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Occupational Pesticide Exposure and Respiratory Effects among Mosquito Control Workers in Kota Bharu and Bachok, Kelantan

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Abstract

Pesticides have been widely used in public health to control mosquito breeding, causing occupational exposures. A cross-sectional study was conducted to evaluate the relationship between pesticide exposure and respiratory health among 43 mosquito control workers in two vector control units in Kelantan by using purposive sampling. Pesticide risk assessment was based on the Chemical Health Risk Assessment (CHRA). A British Medical Research Questionnaire (BMRC) was used to assess respiratory symptoms and lung function was measured using a spirometer. The cumulative pesticide exposure of the individuals was calculated by taking the average number of fogging sessions per month. The risk level for all pesticides was moderate, except for Actellic 50EC. The most common respiratory symptoms were dyspnea (25.6%), cough (18.6%), phlegm (18.6%), and chest tightness (14.0%). Lung function was normal in 30%, restrictive in 45%, and obstructive in 25%. None of the reported respiratory symptoms and lung function values were associated with cumulative pesticide exposure ($p>0.05$). Past respiratory illness had a significant relationship with chest tightness (Adj OR=0.009, 95%CI: < 0.001 – 0.834). Age had a significant relationship with phlegm (Adj OR=1.259, 95% CI: 1.010 – 1.569). In conclusion, cumulative pesticide exposure did not relate to respiratory effects. However, mosquito control workers should be given proper training on pesticide handling and the effective usage of PPE to reduce occupational pesticide exposure.

Keywords: hazard, toxicity, risk assessment, respiratory symptom, lung function

1.0 INTRODUCTION

Pesticides, specifically insecticides are widely used in agriculture and pest management to protect food security and public health. Global pesticide usage has steadily increased from 2.3 million tonnes in 2019 to 4.1 million in 2020. Pesticides have been used in Malaysia since 1967 to combat vector-borne diseases such as Malaria, Dengue, Filariasis, Japanese Encephalitis, Plague, Scrub, Typhus, and Yellow Fever. The most popular insecticides used for mosquito control are Permethrin and Malathion. About 73.5 million USD of public funds (0.03% of Malaysia's Gross Domestic Product) was spent on its National Dengue Vector Control Programme, which represented 1,591 USD per reported dengue case [1]. The District Health Offices (DHOs) consumed higher liquid-based and powder-based pesticide usage than Local Authority (LAs) in their vector control and prevention activities by 53,952 litres and 4,721 kg respectively. Similarly, the consumption of pesticides by DHOs was four times greater than diesel for pesticide dilution [2].

Organochlorines (4429 metric tonnes) are the world's most popular pesticides, followed by organophosphate (1375 tonnes), pyrethroids (414 tonnes), and carbamates (30 tonnes) [3]. Southeast Asia consumes the most organochlorine and organophosphate pesticides. In Malaysia, two types of insecticides are commonly used for vector control purposes namely, organophosphate and pyrethroid. Organophosphates are typically used during the outbreak, whereas pyrethroids are used in more general situations. Pesticides are potentially hazardous to human health due to their inherent biological reactivity. Acute pesticide poisoning kills approximately 300,000 people worldwide each year with organophosphates, organochlorines, and aluminium phosphide being the most reported causes [4]. Prolonged exposure to these insecticides can cause complications to the human respiratory and neuropsychological system. Salivation, headache, dizziness, and excessive secretions that lead to breathing difficulties are initial symptoms if the material has been inhaled. Involvement of the respiratory muscle can lead to respiratory failure. Exposure to permethrin is associated with tremors (T syndrome), convulsions, irregular breathing, increased respiratory rate, incoordination, ataxia, hyperactivity, and paralysis [5]. In addition, Malathion can cause chest tightness, breathing difficulty, or no breathing at all.

Most of the previous studies in Malaysia examined the neurobehavioral effects of pesticides in the agricultural sector (paddy and cocoa) [6-7], foggers [8], and mosquito control workers [9]. However, there is a very limited report on the effect of pesticide exposure on the respiratory health of workers involved in controlling vector-borne diseases. These workers are highly exposed to pesticides during spraying and potentially may experience respiratory effects from their repeated and long-term exposure. More workers would be frequently exposed to high levels of pesticides as mosquito control activities are on the rise. Therefore, this study assessed the pesticide risk assessment and the respiratory effects of mosquito control workers. This would provide basic information on pesticide exposures, chemical safety management, and safety practices for this sub-group of healthcare workers in fogging activities [10]. In addition, conducting the risk assessment would identify the consequences of pesticide exposure and their associated probabilities, while at the same time being able to predict the adverse health effects.

2.0 METHODOLOGY

2.1 Study Design and Subject Recruitment

A cross-sectional study was carried out in two District Health Offices (DHOs), Kota Bharu and Bachok, which are two of Kelantan's DHOs. The staff in both DHO's Vector-Borne Diseases Control units served as the sampling frame. A list of staff in the Vector-Borne Disease Control Unit was obtained from the Kelantan Health State Department. Two DHOs (Kota Bharu and Bachok) were chosen based on the two highest dengue cases reported among 10 districts in Kelantan. Therefore, more fogging activities by health professionals are required to control the outbreaks.

Purposive sampling was used to select respondents based on inclusion criteria. The inclusion criteria were staff aged 21 to 60 years old, have been working for more than 6 months, and can understand and communicate either in Malay or English Language. Those underwent belly, chest, or eye surgery (because there will be increasing pressure in the eye during the procedure), and were diagnosed with chronic problems, heart disease, asthma, chronic obstructive airway disease, chest pain, recent heart attack, unstable heart condition, bulging blood vessel (aneurysm in the chest, belly, or brain), suffer from active tuberculosis (TB), and respiratory infection (cold or the flu) were excluded from this study. The sampling size was determined using Raosoft software with an accepted margin error was 0.05 or 5% and 95% of the confidence interval and the sample population was 67. Therefore, the estimated sample size after considering the 20% dropout and non-response rate were 58 which included all mosquito control workers in selected DHOs that suited the inclusion criteria.

2.2 Identification of Hazards and Evaluation for Potential Risk

Data on chemicals used by the mosquito control workers were collected using guidelines for potential risk and occupational exposure from the Department of Occupational Safety and Health. Details on pesticides used were listed in Table 1 and the qualitative risk assessment of Generic Chemical Health Risk Assessment (GCHRA) on each pesticide used (Table 2) was based on the Manual of Recommended Practice: Assessment of the Health Risk Arising from the Use of Chemical Hazardous to Health in the Workplace published by the Department of Occupational Safety and Health (DOSH) Malaysia [11]. Each pesticide's Safety Data Sheet (SDS) was obtained from its manufacturer for hazard identification. Each pesticide's hazard rating was determined by referring to its acute toxicity data for inhalation (LC50). Other qualitative evaluations, such as exposure frequency, duration, and magnitude were carried out based on the work characteristics of mosquito control workers.

2.3.1 Degree of Hazard

Following the Classification, Labelling, and Safety Data Sheet of Hazardous Chemicals Regulation 2013 under the Occupational Safety and Health Act 1994 [12], the pesticides were rated on a scale of 1 to 5 (from non-hazardous to the most hazardous) [11]. The Chemical Safety Data Sheet (CSDS) provided data for hazard rating evaluation (HR).

2.3.2 Evaluation of Exposure

The degree of chemical release was estimated using a qualitative method based on frequency rating (FR) and magnitude rating (MR). The frequency of exposure was rated on a scale of 1 to 5 (from lower potential exposure to higher potential exposure), pesticide-related work activities were observed to determine, and the degree of absorption (inhalation and dermal) were rated as low, moderate, or high. Once the degree of a chemical release or the presence and degree of chemical inhaled was determined, the magnitude rating (MR) was calculated. Finally, based on FDR and MR, an exposure rating (ER) was assigned [11].

2.3.3 Evaluation of Risk

The level of risk was determined using the risk rating (RR) equation RR = HR X ER, or through the risk matrix. The level of risk was determined by the RR results, which were as follows: low risk (RR=1 to RR=4), moderate risk (RR =5 to RR=12), and high risk (RR=15 to RR 25). The assessment was concluded based on the level of risk and the adequacy of control measures [11].

2.3.4 Individual Cumulative Pesticide Exposure

Individual cumulative pesticide exposure was calculated using the average number of fogging sessions per month and the average duration of each fogging session. It was computed as follows:

$$\textit{Cumulative pesticide exposure}\left(\frac{hour}{month}\right) = \textit{Average hour exposed to pesticide per day}\left(\frac{hour}{day}\right) X \textit{ Day of working }\left(\frac{day}{week}\right) X\ 4 \textit{ weeks per month }\left(\frac{week}{month}\right)$$

2.3 Questionnaire on Respiratory Symptoms

A modified version of the questionnaire on respiratory symptoms was adapted from a previous researcher [13-14] and follows the standard questionnaire from British Medical Research Council (BMRC) [15]. The questionnaire was translated and validated to the Malay version [16] and has been used in local population studies [17-18]. Four domains in the questionnaire were included in the study: cough, phlegm, chest tightness, and dyspnea, The questionnaire included personal details, occupational details, respiratory symptoms, smoking status, personal protective compliance, work practices, and details on pesticide exposure. Respiratory symptoms were based on their experience during the last 12 months. The current smokers were defined as those who smoked a tobacco product at the time of the study. Each subject that participated voluntarily was required to answer a set of questionnaires that approximately took about 10 minutes for them to finish answering all the questions provided. After the subject submitted the questionnaire, the investigator revised the submitted questionnaire to ensure each question was answered by the subject. If there were any questions left unanswered, the investigator would inform the subject to complete the questionnaire.

2.4 Lung Function Test

Measurements for lung function were taken using a spirometer to assess the condition of the workers' respiratory system. The lung function parameters consisted of Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV_1), and Forced Capacity Ratio (FEV_1/FVC). The test was conducted during working hours and was done according to the standard procedures of the American Thoracic Society [19]. The spirometer was calibrated before the investigation. A new mouthpiece was inserted into the spirometer for each subject. The test was done according to the name list of the workers. Each worker was required to do the test in the standing position with the chin slightly raised, and the neck slightly extended, and they must breathe through a mouthpiece where they should blast the air out as fast as they could until the lung was empty. Before the test was conducted on the subject, the investigator demonstrated the right way to do the test according to the standard procedures outlined by the American Thoracic Society.

The investigator would assist the former if the subject did not perform according to the instructions. This test took about 10 minutes to finish. At least three readings were required to get accurate measurements. The best two-tracing of FEV_1 and FVC should not vary more than 5%. The largest FVC and FEV_1 were reported if they did not come from the same maneuver. The maneuver must be free from cough and other variables which followed the guidelines of the American Thoracic Society (ATS) for the acceptability and reproducibility criteria [19]. Finally, the prediction model of spirometry was derived by adding study variables; demographic (age, BMI, smoking status), work characteristics (years of employment and cumulative pesticide exposure), past respiratory illness, and safety practices (mask usage) to the lung function values (FEV_1, FVC, FEV_1/FVC).

2.5 Statistical Analysis

In this study, two types of measurement variables were used: the independent variable and the dependent variable. Meanwhile, pesticide exposure was used as an independent variable, while respiratory health was comprised of reported respiratory symptoms and lung function values. All questionnaires and parameter measurements were analysed using the IBM Statistical Package for Social Sciences version 24 software. The Kolmogorov-Smirnow normality test was used to identify data type distributions that were normally distributed. The frequency, mean, range, and standard deviation of each variable of lung function values were calculated using descriptive data analysis. Multiple Logistic Regression (MLogR) was used to assess the relationship between reported respiratory symptoms with associated factors, whereas Multiple Linear Regression (MLR) analysis was used to assess the associated factors to lung function values. All variables in a block were entered in a single step using the method enter. The modelling procedure was initiated after the variance inflation factor (VIF) was used to assess collinearity between the independent variables. The VIF cut-off point was set at 10. The VIF was less than 10, which was acceptable for all the independent variables. The statistical analysis was deemed significant if the p-value was less than 0.05.

2.6 Ethical Issues and Clearance

The Human Research and Ethics Committee of Universiti Sains Malaysia (JEPeM USM) granted ethical approval; (JEPeM code: JEPeM/18110653). This study was registered with the National Medical Research Registration (NMRR), under the Ministry of Health Malaysia. The Medical Research & Ethics Committee (MREC), Ministry of Health Malaysia also granted ethical approval with the NMRR-19-329-46268 (IIR).

3.0 RESULTS AND DISCUSSION

3.1 Hazard Identification, Potential Risk, and Health Effect of Pesticides

Five different pesticides were identified for mosquito fogging activities to kill (knock down) any adult dengue mosquitoes carrying the dengue virus. All pesticides used for fogging were classified as insecticides. Actellic EC, Abate 500E, and Abate 1.1G were organophosphates classified as pesticides II, III, and IV based on acute toxicity. Endmos-Q was pyrethroid with pesticide class III, whereas VectorBac WG did not apply to any chemical class with pesticide class IV. Table 1 described the active ingredients of pesticides that cause health effects. Cypermethrin, Temephos, and Bacilus thuringeisis subsp. Israelensis all had HRs of 2, while Pirimphos-methyl had a HR of 1. Cypermethrin was classified as having an acute health effect with an inhalation category of LC50 > 2.5mg/L, a dermal toxicity category of LD50=2000 mg/kg, and an oral toxicity category of LD50=1800 mg/kg. Temephos hs an inhalation toxicity category of LC50 (rat): > 4.79 mg/L (4hr) and an oral toxicity category of LD50=3500 mg/kg (rat), LD50=4204 mg/kg (male) and LD 50 > 1000 mg/kg (female). Meanwhile, Bacillus thuringiensis subsp. Israelensis was found to be an acute pesticide with LC50 (rat) >2.84 mg/mL (inhalation), LD50 (rat) 5400 mg/kg for oral, and LD 50 (rat)>5000 mg/kg. Similarly, Pirimiphos-methyl was associated with acute health effects. The oral lethal dose range for chemicals with moderate toxicity was 500 to 5000 mg/kg with a toxicity rating of 3. Pirimiphos-methyl, Cypermethrin, and Temephos were all moderately toxic to humans, while Bacillus thuringiensis subsp. Israelensis was only slightly toxic. This classification was used to investigate pesticide exposure ratings.

A pesticide's risk was determined by two factors: exposure and toxicity. The frequency-duration rating (FDR) and magnitude rating (MR) were used to calculate the exposure rating (ER) (Table 2). All mosquito control workers had FDRs of 3. Most of the pesticide magnitude ratings (MRs) were recorded to be between 2 and 3. The degree of pesticide absorption was considered "high" with more than 50% pesticide exposure [11]. The exposure rating was calculated using HR and MR results. Pesticides had risk ratings from 3 to 6. Control measures were adequate and appropriate PPEs were provided. Four of the five pesticides (Endmos-Q, Abate 500E, Abate 1.1G, and VectoBac WG) had RR=6, indicating a moderate risk level. Only actellis 50EC had RR=1 with a low-risk level. The risk assessment for each pesticide was summarised in Table 2 using the Hazard Rating (HR), Magnitude Rating (MR), Frequency-Duration Rating (FDR), Exposure Rating (ER), Risk Rating (RR), and Risk Level. There was no difference between the types of pesticides used by mosquito control workers in both DHOs (Kota Bharu and Bachok) due to these similar pesticides were recommended and supplied by the Kelantan State Health Department. The pesticides were used as liquid formulations based on their usage during fogging activity. The pesticide was mixed with water to form an emulsion before being applied to the fogging machines. Pesticides in liquid form had a higher risk due to more splash and spillage [20].

Pirimiphos-methyl can cause respiratory paralysis, and death if exposed to high concentrations if exposed to high concentration. It can cause poisoning and trigger symptoms such as headache, weakness, feeling of heaviness in the head, a decline in memory, quick onset of fatigue, disturbed sleep, loss of appetite, and loss of orientation [21]. Cypermethrin in the Endmos-Q is a harmful synthetic pyrethroid and can cause cough, sore throat, precipitate wheezing in asthmatics, hypersensitivity pneumonitis, pulmonary edema, shortness of breath, and congestion when being exposed through inhalation [22]. Those who smoked during spraying activities without wearing a respirator, wet clothing, and short sleeves had eater skin contact with pesticides and had a higher risk of developing health problems [23]. Both Abate 1.1G and 500E contain Temephos as the active ingredients. Abate 1.1G is the least toxic while Abate 500E is harmful. Temephos has relatively low to moderate acute toxicity as compared to other organophosphate insecticides and has the same effects on humans as pirimiphos-methyl which can cause nausea, dizziness, and confusion at high exposure Temephos also can cause respiratory paralysis and death [24]. VectorBac's active ingredient is Bacilus thuringiensis supp which is less toxic. Bti is a bacterial group that is used as a biological control agent for larvae stages. Human health effects because of Bti exposure are extremely rare [25].

Pirimphos-methyl, Temephos, and Bacillus thuringess pesticide formulations contained one active ingredient. Each ingredient's chemical class was classified as Class II, III, or IV except for organophosphate and pyrethroids. The WHO classified Cypermethrin as 'moderately hazardous', Pirimiphos-methyl as 'slightly hazardous', Temephos as 'moderately hazardous', and Bacillus thuringiensis as 'unlikely to present acute hazard in normal use [26]. Based on the classification by the US EPA [27], one product was classified as 'warning', two as 'caution' and two as 'non-required'. According to Classification. Labelling, and Safety Data Sheet of Hazardous Chemical Regulations 2013 (CLASS Regulations) [12], Primiphos-methyl, Cypermethrin, and Temphos are classified as acute toxicity hazard category 4 while Bacillus thuringiensis subsp. Israelensiswas not classified (Globally Harmonized System Category 5). Furthermore, the Pesticide Act 1974 classified Actellic 50 EC as poisonous, Abate 500E, Abate 1.1G as harmful, and Vecto Bac WG as the least toxic [28].

3.2 Sociodemographic and Work Description

From the total of 43 mosquito control workers, the response rate was 74.1%. Malay males had a mean age of 39.7 ± 7.60 years, a mean of BMI 6.2 ± 4.10 kg/ms^2, and a mean duration of employment was 12.9 ± 7.10 years. Most of them were between the ages of 30 and 40 years with 74.4% having less than 10 years of working in current employment. Most of them were SPM holders (69.8%), while 23.3% had a certificate/diploma certified by the Public Health Institute, Ministry of Health Malaysia, and only 7.0% completed primary education. More than half (53.5%) were active smokers with a mean smoking index was 5.6 ± 12.56 per day with a range between 3 to 20 cigarettes. The average smoking duration was 16.6 ± 8.53 years with having been smoking between 10 to 20 years. They were exposed to pesticides for about 2.7 ± 1.48 hours daily and 72% of them worked 6 days per week.

Table 1: Health effects of pesticides used in mosquito fogging activities

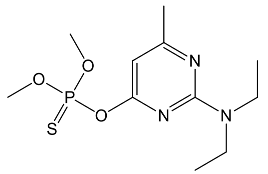
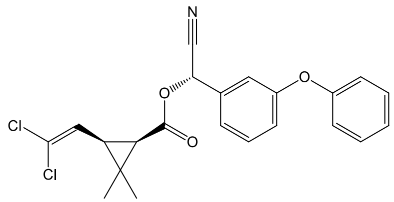
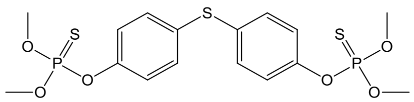
Trade Name	Active Ingredient	Chemical Structure	Pesticide Origin	Health Effects				
				Inhalation	Oral Toxicity	Dermal Toxicity	Skin Irritation	Eye Irritation
Actellic EC	Pirimiphos-methyl		Organophosphate	4 hours (Rat) LC50 > 5.04 mg/L	Acute: (Rat) LD50 = 1414 mg/kg	Acute: (Rat) LD50 > 2000 mg/kg	Slightly irritant (Rabbit)	Mild irritant (Rabbit)
Endmos-Q	Cypermethrin		Pyrethroid	4 hours (Rat) LC50 > 2.5 mg/L	Acute : (Rat) LD50=1800mg/kg	Acute : (Rabbit) LD50=2000 mg/kg	Slightly irritant (Rabbit)	Mild irritant (Rabbit)
Abate 500E	Temephos		Organophosphate	4 hours (Rat) LC50 > 4.79 mg/L	Acute: (Rat) LD50 = 3506 mg/kg	Acute: (Rat) LD50 = 1855 mg/kg	Mild irritant (Rabbit)	Non-irritant (Rabbit)
Abate 1.1G	Temephos		Organophosphate	4 hours (Rat) LC 50> 4.79 mg/L	Acute: (Rat) LD50=4204 mg/kg(male) and LD50>10 000mg/kg (female)	Acute: (Rat) LD50 = 2000 mg/kg (male) and LD50 > 2378 mg/kg (female)	Non- irritant (Rabbit)	Non-irritant (Rabbit)
VectoBac WG	Bacillus thuringiensis subsp. Israelensis strain AM 65-52	None	Bacteria	4 hours (Rat) LC50 > 2.84 mg/L	Acute: (Rat) LD50 > 5000 mg/kg	Acute: (Rabbit) LD50 > 5000 mg/kg	Slightly irritant (Rabbit)	Non-irritant (Rabbit)

Table 2: Risk assessment of each pesticide used by mosquito control workers

Trade Name	Pesticide Origin	HR	MR	FDR	ER	RR	Risk Level
Actellic 50 EC	Organophosphate	1	3	3	3	3	Low
Endmos-Q	Pyrethroid	2	3	3	3	6	Moderate
Abate 500E	Organophosphate	2	3	3	3	6	Moderate
Abate 1.1G	Organophosphate	2	2	3	3	6	Moderate
VectoBac WG	Bacteria	2	2	3	3	6	Moderate

HR=Hazard Rating, MR=Magnitude Rating,
FDR=Frequency Duration Rating, ER=Exposure Rating, RR=Risk Rating

Table 3 : Sociodemographic and work characteristics of the mosquito control workers (N=43)

Variables	Frequency (%)	Mean ± S.D
Age (years)		
20-29	1 (2.3)	
30-39	24 (55.8)	39.5 ± 7.56
40-49	14 (32.6)	
50-59	4 (9.3)	
Body Mass Index (kg/ms^2)		26.2 ± 4.10
Education level		
Primary	3 (7.0)	
Secondary	30 (69.8)	N/A
Certificate/Diploma	10 (23.2)	
Smoking		
Yes	23 (53.5)	N/A
No	20 (46.5)	
Smoking Index (pack/year)	N/A	5.7 ± 12.56
Past respiratory Illness Yes)	40 (93)	
Years of employment		
0-5	12 (27.9)	
6-10	20 (46.5)	
11-15	5 (11.6)	12.9 ± 7.10
16-20	5 (11.6)	
21-25	1 (2.4)	
Day of working per week		
5 days	2 (4.7)	
6 days	31 (72.0)	6.2 ± 0.5
7 days	10 (23.3)	
Average hours exposed to pesticides daily	4 (9.3)	
1 hour	22 (51.2)	
2 hours	12 (7.9)	
3 hours	0 (0)	2.7 ± 1.48
4 hours	2 (4.7)	
5 hours	1 (2.3)	
6 hours	1 (2.3)	
7 hours	1 (2.3)	
8 hours		

3.3 Pesticide Exposures, Personal Protective Equipment Usage, and Work Safety Practices

The average of fogging activities within one month was 23.3 ± 2.74 with 67.4% conducting an average of fogging activities between 20 to 25 sessions. The average duration for each fogging session was 1.9 ± 0.68 hours with 54.3% completing the fogging session in 2 hours. They claimed to have been exposed to the pesticides through inhalation, skin contact, and ingestion with 95.7%, 39.1%, and 2.2%, respectively. Types of Protective Personal Equipment (PPE) provided by each DHOs were a mask, ear plug, safety shoes, long sleeves, and gloves. Figure 1 showed PPE compliance among workers. Most of them (69.6%) always wore personal protective equipment (PPE) while fogging, 26.7% used PPE only when necessary or while being supervised and 4.3% used it infrequently. Safe work practices that were assessed were smoking during work, handwashing before and after eating, and changing clothes after work. Most of them applied safe work practices such as handwashing before and after eating (95.3%), changing clothes after working (97.7%), and 79.0% avoiding smoking when dealing with pesticides (Figure 2).

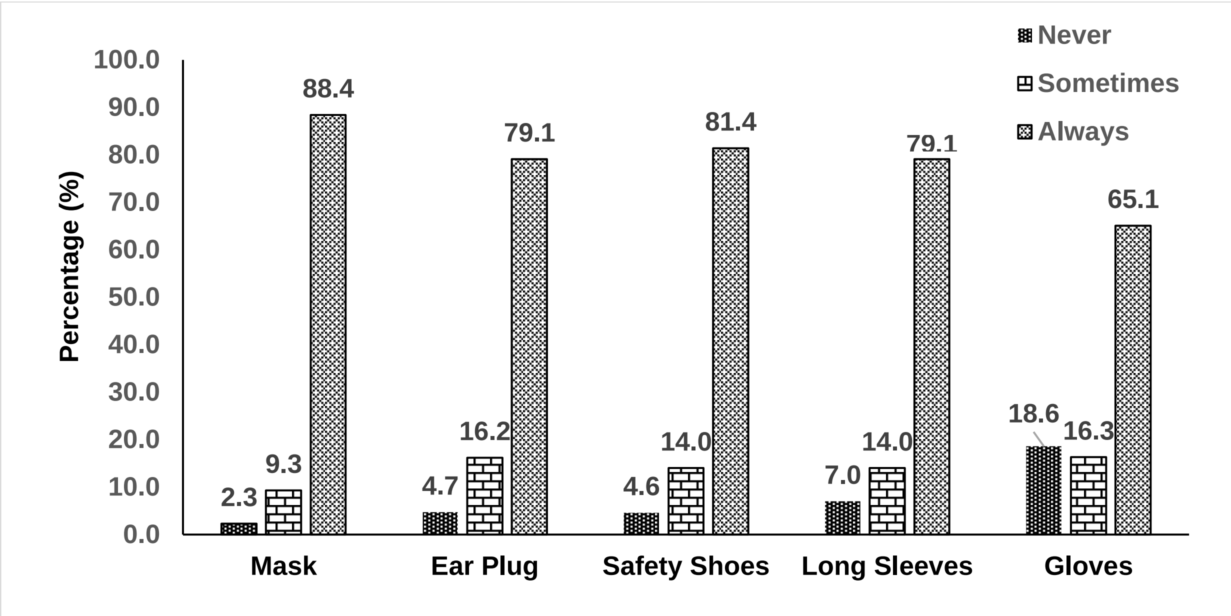


Figure 1: Personal Protective Equipment (PPE) Compliance among workers

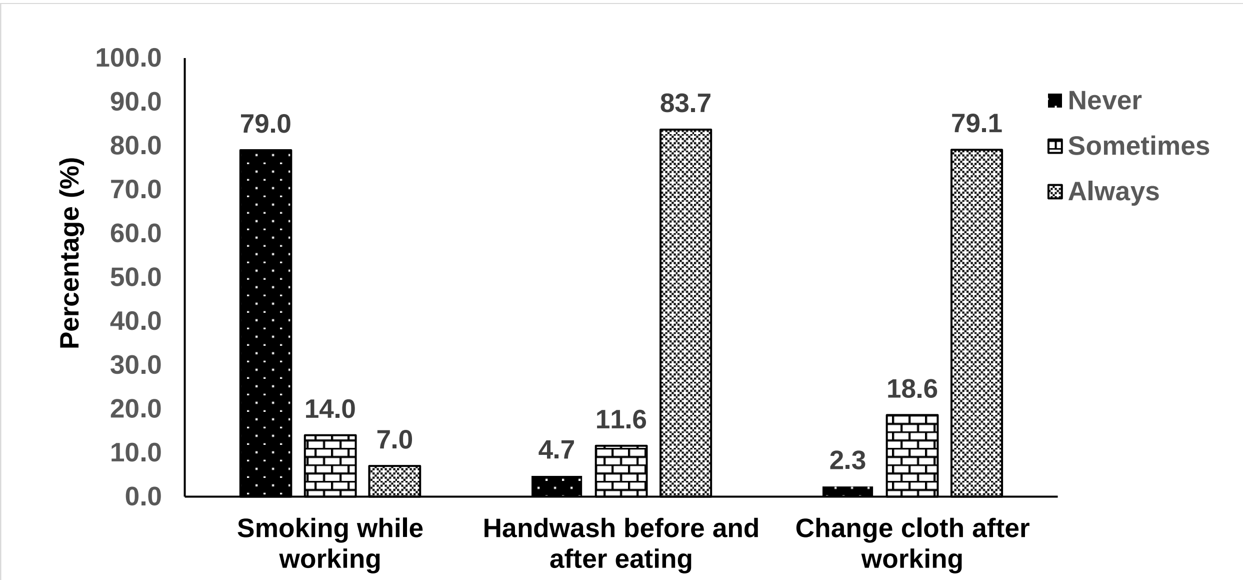


Figure 2: Work Safety Practices among workers

3.4 Respiratory Symptoms and Lung Function

Respiratory symptoms were grouped into four main categories namely cough, phlegm, chest tightness, and dyspnea. Dyspnea was the most common symptom (25.6%), followed by cough and phlegm with 18.6% respectively, and the least was chest tightness (14.0%) (Figure 3). The lung function parameter measured was Forced Expiratory Volume in one second (FEV_1) and Force Vital Capacity (FVC). The mean value of Forced Expiratory Volume in one second (FEV_1) and Force Vital Capacity (FVC) were 3.64 L and 3.08 L, respectively. The % FEV, % FVC and % FEV_1/FVC were 91.26%, 96.98%, and 101.91% (Table 4). Based on the lung function values, 30% had a normal lung, 45% had a restrictive and 25% had an obstructive lung pattern. The prevalence of respiratory symptoms was lower and lung function values were higher compared to other studies among pesticide sprayers [29-31]. This was probably due to control measures in reducing exposure to respiratory hazards.

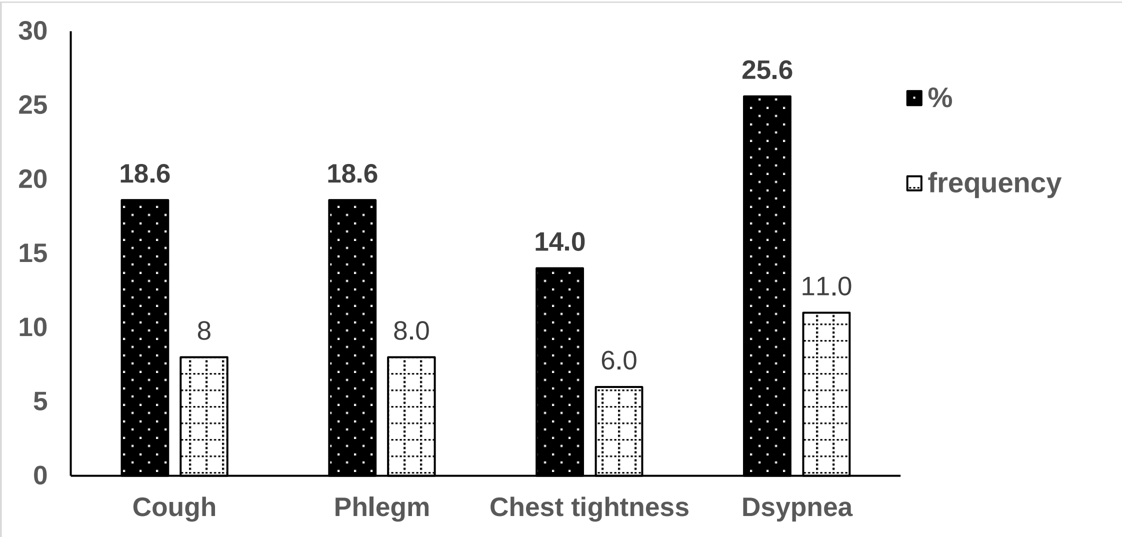


Figure 3: The distribution of respiratory symptoms experienced among workers

Table 4: The lung function values of the workers

Lung Function Parameter	Mean ± S. D	Range
Forced Vital Capacity (FVC) (liter)	3.64 ± 0.78	2.20 -5.11
Forced Expiratory Volume in One Second (FEV^1) (liter)	3.08 ± 0.67	1.19 – 4.23
% Forced Expiratory Volume in One Second (FEV^1)	96.98 ± 39.61	48.00 – 120.00
% Forced Vital Capacity (FVC)	91.26 ± 22.43	50.00 – 120.00
% Forced Expiratory Volume in One Second (FEV^1)/ Forced Vital Capacity (%FEV_1/FVC)	84.40 ± 8.66	50.00 – 97.00

3.5 Relationship between Reported Respiratory Symptoms and Associated Factors

Occupational pesticide exposure has been linked to a variety of respiratory pathologies including chronic obstructive pulmonary diseases and other respiratory manifestations of cough, wheezing, rhinitis, shortness of breath, and dyspnea as previously described. [32-33]. Organophosphate and carbamates have been recognized to affect the lungs, and airways, leading to respiratory symptoms, impaired lung function, and respiratory diseases [34]. However, none of the reported respiratory symptoms was found to be related to cumulative pesticide exposure. Similarly, Wilkins et al. [35] reported that direct exposure to pesticides was not significantly associated with chronic cough and dyspnea. In contrast, Hashemi et al. [36] found that pesticide use was associated with an increased risk of wheezing and phlegm. In addition, acute respiratory symptoms such as cough, wheezing, chest tightness, and dyspnea were significantly increased across the work shift among pesticide workers [37].

This study also found a significant risk of chronic illness as age increased. This finding was also biologically plausible since lung function was known to deteriorate with increasing age [38]. A significant relationship was found between age and phlegm (Adj OR = 1.26, 95% CI: 1.01 – 1.57). An increase of 1 year of age would increase the risk of having phlegm by 1.26 times. This study found that 41.9% of the workers were above 40 years old. Older workers have a higher risk of reporting chest tightness, shortness of breath, chronic cough, and chronic phlegm [39-40]. Moreover, cigarette smoking, an established risk factor for chronic bronchitis and asthma [41-43] was also found to be insignificant. This might be due to a mild smoking index (<20 cigarettes per day) [44] observed among respondents. A significant relationship was found between past respiratory illness with chest tightness (Adj OR = 0.01, 95% CI: 0.00-0.83). Past respiratory illness was contributing factor to reported chest tightness and dyspnea [14]. Personal protective equipment (PPE) including masks, gloves, and safety shoes might decrease pesticide exposure and any potential adverse health effects [43]. No significant relationship was found between mask usage with each of the reported symptoms (p>0.05). More than 60% of the workers always used PPE during pesticide spraying. This was a good point of having occupational health management in educating safety and health among workers at workplaces. Besides, more than 80% of them always used N95 particulate respirators masks as compared to workers in other studies [44-45].

Table 5: Associated Factors with Reported Respiratory Symptoms (N=43)

	SLogR[a]		MLogR[b]		
	Crude OR (95% CI)	**p-value**	**Adjusted OR (95% CI)**	**Wald Stat (df)**	**p-value**
Cough					
Age (year)	1.09 (0.96, 1.24)	0.189	1.11 (0.93, 1.32)	1.30 (1)	0.255
Years of Employment	1.01 (0.87, 1.18)	0.895	0.99 (0.76, 1.20)	0.16 (1)	0.686
Smoking Index (pack/year)	1.06 (0.91, 1.29)	0.451	1.02 (0.92, 1.13)	0.08 (1)	0.784
Cumulative Pesticide Exposure (hour/month)	0.99 (0.98, 1.01)	0.489	0.99 (0.96, 1.01)	1.62 (1)	0.203
Past Respiratory Illness (Yes)	1.21 (0.36, 4.11)	0.763	1.60 (1.11, 3.27)	0.35 (1)	0.325
Mask Usage (Yes)	1.88 (0.76, 4.67)	0.175	2.43 (0.78, 7.59	6.15 (1)	0.266
Nagelkerke R^2 = 0.488					
Phlegm					
Age (year)	1.18 (0.99, 1.39)	0.060	1.26 (1.01, 1.57)	4.18 (1)	0.041*
Years of Employment	0.98 (0.85. 1.14)	0.801	0.82 (0.59, 1.12)	1.54 (1)	0.214
Smoking Index (pack/year)	1.06 (0.91, 1.23)	0.451	1.08 (0.86, 1.36)	0.44 (1)	0.507
Cumulative Pesticide Exposure (hour/month)	0.99 (0.97, 1.01)	0.241	0.98 (0.96, 1.01)	1.84 (1)	0.175
Past Respiratory Illness (Yes)	1.98 (0.61, 6.39)	0.250	1.00 (0.21, 4.62)	0.79 (1)	0.074
Mask Usage (Yes)	1.33 (0.51, 3.51)	0.560	1.59 (0.51, 4.99)	0.64 (1)	0.422
Nagelkerke R^2 = 0.454					
Chest Tightness					
Age (year)	1.21 (0.98, 1.48)	0.078	1.31 (0.91, 1.90)	2.08 (1)	0.149
Years of Employment	0.96 (0.82, 1.12)	0.565	1.09 (0.59, 1.38)	0.24 (1)	0.628
Smoking Index (pack/year)	1.20 (0.86, 1.69)	0.282	1.07 (0.69, 1.66)	0.10 (1)	0.755
Cumulative Pesticide Exposure (hour/month)	0.98 (0.96, 0.10)	0.027*	0.97 (0.94, 1.00)	2.98 (1)	0.084
Past Respiratory Illness (Yes)	0.06 (0.01, 0.76)	0.030*	0.01 (0.00, 0.83)	4.13 (1)	0.042*
Mask Usage (Yes)	0.52 (0.14, 1.93)	0.330	0.43 (0.08, 2.23)	1.02 (1)	0.313
Nagelkerke R^2 = 0.630					
Dyspnea					
Age (year)	1.01 (0.92, 1.11)	0.774	0.98 (0.88, 1.09)	0.18 (1)	0.671
Years of Employment	0.98 (0.86, 1.12)	0.817	1.02 (0.84, 1.25)	0.06 (1)	0.814
Smoking Index (pack/year)	1.08 (0.93, 1.23)	0.336	1.04 (0.91, 1.10)	0.34 (1)	0.558
Cumulative Pesticide Exposure (hour/month)	0.99 (0.97, 1.01)	0.266	0.43 (0.97, 1.01)	0.61 (1)	0.434
Past Respiratory Illness (Yes)	0.15 (0.01, 1.79)	0.132	0.12 (0.10, 1.79)	2.35 (1)	0.125
Mask Usage (Yes)	1.21 (0.48, 3.03)	0.749	1.71 (0.43, 6.90	2.88 (1)	0.449
Nagelkerke R^2 = 0.224					

[a] Simple Logistic Regression, [b] Multiple Logistic Regression
Abbreviation : OR: Odd Ratio, CI: Confidence Interval

3.6 Relationship between Lung Function Values and Associated Factors

Age and Body Mass Index were important variables in determining lung function values. Another occupational variable that could also affect lung function was cumulative exposure to pesticides, years of employment, and mask usage. The smoking index was one of the confounding variables in the respiratory health study, especially for the male study population. No significant relationship was found between age, pesticide exposures, and smoking index with lung function values ($p>0.05$). The types of pesticides also explained some heterogenicity with stronger and more consistent effects for organophosphate, particularly on FEV_1 as compared to paraquat or non-specific pesticide exposure [46]. However, few researchers reported that aging, smoking, excessive smoking, and occupational exposure showed a significant relationship with low lung function [47-49]. In addition, a different pattern of lung function was found in various occupational groups exposed to pesticides. A significant reduction in FEV_1 and FVC was reported among pesticide processing workers as compared to control groups [50]. Similarly, a significant decrease was found in FEV_1/FVC after long-term exposure to cholinesterase-inhibiting insecticides among agricultural workers [51]. In contrast, no significant decrease in FVC and FEV_1 with pesticide exposure among farmers.

Table 6: Associated Factors with Lung Function Values (N=43)

	SLR[a]		MLR[b]		
	β (95% CI)	**p-value**	**Adjusted β (95% CI)**	**t-stat**	**p-value**
FEV_1					
Constant			4.07 (3.25, 7.91)	2.643	0.012*
Age (year)	-0.02 (-0.05, 0.01)	0.133	-0.02 (-0.05, 0.01)	-1.352	0.185
BMI (kg/ms^2)	0.04 (-0.01, 0.09)	0.140	0.03 (-0.03, 0.09)	1.064	0.295
Years of Employment	-0.01 (-0.05, 0.03)	0.547	-0.01 (-0.05, 0.04)	-0.148	0.883
Smoking Index (pack/year)	0.01 (-0.10, 0.02)	0.397	0.01 (-0.01, 0.03)	0.175	1.091
Cumulative Pesticide Exposure (hour/month)	-0.01 (-0.10, 0.01)	0.228	-0.01 (-0.01, 0.01)	-1.125	0.268
Past Respiratory Illness (Yes)	-0.29 (-1.10, 0.53)	0.485	-0.31 (-1.17, 0.55)	-0.725	0.473
Mask Usage (Yes)	0.11 (-1.28, 1.50)	0.869	-0.15 (-1.75, 1.46)	0.185	0.854
R^2 = 0.171					
FVC					
Constant			5.68 (2.10, 9.37)	3.218	0.003*
Age (year)	-0.03 (-0.06, 0.01)	0.060	-0.03 (-0.07, -0.01)	-1.989	0.055
BMI (kg/ms^2)	0.03 (-0.03, 0.09)	0.336	0.01 (-0.06, 0.07)	0.248	0.806
Years of Employment	-0.02 (-0.07, 0.02)	0.327	-0.01 (-0.06, 0.04)	-0.362	0.719
Smoking Index (pack/year)	0.01 (-0.02,0.24)	0.677	0.01 (-0.01, 0.03)	0.579	0.566
Cumulative Pesticide Exposure (hour/month)	-0.02 (-0.01, 0.01)	0.133	-0.01 (-0.02, 0.01)	-1.615	0.225
Past Respiratory Illness (Yes)	-0.33 (-1.27, 0.63)	0.497	-0.19 (-1.18, 0.80)	0.389	0.699
Mask Usage (Yes)	0.38 (-1.24, 1.99)	0.640	-0.07 (-1.92, 1.77)	-0.080	0.937
R^2 = 0.190					
% FEV_1/FVC					
Constant			61.07 (20.18, 101.96)	3.032	0.005*
Age (year)	0.12 (-0.24, 0.48)	0.501	0.24 (-0.16, 0.64)	1.208	0.235
BMI (kg/ms^2)	0.33 (-0.33, 0.99)	0.321	0.63 (-0.11, 1.37)	1.728	0.093
Years of Employment	0.26 (-0.26, 0.79)	0.319	0.19 (-0.41, 0.79)	0.628	0.528
Smoking Index (pack/year)	0.10 (-0.11, 0.32)	0.335	0.12 (-0.10, 0.35)	1.102	0.278
Cumulative Pesticide Exposure (hour/month)	0.03 (-0.04, 0.11)	0.403	0.05 (-0.04, 0.14)	1.223	0.229
Past Respiratory Illness (Yes)	-0.29 (-10.89, 10.31)	0.956	-4.16 (-15.42, 7.10)	-0.750	0.458
Mask Usage (Yes)	-5.74 (-23.56, 12.08)	0.519	-0.55 (-21.56, 20.45)	-0.053	0.958
R^2 = 0.144					

[a] Simple Linear Regression, [b] Multiple Linear Regression
Abbreviation : OR: Odd Ratio, CI: Confidence Interval

3.7 Study Limitation

This study only involved mosquito control workers in Kota Bharu and Bachok, therefore, it might not represent the whole population of mosquito control in Kelantan and Malaysia respectively. No causal relationship between pesticide exposure and respiratory effects was found due to its study design. Besides, this study did not measure the pesticide biomarkers such as blood and urine in assessing the cumulative pesticide exposure among subjects. A qualitative risk assessment was used to determine risk rating and potential risk of pesticide exposures. The risk assessment was done in general, indicating a risk of exposure to all pesticide applicators, therefore the assessment did not determine the actual amount of pesticide exposure for everyone. Healthy Workers' Effects (HWE) was another explanation for the non-significant results obtained in this study. Some workers were not included because they were transferred to another non-pesticides-related job or resigned due to illness caused by their susceptibility to pesticides.

4.0 CONCLUSION

From the risk assessment, Endmos Q, Abate 500E, Abate 1.1G, and VectoBac WG used in fogging activities were categorized as moderate. The active ingredients in those were Primiphos-methyl, Cypermethrin, Temephos, and Bacillus thuringiensis, respectively. Based on the spirometric assessment, more than half (70%) of the respondents had lung function impairment (restrictive and obstructive). However, pesticide cumulative exposure (hours/month) had no relationship to respiratory effects. The spirometric measurement provided baseline health data for the relevant authority to enhance employers' commitment, therefore protecting workers through medical surveillance, updating the existing guidelines, and providing adequate and suitable PPE. Therefore, more research is needed to further understand the relationship between pesticide exposure and lung function, as well as the best way to reduce pesticide exposure among workers.

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