ASSOCIATION BETWEEN OCCUPATIONAL CHEMICAL EXPOSURE AND ACUTE HEALTH SYMPTOMS AMONG BANGKOK VECTOR CONTROL OPERATORS, THAILAND

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ABSTRACT:

Backgrounds: Vector control operators (VCOs) play an important role in controlling vector-borne disease. However, they face occupational risks due to use of pesticides and exposure to chemicals. The purpose of this study was to assess the occupational risks faced by VCOs as a result of exposure to chemicals and the relationship between workers' acute health symptoms and exposure to chemicals among VCOs in Bangkok, Thailand.

Methods: A cross-sectional study was conducted in six areas within the Bangkok Metropolitan Administration (BMA) area among 96 male VCOs. General participant data including personal behavior, environmental working conditions, and health symptoms were collected via questionnaires. Cypermethrin, benzene, and toluene exposure data was collected through personal solid sorbent sampling during the time that chemicals were sprayed. Urine samples were collected for o-cresol and t,t-muconic acid (tt-MA) analysis at the end of the shift. Urine samples were also collected in the morning for biological monitoring of cypermethrin. Descriptive statistics and multiple logistic regressions were used.

Results: The average participant age was 41.76±10.21 years (mean ± SD). The average level of personal exposure to cypermethrin was 0.91±0.38 mg/m^3 or 0.005±0.002 ppm. The level of 3 phenoxybenzoic acid (3 PBA), a metabolite of cypermethrin, was 5.00±2.42 ug/g creatinine. The exposure level of benzene was 0.120±0.86 mg/m^3 or 0.37±0.26 ppm, a figure greater than the National Institute for Occupational Safety and Health (NIOSH) recommendations (NIOSH REL) Ca TWA 0.1 ppm. The level of tt-MA, its metabolite in urine, was 15.75±7.54 ug/g creatinine. Working exposure levels of toluene was 0.228±0.057 mg/m^3 or 0.06±0.01 ppm from mixing of diesel fuel. O-cresol was 159±8.38 mg/g creatinine. The results demonstrated that facial irritation, blurred vision, fatigue, and nausea were significantly associated with airborne biomarkers. Irregular use of personal protective equipment (PPE), especially when spraying indoors (OR 1.46, CI 0.52-4.67, $p<0.05$), and poor use of PPE among operators lead to increase health risks of VCOs (OR 6.08, CI 1.61 22.9, $p<0.05$).

Conclusions: The findings suggest that a program of chemical safety program training should be implemented to reduce chemical exposure and symptoms among VCOs.

Keywords: Occupational chemical exposure; Acute health symptoms; Vector control operators

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INTRODUCTION

Vector-borne diseases are a significant health concern among people worldwide and account for

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an estimated 17% of the global burden of infectious disease according to the World Health Organization. Vector control operators (VCOs) play an important role within vector-borne disease control programs. However, they face occupational risks due to pesticide use and chemical exposure.

Cypermethrin is a synthetic pyrethroid insecticide first synthesized in 1974 and widely used in agriculture, the textile industry, and public health sector [1]. Within the public health sector, this substance has been widely used to control mosquito populations in residential environments. Pyrethroids fall into two categories, Type 1 and Type 2. Type 1 works by causing the inactivation of sodium channels in the peripheral and central nervous system (CNS) to induce repetitive firing of action potentials. Type 2 holds the sodium channels open so long that the membrane becomes depolarized to the point where generation of action potentials might no longer be possible. The United States Environmental Protection Agency (USEPA) has classified cypermethrin as a possible human carcinogen (group C) because there is limited evidence that it can cause cancer in animals [2, 3]. The EPA re-evaluated the substance in 2004, finding "Suggestive evidence of carcinogenicity but not sufficient to assess human carcinogenic potential" [4]. Studies have found that human pyrethroid exposure, including cypermethrin, can cause the reduction of semen quality and increase sperm DNA damage [5].

Cypermethrin enters the body mainly by inhalation and ingestion of particulate matter and spray mist, and can occasionally be absorbed through the skin. However, humans excrete cypermethrin rapidly, typically 49% to 78% within 24 hours after exposure [1] and cypermethrin is rapidly detoxified in the blood and liver, so the acute toxicity to humans is thought to be limited [6]. Several studies based on occupational research have shown that acute exposure may result in dizziness, nausea, anorexia, and fatigue. High doses after direct exposure can cause paraesthesia of the eyes, face, and breasts, asthmatic breathing, palpitations, headaches, anxiety, hyperactivity, tremors, involuntary movement, chronic seizures, confusion, and irritation and itching sensations [7].

The most common method of adult mosquito control is chemical spraying with thermal fog machines. The process consists of a very small amount of pesticide (1-50 um) being mixed with fuel (diesel fuel) in a combustion chamber. The mixture is then sprayed into the air as a fine visible cloud of droplets. The clouds float in the air, killing mosquitoes it comes in contact with. Diesel fuel is used as a carrier for thermal fogging agents, but it creates thick smoke and has a strong smell, leading to some communities opposing its use [8]. Moreover, diesel fuel is a complex of hydrocarbon and contains poly aromatic hydrocarbons such as benzene, which the International Agency for Research on Cancer classified as carcinogenic to humans (Group 1) [9]. Petroleum distillate may "produce eye, skin, and respiratory irritation and symptoms of CNS depression, such as headache, dizziness, nausea, and vomiting" [10]. Benzene and toluene can have the same effects on humans as cypermethrin, including face, eye, and skin irritation, dizziness, and fatigue.

Almost all pesticides used in Thailand were imported. In 2012, the Office of Agriculture Economics (OAE), of the Thai Department of Agriculture reported that some 1,328 metric tons of pesticide were imported into Thailand between 2008 and 2012. Over that period, the three most frequently used pesticides in Thailand were insecticides, herbicides, and fungicides, respectively. Use of these pesticides has increased rapidly over the past five years [11]. The Thai Bureau of Epidemiology reported that 17,340 cases of pesticide exposure were treated between 2003 and 2012. The bureau also reported that an average of 1,734 patients were treated each year in that same time period with a morbidity rate of 2.35 cases per 100,000, though a decrease has been witnessed over the past decade [12]. Kongtip, et al. [13] found that 54 volunteer mosquito control sprayers in the Royal Thai Army developed health symptoms after exposure to pesticides. Of those cases, 75% presented upper respiratory issues, 59% dizziness and nausea, 37.5% headaches, 18.8% shortness breath, 12.5% chest tightness, and 3.1% hand and face numbness.

Although cypermethrin, benzene, and toluene exposure via inhalation or skin contact can contribute to skin, respiratory, and central nervous symptoms, limited information is available on the relationship between occupational chemical exposure levels, especially the level of airborne exposure concentration and biomarkers, and acute health symptoms among VCOs. This study aimed to investigate the relationship between workers' health symptoms and their occupational chemical exposure to cypermethrin, benzene, and toluene due to insecticide spraying.

MATERIALS AND METHODS

Study population

This study was conducted in six administrative areas in Bangkok: Central Bangkok, South Bangkok, North Bangkok, East Bangkok, North Khungthon, and South Khungthon. Ninety-six male (18-60 years old) VCOs were recruited. The sample size calculation was based on Kongtip's 2013 study that found that the prevalence of skin irritation in mosquito control sprayers was 75% [13]. The sample size was calculated by estimating the proportion of binary outcome in which the error of its estimate did not exceed 10% with a 95% confidence level [14]. The study required a sample size of 80 participants and an additional 10% was added to account for participant withdrawal. Therefore, the total sample size was 90 participants. However, 96 VCOs volunteered to participate in the study. Inclusion criteria to recruit participants were: 1) worked as a VCO for over 6 months; 2) sprayed chemicals for over two hours per day with a similar formula pesticide; and, 3) healthy male aged between 18-60 years old.

Permission to conduct this study on human subjects was approved by the Ethical Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University (COA No.172/2558).

Data collection

Questionnaire and content

All participants were interviewed face to face using a questionnaire with a reliability of item objective congruence (IOC) of 0.86 by three occupational health experts. The questionnaire was tested with 30 participants by using Kuder-Richardson-20 (KR-20). The questionnaire consisted of three parts:

Part 1: General demographic information such as age, sex, weight, height, and smoking behavior.

Part 2: Characteristics of working condition such as job activity and time, personal protective equipment use, and time spraying.

Part 3: Occupational health symptoms during work such as facial irritation, paranesthesia, itchy or runny nose, sore throat, blurred vision, rashes, fatigue, muscle weakness, dizziness, drowsiness, headaches, nausea, confusion, anxiety, vomiting, stomach pain, wheezing, coughing, and difficulty breathing.

Airborne analysis

Personal air samples were collected using solid sorbent tubes with flow rate 0.20 liters per minute for 10-12 liters and analyzed by Gas Chromatography - Flame Ionization Detector (GC-FID: Perkin Elmer ATD 400 a DB-1 column of 30 mm x 0.25 mm of length x diameter) The oven temperature program was set at 40ºC for ten minutes, increased at 10ºC/min to 230ºC according to NIOSH 1501 standard methods for the determination of benzene and toluene exposure in the air. The analyzer had a benzene and toluene detection limit of 0.5 μg/ml and 0.8 μg/ml, respectively.

XAD-2 adsorbent tubes with glass fiber filters 270/140 mg were also used to collect cypermethrin samples for 60 minutes with a sampling flow rate of 1.0 liter per minute and analyzed by Gas Chromatography - Electron Capture Detector (GC-ECD):Agilent 7890N, column Hewlett Packard-5 (30 x 0.25 mm of length x diameter). The oven temperature was set at 90ºC and increased at 20ºC/min to 200ºC, then increased at 3ºC/min to 230ºC and held for three minutes, according to OSHA method (PV2063) for the determination of cypermethrin concentration in the air while spraying chemicals. All samples were stored at -20ºC until the time of analysis. The analyzer had a cypermethrin detection limit (LOD) of 0.01 μg/ml, LOQ 0.02 ug/ml, % recovery 86-101 and %RSD 5.5-7.1, respectively.

The environmental working conditions, such as air temperature, relative humidity, and wind speed, were also monitored with indoor air instruments (IQ-610 Gray Wolf).

Biological monitoring

3 phenoxylbenzoic acid (3 PBA) as cypermethrin metabolism

Urine samples were collected into 10 ml polystyrene tubes on first void in the morning and kept at -20ºC until the time of analysis.

3 PBA analysis methods were modified from Thiphom and Prapamontol's method by using high-performance liquid chromatography (HPLC) – Agilent 1260, column Luna 5u C18(2) 100 A 150 x4.6 mm, flow rate 0.8 ml/min, mobile phase water:acetonitrile 40:60, inject volume 20 ul at 25ºC 210 nm (14). Then 100 uL sodium hydroxide (6N) was added to the plasma and heated up to 100ºC for an hour. After cooling, 1 ml of 0.2 sodium acetate buffer (pH 4.5) was added to adjust pH to around 12, and 2 ml of ethyl acetate was added and shaken for 10 minutes to clean up the samples. Then the remaining aqueous phase was combined with 120

uL hydrochloric acid (6N) to reduce pH to around 3, and evaporated in nitrogen steam. The residue sample was dissolved in 200 uL of methanol and 2 ml of sodium acetate buffer was added to adjust pH to 5 and solid phase extraction (SPE) cartridge was used to reduce matrix effect from hydrolyzed urine. A 3 PBA analysis was conducted in the central analysis laboratory of the Faculty of Public Health of Mahidol University. The analyzer had a 3-PBA detection limit of 0.05 μg/ml and, LOQ 0.15 ug/ml, % recovery 85-106 and %RSD 6.5-7.7, respectively.

Trans, trans-muconic acid (tt-MA) and o-cresol

The Scherer method and NIOSH 8301 methods were used to determine the level of trans-Muconic acid and o-cresol benzene and toluene exposure, respectively [15, 16]. Urine samples were collected into 10 ml-polystyrene tubes at the end of the work shift and kept at -20ºC until transported for analysis. For the determination of tt-MA and o-cresol by using high performance liquid chromatography (HPLC -DAD 1260 Agilent , column C18 250 mm 5 μ, Mobile phase : Acetic acid + Methanol + phosphate buffer (10 mL + 100 + 10) total 1000 mL), flow 1.5 mL/min, briefly, 100 uL sodium hydroxide (6N) was added in 1 ml urine and extracted with 1.5 ml ethyl acetate**.** The residue was evaporated in nitrogen steam and dissolved with 0.5 ml mobile phase (10 ml acetic acid + 100 ml methanol + 10 ml phosphate buffer). The tt-MA was analyzed at the toxicology laboratory of the Ramathibodi Hospital of Mahidol University which has a limit of detection (LOD) and limit of quantification (LOQ) for tt-MA at 10 ug/ml and 70 ug/ml, % recovery at 200 ug/l 93% and 800 ug/L 101%, % RSD 6.5% at 200 ug/l and 5.8% at 800 ug/l and for o-cresol had LOD 0.02 mg/L and 0.07 mg/L, % recovery at 0.15mg/L 90 % and1.0 mg /L 98 %, % RSD 6.5% at 0.15 mg/L 3.6% and 1.0 mg /L 2%, respectively. The quantities of metabolite concentration were used after adjusting for urine creatinine concentration.

Statistical analysis

This study used SPSS version 16 for data analysis. Descriptive statistics in terms of mean (standard deviation), median, range, frequency, and percentage were used to analyze participants demographic, environmental monitoring, and biological monitoring data, and current health condition of participants. Association between the environmental monitoring, biological monitoring, personal and working conditions (independent variables) and workers' health (dependent variables) were tested with bivariate analysis for analysis of each outcome in relation to each independent variable. A semi-final multiple logistic model was constructed in each independent variable for which $p \leq 0.2$ in bivariate analysis was used. Final logistic regression models were analyzed, including environmental monitoring, biological monitoring factors, and personal and working conditions for which $p \leq 0.2$ was used in the semi-final multiple logistic models. Statistical significance was designated at $p \leq 0.05$.

RESULTS

General characteristics

The 96 VCOs were recruited from six administrative Bangkok zones (North Bangkok, South Bangkok, East Bangkok, North Klongthon, South Klongthon, and Central Bangkok). Participants had been working as VCOs for over six months. All participants were male with an average age of 41.76±10.21 years. Most participants had completed secondary school (79%). The average work experience of the operators was 11.31±8.35 years and over half worked 3-4 hours per day (59.4%). Personal habit characteristics were the following: smoking (90.8%), drinking (84.4%), and processed food consumption, such as sausage, sour pork, and white pork sausage, (28.1%). Regarding environmental working factors, 26% of participants regularly used (every day) personal protective equipment (PPE) while spraying and mixing. Moreover, 33% of participants regularly used PPE, including chemical masks (11%), cotton masks (80.2%), goggles (10.4%), clothing (64.6%), rubber gloves (5.2%), and rubber boots (11.5%). Most operators worked or sprayed indoors (59%) as shown in Table 1.

Occupational chemical exposure and metabolites

Table 2 shows the average level of exposure to cypermethrin from pesticides among operators was 0.91±0.38 mg/m^{3}or 0.005±0.002 ppm and 3 phenoxylbenzoic acid (3 PBA) level, a metabolite of cypermethrin, was 5.00±2.42 ug/g creatinine. Exposure level of benzene was 0.120±0.86 mg/m^3 or 0.37±0.26 ppm and tt-MA, its metabolite in urine, was 15.75±7.54 ug/g creatinine. Working exposure level of toluene was 0.228±0.057 mg/m^3 or 0.06±0.01ppm from diesel fuel mixing and o-cresol was 159±8.38 mg/g creatinine.

Cypermethrin has not been assigned an occupational exposure limit or threshold limit value (TLV). Regarding benzene exposure, operators were exposed to concentrations greater than National

Table 1 General characteristics of participants; socio-demographic characteristics, personal factors and environmental working factors (n=96)

Characteristics	Number	Percentage
Socio-demographic		
Age group (years)		
<30	17	17.7
>31-40	20	20.8
>41-50	30	31.2
51>60	29	30.2
Mean (SD)	41.7(10.21)	
Education		
Primary school	24	25.0
Secondary school	67	79.8
Other diploma	5	5.2
Personal factors		
Smoking		
Don’t smoke	28	29.2
Smoke	68	90.8
Drinking		
Don’t drink	15	15.6
Drink	81	84.4
Working condition factors		
Work experience (years)		
Mean (SD)	11.31(8.35)	
Processed food consumption		
Don’t consume	79	71.8
Consume	27	28.1
Duration of spraying		
<hrs/day	39	40.6
>3 hrs/day	57	59.4
Spraying area		
Outdoor	39	40.6
Indoor	57	59.4
PPE used regularly		
No	71	74.0
Yes	25	26.0
Type PPE use		
Chemical mask use		
Never	63	65.6
Once in a while	22	22.9
Regularly	11	11.5
Cotton mask use		
Never	5	5.2
Once in a while	14	14.6
Regularly	77	80.2
Goggle use		
Never	69	71.9
Once in a while	17	17.7
Regularly	10	10.4
Rubber gloves use		
Never	66	68.8
Once in a while	25	26.0
Regularly	5	5.2
Use clothing		
Never	24	25.0
Once in a while	10	10.4
Regularly	62	64.6

Table 1 General characteristics of participants; socio-demographic characteristics, personal factors and environmental working factors (n=96) (cont.)

Characteristics	Number	Percentage
Wear rubber boots		
Never	69	71.9
Once in a while	16	16.7
Regularly	11	11.5

Table 2 Concentration of working chemicals and metabolites among Bangkok VCOs (n=96)

Parameters	Unit	Standard	Concentration Mean ± SD
Airborne exposure			
Cypermethrin	ppm	NO	0.005 ± 0.002
Benzene	ppm	NIOSH REF [17] 0.1	0.37 ± 0.26
Toluene	ppm	OSHA 100	0.06 ± 0.01
Metabolites (urine)			
3 phenoxylbenzoic acid (3 PBA)	ug/g creatinine	NO	5.00 ± 2.42
Trans,trans-muconic acid(tt-MA)	ug/g creatinine	ACGIH [18] 500	15.75 ± 7.54
O-cresol	mg/g creatinine	ACGIH [18] 0.30	159.95 ± 8.38

Institute for Occupational Safety and Health (NIOSH) recommendations (NIOSH REL) Ca TWA 0.1 ppm. Exposure level to toluene among operators was less than ACGIH and NIOSH occupational exposure limits.

Logistic regression analysis

Table 3 shows the results from multiple logistic regression analysis of all independent variables including environmental monitoring, biological monitoring, and personal and working condition factors with the significant value at $p \leq 0.2$. This study used LOD of airborne and metabolite to categorize concentration. The levels of concentration for cypermethrin, benzene, toluene, 3 phenoxylbenzoic acid (3 PBA), Trans,trans-muconic acid and o–cresol was 0.01 ug/ml, 0.5 ug/ml,0.8 ug/ml, 0.05 ug/ml,10 ug/ml and 0.02 mg/ml, respectively. Association between the environmental monitoring, biological monitoring, personal and working condition factors (independent variables) and workers' health symptoms (dependent variables) were tested with bivariate analysis for analysis of each outcome in relation to each independent variable. First-final multiple logistic models were constructed for each environmental exposure and metabolite factor (independent variable) and factors that had $p \leq 0.2$ were selected to test final logistic regression models. Then, semi-logistic regression models were used to analyze personal and working condition factors and selected for factors that had $p \leq 0.2$ to analyze in final multiple logistic models. Then, a final multiple logistic model was analyzed including environmental exposure, metabolite, and personal and working condition factors, with statistical significance at $p \leq 0.05$

Eye and facial irritation symptoms

Results indicated that VCOs exposed to chemicals while spraying, and not using PPE regularly, were twice as likely to experience facial irritation (odds ratio (OR), 1.88; 95% confidence interval (CI) 0.6-5.6). VCOs exposed to cypermethrin were also more likely to experience facial irritation (OR 1.03; CI 1.0-0.05). The odds ratio of facial irritation was greater for VCOs with o-cresol in their urine (Table 3).

The odds ratio of paraesthesia, tingling, or numbness was slightly significant among operators who worked indoors or sprayed indoors (OR 0.16; CI 0.04-0.55). In addition, operators exposed to toluene in the air while spraying were more likely to experience paraesthesia, tingling, or numbness, as shown on Table 3.

Operators exposed to benzene in the air while spraying were more likely to experience itchy/scratchy skin or eye irritation (OR 1.02; CI 1.0-1.04). The odds ratio of itchy/scratchy skin or eye irritation was approximately three times greater for VCOs with 3 PBA l in their urine (OR 2.52; CI 1.3-5.06). Interestingly, operators who worked indoors were 1.5 times more likely to experience blurred vision (OR 1.46, CI 0.52-4.67). In addition, operators exposed to toluene in the air while spraying were more likely to experience blurred vision (Table 3).

Table 3 Factors associated with prevalence of health symptoms during work (odds ratio and 95% confidence interval)

	Factors													
	Chemical exposure (air concentration)			Metabolites (urine)			Personal and working conditions							
Health symptoms	**Cypermethrin**	**Benzene**	**Toluene**	**3 PBA**	**t t-MA**	**O-cresol**	**Age**	**Education**	**Smoking**	**Drinking**	**Food**	**Time spraying**	**Regular PPE use**	**Indoor spraying**
Face irritation	1.03* (1.00-1.05)					1.01* (1.00-1.01)		0.64 (0.20-1.70)					1.88 (0.60-5.60)	0.68* (0.10-3.20)
Paraesthesia			1.02 (1.00-1.02)		0.95 (0.88-1.03)		1.05 (0.90-1.12)							0.16** (0.04-0.55)
Itchy	0.98 (0.94-1.03)	1.02* (1.00-1.03)		2.52* (1.30-5.06)		1.01 (0.99-1.02)		0.75 (0.20-2.76)			0.4 (0.10-1.77)	0.52 (0.14-1.90)		0.37 (0.05-2.89)
Runny nose								0.53 (0.20-1.38)					1.78 (0.73-4.33)	
Sore throat				1.25 (0.98-1.58)	0.927 (0.84-1.02)		0.96 (0.92-1.01)			0.63 (0.14-2.86)			6.08* (1.61-22.97)	
Blurred vision			1.01* (1.00-1.03)			1.00 (0.99-1.01)	0.96 (0.92-1.01)							1.46* (0.53-4.67)
Rash									1.96 (0.60-6.45)		0.295 (0.01-1.28)	0.40 (0.14-1.18)		
Fatigue		1.00* (1.00-1.01)	1.008 (0.99-1.02)		0.92 (0.85-1.00)				0.27* (0.95-0.80)	3.70* (0.95-14.39)		0.43* (0.17-1.11)	0.30* (0.10-0.87)	
Muscle weakness									4.16 (0.76-22.76)	0.365 (0.76-1.76)				
Drowsiness	1.02 (0.99-1.03)													0.90 (0.16-4.89)
Dizziness		0.98* (0.97-0.99)	1.12** (1.00-1.20)				0.93 (0.80-1.00)		0.73 (0.10-5.10)					4.39 (0.50-32.90)
Headaches		0.99 (0.98-1.00)	1.06* (1.04-1.09)		0.92 (0.82-1.02)				0.66 (0.14-3.11)	0.36 (0.05-2.51)		0.21* (0.05-0.92)		2.82 (0.60-13.15)
Confusion	none													
Anxiety	none													
Nausea		0.99* (0.98-1.00)	1.04* (1.02-1.05)		0.92 (0.85-1.02)	1.01 (1.00-1.012)			0.77 (0.20-2.89)	0.34 (0.05-1.95)				0.58 (0.42-5.84)
Vomiting	none													
Stomachache	none													
Wheezing											5.83 (0.83-41.01)		4.64 (0.66-32.74)	
Cough				1.03 (0.97-1.10)									4.58 (0.60-30.60)	
Difficult breathing	1.03* (1.00-1.06)			0.72 (0.48-1.08)	1.03 (0.97-1.10)							4.04* (1.47-11.07)		1.21 (0.24-6.06)

* $p < 0.05$

Skin symptoms

No significant associations were found between exposure to chemicals and skin symptoms or rashes among VCOs (Table 3).

Muscular symptoms

Results indicated that VCOs exposed to benzene in the air while spraying were more likely to experience fatigue (OR 1.0; CI 1.0-1.01). Those who did not use PPE regularly were 0.3 times (OR 0.3; CI 0.1-0.8) more likely to experience fatigue. No significant associations were found between exposure to chemicals and other demographic and work characteristics and muscle weakness among VCOs (Table 3).

Digestion symptoms

Nausea was more likely to be experienced by operators exposed to benzene (OR 0.99; CI 0.98-1.00) and toluene (OR 1.04; CI 1.01-1.05) in the air. However, no significant associations were found between chemical exposure, biological factors, or personal and working conditions and vomiting and stomach symptoms.

Neurological symptoms

Results indicated that operators exposed to benzene and toluene in the air while spraying were more likely to experience dizziness (OR 1.02; CI 0.99-1.03) and (OR 1.12; CI 1.0-1.2), respectively. Headaches were more likely to be experienced by operators exposed to benzene (OR 1.06; CI 1.04-1.09). Interestingly, operators who spent more hours spraying were 0.21 times more likely to experience headaches. No significant associations were found between chemical exposure, biological factors, or personal and working conditions and confusion and anxiety.

Respiratory symptoms

Difficulty breathing was greater among operators who reported being exposed to chemicals due to spraying for a greater amount of time (OR 4.04; CI 1.4-11.07). In addition, operators exposed to cypermethrin while spraying were more likely to experience difficulty breathing (OR 1.03; CI 1.0-1.06).

DISCUSSION

The average concentration of cypermethrin among the 96 VCOs exposed while spraying for mosquitos was 0.005±0.002 ppm or 85 ug/m^3±$32ug/m^3$. Cypermethrin exposure among the VCOs sampled in this study was higher than in previous studies. Previous studies conducted on workers from Durban, South Africa, showed cypermethrin exposure levels of 2.8-4.9 $\mu g/m^3$ [19]. Moreover, Zhang, et al. reported that pesticide-spraying operators exposed to deltamethrin had levels of 0.01-0.89 $\mu g/m^3$ in the breathing zone [20]. However, most previous studies focused on outdoor spraying activities. In this study over half of the VCOs (59.4% n=57) sprayed indoors.

The findings regarding 3 PBA levels in urine, a biomarker of cypermethrin, of 5.00±2.42 ug/g creatinine was consistent with Hardt [21] that looked at indoor pest control operators. The benzene concentration in the air was greater than NIOSH recommendations (NIOSH REL) Ca TWA 0.1 ppm. Results from this study were similar to those of Moolla, et al. (2015) who indicated that benzene concentration from diesel exceeded EPA inhalation standard reference concentration [22]. However, tt-MA as a metabolite of benzene exposure in urine was not higher than the biological exposure indices standard of the American Conference of Government Industrial Hygienist 2007 (ACGIH) which recommended the biological exposure indices standard at end of shift to be 500 ug/g creatinine [18]. Operators' exposure to toluene and o-cresol was not higher than the occupational exposure limits set by ACGIH recommendations.

Previous studies reported that pest and vector control operators could be exposed to various hazardous chemicals while mixing, loading, and spraying [23]. The findings show that cypermethrin exposure was linked to facial irritation, itchy eyes, blurred vision, drowsiness, and dizziness ($p \leq 0.05$). These findings were consistent with He, et al. [24] and Perger and Szadkowski [25].

This study found that benzene exposure was associated with itchy eyes, fatigue, and dizziness. Toluene exposure was found to be associated with facial irritation, paraesthesia, itchy eyes, blurred vision, dizziness, headaches, and nausea. These findings were consistent with previous studies that stated that neurophysiological and psychological disorders could occur as a result of exposure to solvents [26]. Moreover, results showed 63 operators (65.3%) were not wearing chemical masks while working.

Association between occupational risk factors and vector control operators' health symptoms

This study adjusted for age, smoking, drinking, processed food consumption, time spent spraying, regular use of PPE, indoor spraying, chemical exposure and metabolites and used logistic regression models to analyze data. Results from this study indicated that not using PPE regularly had greater adjusted odds ratio of facial irritation, sore throat, and fatigue than the other factors. Furthermore, indoor spraying resulted in higher probability of paranesthesia, blurred vision, and headaches. Time spent spraying was found to result in the highest difficulty breathing. In addition, results showed 71 operators (74%) who did not use PPE regularly and were exposed to cypermethrin had higher probability of face irritation, eye irritation, difficulty breathing, and drowsiness. Similarly, previous studies found that cotton farm workers exposed to pyrethroid could develop various health symptoms such as facial sensations, dizziness, headache, fatigue, and nausea [27, 28].

Operators who reported that they sprayed at indoor locations and were exposed to toluene were associated with paraesthesia and blurred vision. This finding was similar to van Netten [29] which indicated that airplane passengers and crew often complained of eye irritation due to residual permethrin emulsion spraying for aircraft disinfection, as these products were found to contain volatile organic compounds in all aerosol preparations. Moreover, this study found that operators exposed to benzene and toluene experienced dizziness. This is consistent with Lee, et al. [30] who indicated that workers with chronic toluene exposure developed palpitations, insomnia, and dizziness with headaches. This study also found that operators exposed to benzene while spraying experienced fatigue, a finding consistent with Tunsaringkarn, et al. [31], and Moura-Correa, et al. [32] who indicated that workers exposed to benzene were significantly associated with fatigue.

This study had several limitations. First, self-reporting could result in the inability to recall events and questionnaire participants could answer by over or under estimating. These factors may reduce the disclosure of addict behavior and the reliability of responses. Second, time spent indoors spraying versus outdoors spraying were not included in this study, operators were only asked about overall time spraying which may be a confounding factor.

CONCLUSION

This study found that VCOs are a vulnerable population and face many risk factors leading to detrimental health symptoms. The results demonstrated that facial irritation, blurred vision, fatigue, and nausea were significantly associated with chemical exposure, biomarkers, the frequency of PPE use, and indoors spraying. In particular, indoor spraying and poor use of PPE may increase risks that could lead to health symptoms. The findings suggest that the introduction and implementation of chemical safety programs could reduce chemical exposure and symptoms among the VCOs. Further research in occupational health is necessary in order to determine the effectiveness of chemical safety programs under real life conditions and control studies are needed to integrate personal protective equipment and fit test programs to reduce chemical exposure with a focus on biological monitoring.

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