher exact tests for categorical data. Binary logistic regression identified the risk factors as adjusted odds ratio (AOR) and 95% confidence interval (CI). The statistical significance was set at $p < 0.05$.

RESULTS

Respondents' Characteristics

The response rate was 91.1% (163 of 180). The data of the respondents was normally distributed. There were 88 male and 75 female participants with a

mean age of 43 (SD 11.78)). Most of the respondents (85.3%) studied until secondary school. One-third (30.1%) of respondents were overweight (BMI ≥ 25.0). Almost half (49.1%) of the respondents smoked. Most vegetable farmers earned an income within the range of RM1001.00 to RM3000.00 per month. (Table 1). Most vegetable farmers are small-scale farmers with holdings of less than five acres. The vegetable farmers used herbicides, insecticides, fungicides, and termites. The hazard

classification of pesticides used by respondents ranged from I-b (85.5%), II (98.2%), III (100%), and IV (U) (100%). Boots, aprons, long sleeves and long pants, and head covers such as hats are the respondent's most common personal protective equipment (PPE). Field observations revealed that some vegetable farmers wear cotton clothes while working, which are unsuitable for pesticide spraying.

Table 1 Characteristics of Respondents

Characteristic	Frequency (N=163)	Percentage (%)
Age group (years)		
18-30	25	15.3
31-40	45	27.6
41-50	49	30.1
51-60	27	16.6
> 60	17	10.4
Gender		
Male	88	54.0
Female	75	46.0
Education level		
No formal education	3	1.8
Primary school	8	4.9
Secondary school	139	85.3
Diploma / Degree	13	8.0
Body Mass Index (BMI)		
Normal (< 25.0 kg/m ²)	114	69.9
Abnormal BMI (≥ 25.0 kg/m ²)	49	30.1
Smoker		
No	83	50.9
Yes	80	49.1
Income per month		
\leq RM1000	4	2.4
RM1001 - RM3000	117	71.8
RM3001 - RM5000	42	25.8

Prevalence of Organophosphate Exposure Among Vegetable Farmers

According to the results of blood cholinesterase testing, 23.3% of respondents were overexposed to OP pesticides. The most common reported symptoms by respondents were a cough (103, 63.2%), followed by face and eye irritation (94, 57.7%), headache (66, 40.5%), dizziness (47, 28.8%), and skin rashes (30, 18.4%).

Associated risk factors of organophosphate exposure among vegetable farmers in Sabah.

The risk factors associated with OP exposure among vegetable farmers include age, Body Mass Index (BMI), frequency (days) of pesticide exposure a month, had not attended pesticide safety training, no designated pesticide storage, and low practices scores on pesticide handling. Older farmers had

higher odds of developing abnormal cholinesterase compared to younger farmers. High BMI had higher odds of developing abnormal cholinesterase compared to lower BMI. The odds of abnormal blood cholinesterase among the vegetable farmers were six times higher in farmers who were frequently exposed to OPs for five days or more in a month than one to four days. The odds of abnormal blood cholinesterase among the vegetable farmers were nine times higher in farmers who had not attended any safety training on pesticides than has had attended. The odds of abnormal blood cholinesterase among the vegetable farmers were seven times higher in farmers who did not place their pesticides in a designated area than has done it. Low practices scores on pesticide handling had higher odds of developing abnormal cholinesterase compared to high scores. (Table 2-3)

Table 2 Associated Risk Factors of Organophosphate Exposure Among Vegetable Farmers In Sabah

Variables	Abnormal Cholinesterase ((n=38)		Normal Cholinesterase (n=125)		Chi-square test	t-test	p-value
	No. (%)	Mean (SD)	No. (%)	Mean (SD)			
Age (years)		48.0 (25.7)		41.6 (23.8)		-3.012	0.003
Body Mass Index (kg/m ²)		25.7 (1.4)		23.8 (2.0)		-5.234	0.001
Gender:							
- Male	21 (23.9)		67 (76.1)		0.032		0.857
- Female	17 (22.7)		58 (77.3)				
Education level:							
- Without formal education till primary school	6(54.5)		5 (45.5)		6.436		0.021
- Secondary school or above	32(21.1)		120(78.9)				
Income per month (RM):							
- ≤ 1000	0 (0.0)		4 (100.0)		1.998		0.368
- 1001 - 3000	30 (25.6)		87 (74.4)				
- > 3000	8 (19.0)		34 (81.0)				
Frequency of exposure (per-month):							
- Five days or more	10 (41.7)		14 (58.3)		5.303		0.034
- 1-4 days	28 (20.1)		111(79.9)				
Duration of pesticide usage:							
- More than ten years	20 (29.9)		47 (70.1)		2.720		0.132
- Less than ten years	18 (18.8)		78 (81.2)				
Pesticide storage:							
- No designated area	32 (31.7)		69 (68.3)		10.406		0.001
- Designated store	6 (9.7)		56 (90.3)				
Had attended pesticide safety training:							
- No	26 (45.6)		31 (54.4)		24.383		0.001
- Yes	12 (11.3)		94 (88.7)				
Knowledge, attitude, practice on pesticide handling:							
- Knowledge score		22.4 (1.3)		22.8 (1.1)		1.526	0.129
- Attitude score		19.8 (4.4)		19.9 (4.4)		0.076	0.940
- Practice score		18.0 (3.1)		20.9 (3.0)		5.236	0.001

Table 3 Multivariate Logistic Regression on Factors Associated with Organophosphate Exposure Among Vegetable Farmers In Sabah

Variable	Multiple Logistic Regression		
	b	Adjusted OR (95% CI)	P
Age (year)	0.07	1.07 (1.02, 1.13)	0.007
Body Mass Index (kg/m ²)	2.15	8.60 (2.80,26.51)	<0.001
Frequency (days) of exposure a month	1.79	5.99 (1.29,27.76)	0.022
Had no attended pesticide safety training	2.21	9.08 (2.97,27.74)	<0.001
No designated pesticide storage	1.93	6.92 (1.70,28.25)	0.007
Low practices scores on pesticide handling	1.79	6.01 (1.97,18.36)	0.002

^aForward LR Multiple Logistic Regression model was applied. Multicollinearity and interaction terms were checked and not found

Hosmer-Lemeshow test (p=0.323), classification table (overall correctly classified percentage=88.3%), and area under the ROC curve were applied to check the model fitness.

Exposure Risk Assessment of Organophosphate Pesticide among Vegetable Farmers

HIRARC is an approach to assess hazards and their related risks and to create a system to confine the

risks¹⁴. The assessment results for organophosphate exposure are shown in Table 4.

Table 4 HIRARC for the Use of Organophosphate Pesticides among Vegetable Farmers

Hazard Identification				Risk Analysis			Risk Control
Work activity	Hazard:	Which can cause/ effect	Existing Risk Control	Likelihood (A)	Severity (B)	Risk (AXB)	Recommended Control Measures
Purchasing pesticides from shop/ supplier And Transportation	Chemical: Direct contact - spillage or leakage from packaging.	Skin irritation, respiratory effects, absorption, and entry to the body due to repeated contact, prolonged exposure potential to cause cancer.	NIL	1	3	3	Personal hygiene PPE: Hand gloves Placed pesticides at the back of vehicle truck.
Storage	Chemical: Direct contact - spillage or leakage during unloading or loading.	Skin irritation, respiratory effects, absorption, and entry to the body due to repeated contact, prolonged exposure potential to cause cancer.	Designated store	3	3	9	It required all vegetable farmers to provide specifically designated places to store pesticides. Self-personal hygiene, labeling of pesticide in store PPE: as necessarily
Mixing or preparation of pesticide solutions (adding water and transferring to the pump sprayer). And Spraying	Exposure to OP pesticide: Direct contact and inhalation - splashing or spillage of pesticide. Unsuitable PPE or without PPE	Skin irritation, difficulty breathing, coughing, absorption, and entry to the body due to repeated contact, prolonged exposure potential to cause cancer.	Boots, long sleeve shirt & pants	3	3	9	Personal hygiene, guidance, and training on emergency treatment. PPE: training for proper use of PPE (e.g., respirator and nitrile rubber). Substitute with organic compost control or use a pesticide in a less harmful category.
Cleaning and minor maintenance of spray equipment	Chemical: Direct contact to skin, eye, oral (splashing or spilled)	Skin irritation, respiratory effects, absorption and entry to the body due to repeated contact, prolonged exposure potential to cause cancer.	Minimal PPE	3	3	9	Personal hygiene Health education PPE: proper PPE

DISCUSSION

Agricultural workers who perform jobs directly in contact with pesticides are at high risk of pesticide poisoning¹⁵. Blood cholinesterase levels found that 23.3% were overexposed to OP pesticides. This prevalence is higher as compared to the findings reported by Norsyazwani et al. (15.2%) and Hod et al. (7%) among farmers in Malaysia and the study conducted by Guytingco et al. (12.5%) in Thailand among agricultural workers^{16,17,18}. The results revealed that most of the vegetable farmers in Kundasang had experienced multiple health symptoms. The symptoms experienced by the vegetable farmers in this study are consistent with earlier studies reported in Malaysia by Haswanee et al. 2018, and Syahidatul et al., 2020. Older age is a determinant of abnormal blood cholinesterase and is similar to other studies^{19,20}. This finding agrees with earlier studies reported in Malaysia^{21,22}. In this study area, most agriculture practices are operated in the family as an informal business and small-scale vegetable farming. Traditionally they learn the technique from family members and nearby friends. Currently, there is no system available to monitor pesticide usage by relevant agencies among this group of workers. Since the activity was traditionally practiced long ago, older vegetable farmers were probably exposed to OP.

A health surveillance program is the time needed to monitor the impact of pesticide exposure among family farmers. This study found that one-third of the respondents were overweight with BMI \geq 25kg/m². There is a significant relationship between abnormal blood cholinesterase level and BMI \geq 25kg/m². The finding is in line with results from a study conducted in Tanzania, which showed a significantly depressed blood cholinesterase level among overweight farmers²³. Organophosphates are known to be lipophilic and, therefore, rapidly distribute into tissue and fat. It is essential to educate the farmers to keep their normal body weight. Many previous studies revealed the frequency of pesticides among vegetable farmers contributing to the high prevalence of pesticide poisoning. Statistical analysis of this study showed that vegetable farmers who more frequently apply pesticides have almost six times higher odds of pesticide exposure than those with less pesticide application. The increased duration of exposure to OP pesticides increased the potential risk of OP pesticide exposure. This current study agrees with the surveys conducted by other researchers. It found longer exposure time and more frequency of pesticide application, increasing the risk of pesticide exposure and poisoning^{25,26,27,28}. The frequency can be reduced if they substitute with organic compost control or use a pesticide in a less harmful category.

Nearly two-thirds (65%) of the respondents had attended training at least once in the last five years regarding pesticide safety provided by government authorities or pesticide suppliers. Attending pesticide safety training contributes to better knowledge, attitude, and practice among farmers²⁴. This study found that vegetable farmers who had not participated in pesticide safety training have odds more than nine times pesticide exposure than those who have participated in pesticide safety training. The importance of training is to enhance their knowledge of pesticide use, beliefs in pesticide hazard control, and levels of safety behavior. Relevant authorities can make it compulsory to attend the training by integrating it in their agriculture or business license renewal. These interventions may facilitate knowledge enhancement and compliance with safety behaviors and become a priority for decreasing pesticide exposure among farmers.

The storage of pesticides was significantly associated with the risk of OP exposure. Nearly two-thirds (62%) of the respondents do not keep their pesticides in a designated place. Some of them keep their pesticides in the home and even in the living room area. Inadequate storage may increase the risk of exposure among vegetable farmers and their families due to highly accessible places. The association between abnormal blood cholinesterase and storage of pesticides is significant (aOR: 6.92, 95%CI: 1.70-28.25, p=0.007). The analysis concludes that vegetable farmers who have not adequately stored their pesticides have seven times greater odds of OP exposure than those keeping their pesticides in a designated store. This current study is in line with findings reported in other previous studies^{29,30}. The recommended storage is stock in a separate, locked cabinet or other secure structure, away from children and pets. To reduce storage problems, advisable to buy only enough pesticide for one season's use. A study on the respondents' knowledge, attitude, and practice (KAP) toward OP pesticide handling showed that all respondents had a high score on knowledge questions, with scores above 75% of the correct response. 65.7% of respondents indicate a high level of practice, and only 1.8% of respondents have a high attitude level. The odds risk analysis of OP exposure found that practices adopted by vegetable farmers toward pesticide handling were significantly associated with abnormal blood cholinesterase (aOR: 6.01, 95%CI: 1.97-18.36). These results agree with the findings of other researchers^{12,29,33}. However, there was no significant relationship between OP exposure and knowledge levels and attitude levels of the respondents.

This poor practice of pesticide handling can be monitored by regular educational enforcement by the relevant authority. PPE use is a last line of defense to reduce the risk of chemical hazards. Failure to use appropriate PPE during the handling of pesticides increased the risk of being poisoned by pesticides. Most of the vegetable farmers in Kundasang adopted three forms of PPE, including boots, long sleeves, long pants, and hats. This finding agrees with previous studies^{23,25,29,30,31,32}. PPE availability in the local market, lack of awareness of the potential health effects of pesticides, attitudes, and practices might influence PPE use among vegetable farmers in Kundasang. A HIRARC study was undertaken to determine the magnitude of hazards, risks level, and recommended control measures. The highest risk level for vegetable farmers was a medium risk (RR=9). This risk level may be elevated if vegetable farmers have no extra precautions, such as wearing PPE and hygienic practices. This finding is in line with a previous survey on safety and health in commodity agriculture in Malaysia¹⁵. The recommended control measures will be able to reduce the risk of getting OP exposures.

CONCLUSION

Organophosphate exposure among the vegetable farmers in Kundasang was higher than in other settings. 23.3% of them were overexposed to OP pesticides. The risk factors associated with organophosphate exposure include old age and overweight. The significant occupational factors were frequency (days) of exposure a month, had no attended pesticide safety training, did not have designated pesticide storage, and standard practices scores on pesticide handling. The exposure risk assessment level for vegetable farmers was at low-medium risk. This study provides additional evidence of the negative impacts of pesticide exposure on health. Relevant authorities such as the District Agriculture Office, Federal Agricultural Marketing Authority (FAMA), and Malaysian Agricultural Research and Development Institute (MARDI) are required to provide regular training on safe pesticide handling to increase awareness among vegetable farmers Kundasang Sabah.

Limitations

Pesticide-related health symptoms relied on self-reports by the vegetable farmers.

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Ethical Committee Approval: The Ethical Board of Universiti Malaysia Sabah (UMS) has approved this study with approval code: JKEtika 3/17(7).

Informed Consent: All study participants signed a consent form. We provided an information sheet containing the research objectives, data collection method, roles of participants, personal and community benefits, and any possible harm to the participant. Confidentiality of the information gathered was assured.

Conflict of interest: The authors declared that they have no conflict of interest.

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