ORIGINAL ARTICLE

PESTICIDE APPLICATION, DERMAL EXPOSURE RISK AND FACTORS INFLUENCED DISTRIBUTION ON DIFFERENT BODY PARTS AMONG AGRICULTURE WORKERS

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ABSTRACT

Agriculture sector accounts significant numbers of injuries and fatalities in the workplace particularly related to pesticide management. Among three main pathways of pesticide exposure, dermal contact is the most common route, which exposure usually occurs during pesticide mixing/loading, application, harvesting and other farming activities. This review aims to present and discuss several vital components of pesticide dermal exposure among agriculture workers, as well as pesticide application in agriculture sector in Malaysia involving different commodity agriculture sub-sectors. Pesticide exposure was discussed from perspective of three pesticide management activities (i.e. preparation, application and cleaning) that contribute to the risk of exposure through three routes (i.e. emission, deposition, transfer). Moreover, this paper also discussed pesticide dermal exposure risk assessment methods which can be defined into exposure assessment and effect assessment. The exposure rate was affected by various factors such as application equipment, application rate and duration, type of pesticide formulation, pesticide management stage, usage of personal protective equipment, training and aptitude of the applicator as well as environmental factors (i.e. temperature, humidity, wind speed and direction). The factors mention earlier have been used to explain the exposure distribution over different parts of the body and support the fact that pesticide type was not a major factor in total exposure.

Keywords: *Pesticide, dermal exposure, exposure risk, distribution*

INTRODUCTION

Agriculture sector accounts significant numbers of injuries and fatalities in the workplace hence ranks among the top risky occupation[1]. Pesticides play an important role in agricultural production and the principle of its usage is that it should reach the target organism, having its intended effect towards them, and finally decompose into harmless compounds[2]. However, their inappropriate use has affected the health of the workers who handles such toxic substances. Agriculture workers faced exposure risk to pesticides through three main pathways which are inhalation, ingestion and dermal contact[3]. Among these three, dermal contact is the most common route[4]. Usually, pesticide exposure happens during mixing/loading, application, harvesting and other farming activities[5].

Occupational dermal exposure can lead to numerous diseases and adversely affect worker's health and their capacity to perform work, which result in significant economic loses, including decreased productivity, medical expenses, and loss of work because of illness suffered. Without proper consideration on safety while dealing with pesticides activities, long-term exposure to pesticides may lead to several chronic health problems such as cancer, neuro-behavioural changes, liver abnormalities and kidney dysfunction[5]. According to the World Health Organization, at least 3 million pesticide poisoning incidents occur annually worldwide, and about 30,000 people are killed as a result of pesticide poisoning every year[6]. However, pesticide exposure assessment is a very complicated task as it depends on several factors often reported in previous studies.

Since dermal exposure is an important issue among pesticide operators, the purpose of this paper is to present and discuss: (1) pesticide application in agriculture sector in Malaysia perspective, (2) pesticide management activities that contribute to different pesticide exposure routes, (3) and factors influence pesticide dermal exposure, and its distribution on different body parts of agriculture workers.

METHODOLOGY

This review paper covers related study from year 2002 to 2015, with total number papers referred to complete this review paper were 38 published papers. All screened articles were searched through Google scholar and Scopus search engine with numbers of keywords related to the title reviewed, such as pesticide, dermal exposure, risk assessment, pesticide exposure assessment, pesticide distributions and pesticide toxicity. Inclusions of the articles were based on the year the paper has been published and the fulfilment to the category listed.

This review paper focused on dermal exposure to pesticides among pesticide operators, which covered pesticide application, pesticide management activities and exposure routes, common health effects and factors influence its distribution on different body parts.

PESTICIDE APPLICATION IN AGRICULTURE SECTOR IN MALAYSIA

The Malaysian agricultural sector can be categorized into three sub-sectors, namely (i) agro-industrial subsector which serve the export market; comprise of oil palm, rubber, cocoa and timber industries, (ii) food subsector for domestic consumption including rice, fruits and vegetables, livestock and fisheries and (iii) miscellaneous group serve both domestic and export market; including pepper, coconuts, sweet potato, cassava and tea[7]. Extensive use of agrochemicals appear to be one of the issues that have bearings on the future roles of the agricultural economy in Malaysia, where Malaysian farming sector is still depending on chemical fertilizers and pesticides to sustain the needed yields and ensure adequate profit levels of producers. Beside health risk it poses on farmers, these situations eventually lead to unintended environmental damages as well as food safety issues[8].

According to the United States Environmental Protection Agency (EPA), pesticides can be defined as substance used to prevent, destroy, repel or mitigate any pest which is harmful living things ranging from insects, animals, weeds to microorganisms[9]. It can be classified into herbicides, fungicide, insecticide, nematicide, rodenticide and bactericide according to target organisms, or chemical structure of the compound (i.e. organochlorine, organophosphorus, phenoxy acid herbicides, urea and pyrethroids), or even based on type of health hazard involved. Chemical pesticide formulations consist of an active ingredient, which is the actual poison to the pest, and a variety of additives, which are added to improve the efficacy of its application and action[10]. It is either in liquid form, concentrated, powder, dust, particle, aerosol and fog. From 250 types of chemical utilized in agriculture sector worldwide, 100 types are insecticides, 50 types are herbicides, 50 types are fungicide, 20 kinds are nematicides and 30 kinds are other chemical substance[11].

Herbicide is commonly used to control weeds in oil palm plantation as well as other crops [12], and paraquat was the most frequently utilized herbicide in Malaysia plantation back then. However, it has been banned by government of Malaysia since 2002 due to toxicity and hazards it pose to humans, and lifted in 2006 to allow more comprehensive study. Application of paraquat in Malaysia has been a major concern due to pesticide poisoning cases frequently suffered by plantation workers, especially when most of them are woman[13]. There are several other common broad-spectrum herbicides available in Malaysian market, such as glufosinate-ammonium and glyphosate. All these herbicides are foliar applied, with paraquat was effective through contact, glufosinate-ammonium being partially systemic, and glyphosate being systemic[14].

Glyphosate (N-phosphonomethyl-glycine) is organophosphorus and nonselective herbicides used in oil palm plantation and marketed in Malaysia about 15 million litres/year[15]. It is categorized under class III pesticide by Pesticide Board of Malaysia, which is classified as harmful or slightly hazardous. It was initially commercialized by Mosanto company under the trade name *Roundup*® in form of isopropylamine salt formulation. Glyphosate as active principle on plants is often added with other ingredients to create the commercial formulas[16]. Formulation usually contain three basic components, i.e. glyphosate in the form of salt (isopropylamine/IPA, potassium and ammonium salt), surfactant or surfactant mixture (adjuvants), and water[17,18]. Most of commercial formulations contain the isopropylamine (IPA) salt of glyphosate.

According to Department of Agriculture (2013), rubber sector is the second largest agriculture industry in Malaysia comprise of 1,311,947 hectares of land use, while 15,884 hectares were used for vegetable growing, and pineapple sector utilized 15,689 hectares mainly in Johore. From a survey, 14.5% of farmers in Cameron Highlands (of 4,531

Table 1: Chemicals commonly used for rubber, vegetable and pineapple plantations in Malaysia[19]

Active ingredients	Trade names	Type	Chemical group
Glyphosate	Roundup, Touchdown, Victor, Laredo, Wrangler, Manage, Credit, Renegade, Cutter, Vantage, Bronco, Maverick, Deputy, Outlaw, Shootout, Holster	Herbicide	Glycine
Paraquat	Gramoxone	Herbicide	Bipyridylium
Permethrin	Ambush, Pounce, Ectiban, Sentinel, Delice, Vitolice	Insecticide	Pyrethroid
Lyphosate + 2,4-D	Focus, Rustler	Herbicide	Glycine + Phenoxy
Gluphosate + Dicamba	Rustler	Herbicide	Glycine + Benzoic acid
Glyphosate + Florasulam	Prepass	Herbicide	Glycine + Triazolopyrimidine
Permethrin + Pryethrins + Piperonyl butoxide	Disvap V	Insecticide	Pyrethroid + Pyrethrins + P450-Dependent monooxygenase inhibitors
Oxycarboxin +Carbathiin +Thiram	Arrest	Fungicide	Carboxamide + Dithiocarbamate
Thiophanate methyl	Senator	Fungicide	Benzimidazole
Methomyl	Lannate	Insecticide	Carbamate
Metribuzin	Lexone, Sencor, Evict	Herbicide	Triazinone
Nicosulfuron	Accent	Herbicide	Sulfonylurea
Propanil	Stempede EDF	Herbicide	Amide
Propiconazole + azoxystrobin	Quilt	Fungicide	Triazolesconazoles + Strobilurin

farmers) involved in growing vegetables, flowers and fruits had symptoms of pesticide poisoning. A study reported that compared to other states in Malaysia, Johore was among the highest state of pesticide poisoning cases. Moreover, a study involved 400 Malaysian rubber workers suggested that improvement should be focused on standard in storage of pesticide containers and disposal of empty containers, as well as ensure continuous education and training programme on pesticide use.

PESTICIDE MANAGEMENT ACTIVITIES

Pesticide management is normally performed through three main activities which are preparation of pesticide, application and cleaning of spraying equipment[20]. Other operations such as re-entry were often taken into account when considering pesticide handling in agricultural practices[21]. Throughout pesticide preparation, exposure may occur with pesticides being dispersed, leaked or spilled during mixing and tank loading, subsequently enter human body[22]. The process involves opening the bottle containing pure pesticide substance, mixing the pesticide solution with other pesticide and water, as well as loading the sprayer tank. There are usually spills out of the container during this process, reaching handler's body parts such as hands, arms and legs[20].

During pesticide application, operator's body is exposed to the droplets from the nozzles. This occurrence may be influenced by various factors (i.e. meteorological factors, application factors, and formulation factors). Previous study reported that less than 0.1 % of applied pesticides to control agricultural pests actually reach the target, meanwhile the remainder spreading out into the environment due to airborne drift[23], and eventually affects workers, consumers, wildlife, air, soil and water system. Cleaning operation involve workers clean the sprayer equipment and containers by pouring clean

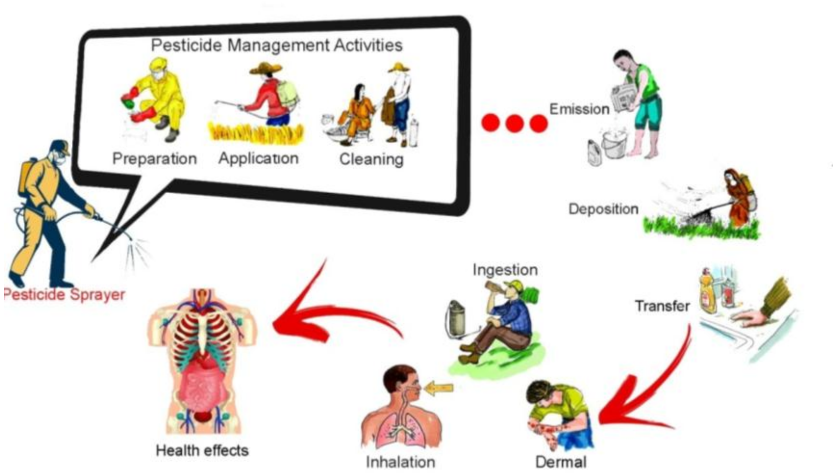

Figure 1: Exposure pathway of pesticides

water on all the accessories once the spraying process is finished. During this activity, there are numerous spills from the spraying equipments towards worker's body.

There are three exposure routes of applicators to pesticides, which are inhalation, oral ingestion and dermal uptake. However, the most common exposure routes are inhalation and dermal routes[24]. According to conceptual model of dermal exposure developed by Schneider et al. (1999), transport of contaminant mass from its sources to the skin surface occurred through three main routes, which are emission, deposition and transfer. The exposure pathway of pesticides was explained in Figure 1.

Emission can be described as mass transport of pesticide by direct release from its sources towards skin or clothing, for example by splashes and spills, as well as immersion of hands onto liquid or powder-form pesticides. Deposition is mass transport from air as environmental medium to skin or clothing, and the distribution of airborne pesticides is greatly influenced by its physical and chemical properties and environmental factors such as meteorological condition. Normally the contaminant mass of small particles such as vapours and mist (aerodynamic diameter of <100 μm) is first released into the air and eventually deposited on skin or clothing. During pesticide application, up to 30-50% of total amount pesticide applied can be lost to the air. Transport of mass from contaminated surfaces onto skin or clothing is known as transfer. For example, workers come into contact with surfaces such as floor and worktables, or working tools and equipments that have been contaminated with the pesticide[25].

PESTICIDE DISTRIBUTION ON DIFFERENT BODY PARTS

Dermal exposure level and its distribution on different body parts were reported varies in several studies[6,26,27,28]. The variability distribution pattern of exposure found on the applicators' bodies indicate nonuniformity of dermal exposure, depending on many different factors. Previous study found that the primary exposure was on the front parts of the body, and the lower body parts were exposed more compared to upper body parts[28]. In some cases, significant pesticide contamination was also observed on the back of the operator. This can be explained by indirect contamination through contact with sprayed plants, especially in the cases of very dense crop foliage[26].

For leg exposure, it is usually affected by various factors such as crops' growth stage, foliage density, operator height, application method and technique and other parameters. It is reported that leg exposure accounts 72-75% of the total dermal exposure, and similar findings recently reported by Cao et al. (2015) that thigh and lower leg was the most contaminated parts, accounted approximately 76-88%[28]. Study by Capri et al. (1999) also reported that lower legs, arms and chest were most contaminated with procymidone in flower greenhouses. When manual spraying method was performed in greenhouses, main proportion of pesticide distribution was found on lower legs and feet which represents 60-80% of the total exposure when a spray lance was used by walking forward or backwards[29].

It is very important to put great protection on hands during pesticide application in order to increase self protection. Study by Machera et al. (2003) concluded that hand exposure is a major contributor to the total potential dermal exposure among the operator[30]. The hand exposure values determined in the study through whole-body dosimetry method accounted on average of <76% of total potential dermal exposure, which also much higher than the value of 6.0 ml/h determined in dye tracer studies[26]. This situation can be associated with several reasons such as sprayer lance leak and accidental spill, which reflects common farm practices including workers carelessness and poor maintenance of application equipments, subsequently resulting to heavy handed contamination. Since most of the operators held the spray lance with their right hand, the spraying that was closer to the right side of the body resulted in higher contamination on the right half compared to the left side of the body. Thus, any leakage from the components of spraying equipment, for instance the lance, trigger handle and hose were generally formed over the right half of the body[28]. Moreover, hands can come into contact with many parts during the application, such as spraying equipment, clothes and plants, leading to higher pesticide exposure[6].

FACTORS INFLUENCE OCCUPATIONAL DERMAL EXPOSURE TO PESTICIDES

The exposure rate was usually affected by various factors such as application equipment (e.g. hand-held or vehicle-mounted sprayer, airplane, helicopter), application rate and duration, the type of pesticide formulation (e.g., powders, granules, micro-encapsulates)[31], the pesticide management stage[20,21], the usage of personal protective equipment (e. g., coveralls, gloves, face mask), and the training and aptitude of the applicator. Moreover, operator exposure also depends on environmental factors such as temperature, humidity, wind speed and direction[5,28]. Thus, the growth stage of the crop, foliage density, applicator height, and all parameters mention earlier have been used through several studies to explain the exposure distribution over the different parts of the body and support the fact that pesticide type was not a major factor in total exposure[27].

Spray application equipment

Type of spraying equipment is one of the important factors affecting the risk of inhalation as well as dermal exposure to pesticides among operators[5]. Different types of spray application equipment include aircraft and helicopters, field sprayers, orchard sprayers, vineyard sprayers and different types of hand-operated sprayers[29] There are several characteristics influence the equipment used by the farmers. Since pesticide use scenarios in developing countries are differ from those in developed countries, general exposure data cannot be readily extrapolated from the existing international predictive exposure models. For instance, manual backpack sprayer is commonly practiced in most regions of China for general plant protection[28], while hand spraying using power sprayer is an application method generally used in Korea[27]. In contrast, survey conducted among paddy farmers in Kerian district, Malaysia found that three types of spraying equipment are widely used, which are manual knapsack sprayer, motorized knapsack sprayer and pressurized sprayer[5].

Handheld spraying equipment is found to pose greatest exposure risk than other pesticide application techniques especially when operator is well protected inside the tractor cab[27]. This is due to the operator that walks into the area where the crop is being treated and covered with spray, particularly when treating large and dense crops. Moreover, different spray application techniques and pressures highly influence the droplet size of pesticide, which is one of the main factors contributing to operator contamination. For example, study reported potential dermal exposure (PDE) contaminating the operators' body that practice handheld applications in tomato greenhouses was ranges from 25.4 to 35.8 $mL\ h^{-1}$ [30], while for spray lance the mean values of 48.1 $mL\ h^{-1}$ were reported by Nuyttens et al. (2009)[29], which can be associated with usage of different spray application techniques.

Application dosage, frequency and duration

Most farmers believe that usage of higher pesticides concentration and mixing several pesticides together are effective to kill pests in shorter time and increase crop yield[32]. However, this will also results to higher pesticide exposure. Furthermore, the frequency and duration of pesticide handling shows different effect on exposure when comparing both seasonal and lifetime basis. For example, the exposure of an operator that handles pesticide once a year is lower than those who normally apply pesticide for many consecutive days or weeks in a season[31].

Type of pesticide formulations

The types of pesticide formulation are known to affect dermal exposure potential. The pesticide is either in liquid form, concentrated, powder, dust, particle, aerosol and fog[11]. For example, liquids are likely to splash and occasionally spill, resulting in higher risk of direct skin contact, or even indirect skin contact through clothing contamination. On the other hand, solid may generate dust while it being loaded into the spraying equipment, causing exposure to the several body parts, especially face and eyes.

Moreover, pesticides packaging may also affect the exposure happen in the process of opening the bags, depending on the packaging types[31].

Pesticide Management Stage

Dermal exposure to pesticides are usually occurs with pesticides being dispersed, leaked or spilled during mixing/loading, application, cleaning[3] and other farming activities, such as harvesting[6]. Therefore, pesticide exposure assessments should be considered before and after the spraying process. When comparing the relative exposures of three pesticide main operations which are mixing/loading, application and re-entry[21], study found that the mix and load operation can be identified with higher exposure levels, as indicated by the low MOS (Margin of Safety).This situation is due to the volumetric measuring step of the active ingredient in order to achieve appropriate application concentrations. In addition, this may also results from the workers that rarely use protective gloves. This study reported that the potential dermal exposure of application step was 38 ± 17 mL h^{-1}, with the highest distribution proportion on torso, head and arms. When comparing three stages involved, reentry was found to contribute least towards the total exposure, meanwhile mix/load stage contribute the most. Similar findings reported in other study where mix and load operation accounted for two-thirds of total daily exposure in mechanized open field farms.

Usage of personal protective equipments (PPE)

For most organization, PPE is a critical component in the safety program. The uses of PPE involve protection of head, hand, back, eye, eye, face, foot, skin and breathing. Usage of proper PPE found to contribute significantly in reducing acute and chronic injury, or even fatalities among farmers, caused by pesticides exposure[1]. This is supported by significant association between high poisoning symptoms and non-usage of PPE reported in previous study where the Prevalence Risk Ratio for ‘Non usage/Usage’ is 1.3 (95% CI = 1.0-1.6)[33]. However, previous study identified that workers in smaller agricultural sectors were less likely to comply with these safety protection standard[9]. There are several reasons cited among farmers for not wearing PPE, including being uncomfortable, inconvenient, unavailable to purchase and high cost of PPE[33], and interference to hear machinery [1]. The use of relatively cheap PPE such as dust masks may suggest that the farmer’s choices of PPE were influenced by considerations of minimizing costs. Similar findings reported from a study in developing county where non usage PPE among farmers reported to be associated with discomfort due to hot and humid environment and prohibitive costs[33].

Study on the effectiveness of correct usage of PPE in reducing pesticide dermal as well as inhalation exposure has been done among Malaysian paddy farmers. The mean of dermal exposure to pesticides tested recorded much higher for respondents adopting improper use of PPE, using both manual and motorize operated spraying equipments. Paraquat dermal exposure mean for farmers with improper PPE usage was found to be 80.91 ± 57.30 ppm compared to 36.37 ± 22.78 ppm for respondents using proper PPE. Similar findings reported when high mean of paraquat inhalation exposure of 0.054 ± 0.037 ppm and 0.056 ± 0.021 ppm recorded among farmers with improper use of PPE for manual and motorized sprayer respectively[5].

Training and aptitude of the operator

Poor knowledge on the risk associated to pesticide usage among pesticide operators, including the correct application and the necessary precautions appears to be a factor influence the degree of exposure. In some cases, the risk of pesticide exposure increases when the workers not paying attention to the instructions on proper way to use the pesticides, resulting in accidental spills of chemicals, leakage or faulty spraying equipment[31]. As equipment calibration is very important to prevent both over and under-application, 80% of farmers interviewed did not calibrate their spraying equipment and did not familiar with the concept of calibration. The study also reported association between high poisoning symptoms experienced by the farmers and failure to calibrate their equipment properly. This supports the argument that poor application practices can result in higher exposure through increased emission rates[33].

Ignorance on safety guidelines on PPE usage may extent the exposure, beside fundamental sanitation practices such as hand washing after pesticide handling[31]. High level of knowledge was recorded among the respondents with higher education level. The assessments of pesticide application among farm workers by showed higher levels of pesticide knowledge among those with high education level, but the use of protective equipment was poor.

Applicator height

Applicator height was found to affect the exposure rate to pesticides. Previous study shows that highest amount of chlorpyrifos residue in paddy a field was found on lower leg of male applicators and least on the chest underneath the clothes[32]. In contrast, for female applicators, the highest concentration of residue was recorded on the chest outside the clothes while the least was found on the chest underneath the clothes. The difference in chlorpyrifos concentrations and body parts between male and female workers can be explained by the differences in body size and posture during pesticide application. Concentrations of chlorpyrifos reported by this study were greater in males (526.34 ± 478.84 mg/kg) than the females (500.75 ± 595.15 mg/kg). However, females generally showed a higher exposure rate on the upper body (9.5–15.1% of total dermal exposure) more than that of male applicators (1.3–4.6% of total dermal exposure)[27]. This is due to female workers which are normally shorter in height may have to lift their sprayer to higher position closer to their chest[32]. This also results in more spray droplets depositing on head, upper arms and forearms than male applicators of greater height[27].

Crop height and density

The degree of direct contact with plants could directly influence human exposure level to pesticide. Exposure and risk assessment of chlorpyrifos in a maize field under different heights of maize, with average maize height of 61.8 cm (A1) which below the applicators' waist, the average maize height of 108 cm (A2) which close to the applicators' chest, and the average maize height of 212 cm (A3) which above the applicators' head. Highest exposure rate was recorded on the situation of highest crop height[6]. Total potential dermal exposure (PDE) values were 27.8, 90.6, and 462.1 mL h^{-1} for the applicators under A1, A2, and A3 spraying environments, respectively. Moreover, the crops with higher foliage density will result in higher exposure rate compared to less density crops due to more contact frequency. Thus, more pesticide residues were measured on the patches during spraying on a very dense crop compared to less dense crop application[27].

Crop type

Potential dermal exposure to pesticides also depends on the size and geometry of the crop since these variables may influence the amount of pesticides comes into contact with the operator's clothing[34]. Study reported the PDE to deltamethrin among workers of small scale with low technology vegetable production units, and analysing the influence of crop types, which are maize (Zea mays) and broccoli (Brassica oleracea). Both crop types are different in height, where broccoli was planted in regular rows as knee-high plants, while maize had a mean height of 2.0 m. The mean PDE value recorded were 258.4 mL h^{-1} for maize and 139.4 mL h^{-1} for lower crop. In terms of the distribution on different body parts grouped into hands; head, torso and arms; thighs and legs, the mean values recorded were far greater exposure in upper body part for maize than for broccoli. This effect is due to operator's movements that involve spraying upwards and downwards, practically from shoulder to knee height to cover all the maize plant adequately, compared to broccoli plant that needs to be sprayed downwards[34].

Clothing penetration rate

Penetration rate of protective clothing is one of the factors to be considered when evaluating pesticide exposure towards applicators. Several studies assumed ten percent clothing penetration, while average of 6.9% clothing penetration was obtained from study by An et al., 2014, where the applicators wore double protective garments of 100% cotton. There are numerous factors that affect the penetration rate, for example fabric thickness, yarn twist and wicking, as well as pesticide mixture's properties such as viscosity and surface tension[6].

Environmental factors

Previous studies have shown that less than 0.1% of applied pesticides actually reach the target, while the remainder spreading out into the environment particularly due to airborne drift[23], and consequently affects workers, consumers, wildlife, air, soil and water[5]. Pesticide drift is a complex phenomenon that also affected by several environmental factors such as droplet size, wind, air movement and humidity[2]. For instance, observing the wind direction and appropriate time of pesticide application are important practices that should be took into account to minimize human exposure in tropical region, where higher atmospheric temperatures would increase the chemicals volatility, thus increase their availability for inhalation and dermal absorption[35].

CONCLUSIONS

Dermal exposure appears to be the main exposure route among pesticide handlers. Lack of knowledge about pesticides and their safety labels, non-compliance of personal protective equipments (PPE) usage, inappropriate pesticide use, storage and disposal of empty containers, were frequently reported in previous studies as factors contributing to human exposure. Therefore, several recommendations can be adapted to ensure minimization of total pesticide exposure. Mechanisms to control usage and sale of restricted and banned pesticides should be well developed. Besides, adequate protective clothing that covers sensitive and frequently exposed body parts and good-quality and appropriate spraying equipments are imperative. To ensure availability and affordability for these products, distribution and subsidizing scheme would be able to help farmers. In order to raise knowledge and awareness on pesticide risks among farmers, visual instructions on packaging labels describing pesticide formulations and warning descriptions written in their local language can be practiced. Besides, farmers in both central and remote areas should be trained on pesticide usage and alternatives to ensure accessible of knowledge regarding integrated pest management. Furthermore, review of integrated pest management programme through monitoring pesticide usage and application methods should be considered after training participation allowing continuous improvement.

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