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Dermal Exposure and Health Risk Assessment of Pesticide Use in Palm Oil Plantation in Malaysia: A Concept Paper

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ABSTRACT

Objective: This paper provides an empirical literature on the methodology used in the health risk assessment of pesticide use in palm oil plantation with the aim for a comprehensive assessment framework through both semi-quantitative and quantitative methods.

Method: Semi-quantitative assessment model DREAM and DERM assessed occupational dermal exposure to pesticides. The whole body dosimetry method using uranine tracer is the quantification method of the level to pesticides exposure. The biological monitoring through acetylcholinesterase (AChE) catalytic activity in saliva measures the health risk from the prolong exposure.

Conclusions: Incorporate a comprehensive assessment framework through both semi-quantitative and quantitative methods allow us to model the health risk of pesticide use in the oil palm plantation. It is useful for stakeholders for the improvement of the risk assessment scheme, optimization of factors influence level of exposure and development of programs to aware workers on the appropriate use of pesticides.

Keywords: *Health risk, pesticide, models, whole body dosimetry, saliva*

1. Introduction

In recent years, there has been increasing awareness on the need for sustainable productivity of agricultural supply chain, including palm oil to secure increasingly growing population. As a country long recognized one of the leading producers and exporters of palm oil in the world, Malaysia has recorded a production of more than 18 million tons of crude palm oil (CPO) in 2012. In order to increase level of production, pesticides appear to be crucial elements in pest management program aim to control agricultural pests. The application of herbicide to control weeds is the most common practice in oil palm plantation (Wahyu & Dedi, 2013).

Previous studies have shown that less than 0.1% of applied pesticides intended to control agricultural pests actually reach the target, while the remainder spreading out into the environment particularly due to airborne drift (García-Santos et al., 2011), and consequently affects workers, consumers, wildlife, air, soil and water (Baharuddin et al., 2011). Pesticide drift is a complex phenomenon affected by several factors such as droplet size, wind, air movement, humidity, sprayer equipment and pesticide formulation (Snelder et al., 2008). Therefore, repeated pesticide exposure may put the handler's health at risk, with pesticides being dispersed, leaked or spilled during mixing and

application processes, hence entering the human body either directly or indirectly. 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 (Baharuddin et al., 2011).

Human exposure to pesticides occurs through three main pathways which are inhalation, ingestion and dermal contact (Lesmes-Fabian et al., 2013). Among these three, agriculture workers extensively exposed to pesticide through dermal contact (Acquavella et al., 2004), and there is still no consensus about the most appropriate way to evaluate it (Lesmes-Fabian et al., 2013; Schneider et al., 2000). Considering situation in developing countries, exposure assessment methods preferably must be inexpensive and easy to use. Semi-quantitative and qualitative methods such as Fenske's visual scoring system (VSS) and field observations are examples of such simple assessment methods (Blanco et al., 2008). The model DREAM (Dermal Exposure Assessment Method) was developed as a semi-quantitative method to assess occupational dermal exposure to chemical agents and has been partially validated in several case studies with different characteristics (Van-Wendel-De-Joode et al., 2005). As an easy-to-use method of exposure assessment based on determinants of dermal exposure, Dermal Exposure Ranking Method (DERM) could also be used to define priorities for prevention and training programs (Blanco et al., 2008). Thus, the feasibility of these methods to be implemented on palm oil plantation system in a developing country becomes necessarily assessed.

Quantification of dermal exposure to pesticide is important to establish the level of health risk faced by pesticide operators. There are two well-known techniques for assessing the pesticides drift, which are chemical analysis and use of tracers (García-Santos et al., 2011). Patch and whole body sampling are the commonly used methods to estimate dermal exposure. However, whole body sampling has an advantage over the patch sampling as it does not rely on uniform distribution of the contaminant over large section of the body (Soutar et al., 2000).

The main mechanism of action for organophosphorus (OP) and carbamate pesticides is the inhibition of cholinesterase activity, an enzyme that hydrolyzes the neurotransmitter acetylcholine, which allows for normal neurological and motor function (Henn et al., 2006). The conventional method to assess the degree of occupational exposure among workers exposed to OP pesticides is the measurement of cholinesterase (ChE) levels in blood. Although the determination of erythrocyte AChE indicates acute intoxication with anticholinesterase pesticides, the interpretation of ChE inhibition in both erythrocytes and serum is complex. However, since AChE catalytic activity has been detected in saliva, the procedure of determination salivary AChE is more readily acceptable for biological monitoring as saliva collection is less invasive as compared to blood samples collection (Ng et al., 2009).

This paper provides an empirical literature on the methodology used in the health risk assessment of pesticide use in palm oil plantation with the aim of providing a foundation from which to build a comprehensive assessment framework through both semi-quantitative and quantitative methods. Considering situation in developing countries, exposure assessment methods preferably must be inexpensive and easy to use. Although development of semi-quantitative model such as DREAM (Dermal Expo-sure Assessment Method) serves as a method to assess occupational dermal exposure to chemical agents and has been partially validated in several case studies with different characteristics, the validity of this method to be implemented on palm oil plantation system in a developing country was not yet assessed. In addition, limited study reporting the pesticide exposure in palm oil plantation under different sprayer types and PPE usage levels, as well as pesticide exposure on different body parts and pesticide management activities.

Despite of providing information on level of health risk, dermal exposure quantification is also useful to support the development of proper policy measures. It is useful for stakeholders for the improvement of the risk assessment scheme, optimization of factors influence level of exposure and development of programs to aware workers on the appropriate use of pesticides.

2. Review of the literature

2.1 Dermal Exposure Assessment Method (DREAM)

Dermal Exposure Assessment Method (DREAM) and Dermal Exposure Ranking Method (DERM) is the

most common model used to assess the dermal exposure from the pesticide use in agriculture setting. The DREAM method consists of two parts which are inventory and evaluation (Van-Wendel-De-Joode et al., 2003). For the inventory part, hierarchical structured questionnaire include following modules (i.e. company, department, agent, job, task and exposure) constructed to be filled in after observing workers performing their pesticide spraying tasks. However, information will be obtained by interviewing workers whenever not feasible. The modules address general information as well as dermal exposure determinants that identified with the conceptual model of Schneider et al. (1999) and by evaluating literature. The inventory information will be programmed in MS-ACCESS to facilitate data collection.

For the evaluation part, 33 variables have been included in the questionnaire. Evaluation of exposure takes place at the task level, assessing both potential dermal exposure (Skin−$P_{TASK.BP}$) and actual dermal exposure estimates (Skin−$A_{TASK.BP}$) for 9 different body parts (BPs): head, upper arms, lower arms, hands, torso front, torso back, lower body parts, lower legs and feet. Potential dermal exposure concerns exposure on clothing and uncovered skin, whereas actual dermal exposure is defined as exposure on skin. To estimate exposure for each body part, total dermal exposure estimates are calculated (Skin−P_{TASK} and Skin−A_{TASK}).The potential exposure estimate (Skin−P_{BP}) (Equation 1) for a certain body part comprised the sum of dermal exposures caused by three different exposure routes: emission (E_{BP}) (Equation 2), deposition (D_{BP}) (Equation 3), and transfer (T_{BP}) (Equation 4).

$$Skin–P_{BP} = E_{BP} + D_{BP} + T_{BP} \quad (1)$$

The exposure route estimates consist of the products of probability (P_{BP}) and intensity (I_{BP}) of each exposure route, which will be assessed for each body part, and subsequently multiplied by estimates of intrinsic emission (E_I).

$$E_{BP} = P_{E.BP} * I_{E.BP} * E_I * ER_E \quad (2)$$
$$D_{BP} = P_{D.BP} * I_{D.BP} * E_I * ER_D \quad (3)$$
$$T_{BP} = P_{T.BP} * I_{T.BP} * ER_T \quad (4)$$

The variable for probability (P) in Equations 1, 2 and 3 [(P_{BP}), ($P_{E.BP}$) and ($P_{D.BP}$)] is defined as the frequency of occurrence of the concerned exposure route, divided into four categories. The probabilities for "emission" ($P_{E.BP}$) and "deposition" ($P_{D.BP}$) are categorized into the following categories and assigned values as indicated: unlikely (<1%of task duration) 0; occasionally (1–10% of task duration) 1; frequently (10–50% of task duration) 3; almost constantly (>50% of task duration) 10. The variable for intensity in Equations 2 and 3 [($I_{E.BP}$) and ($I_{D.BP}$)] is defined as the assessed amount of pesticide on clothing and uncovered skin resulting from the exposure route. For emission and deposition, the following categories as well as the assigned values are indicated as: small amount (<10% of body part exposed) 1; medium amount (10–50% of body part exposed) 3; large amount (>50% of body part exposed) 10.

The variable for probability in Equation 4 ($P_{T.BP}$) is defined as frequency of contact of pesticide with surfaces such as the floor, worktables, machines and working tools; the categories are the same as for emission and deposition. The variable for intensity in Equation 4 ($I_{T.BP}$) is defined as the contamination level of the contact area of these surfaces. The categories of intensity of contamination and the assigned values for these categories are as follows: not contaminated (0); possibly contaminated (1); less than 50% of contact surface are contaminated (3); more than 50% of contact surface contaminated (10).

Exposure due to emission will be given more weight [exposure route factor for emission (ER_E) = 3] than exposure due to deposition (ER_D = 1) or transfer (ER_T = 1) since emission, or mass transport of substances onto clothing and uncovered skin, is directly released with little loss of mass, whereas deposition and transfer result from indirect mass transport of substances after interference with air or surface compartments, where loss of mass is likely to occur. Moreover, absolute mass being released due to emission is likely to be higher than that due to transfer or deposition.

Intrinsic emission (E_I) comprises of physical and chemical characteristics of the substance, such as concentration of active ingredients in the substance, its physical state, boiling temperature, viscosity and dustiness. Solids, liquids and vapours substance will be calculated using different formulae (Equations 5–7, respectively). For solids, intrinsic emission will be calculated by multiplying the physical state (PS) of the agent, concentration (C), formulation (F), dustiness (DU), and stickiness-wax-moist (SS) estimates (Equation 5). For liquids, the intrinsic emission it will be the estimates of physical state (PS),

concentration (C),evaporation (EV) and viscosity (V) (Equation 6), whilst intrinsic emission for vapours will be the product of the estimates of physical state (PS) and concentration (C) (Equation 7).

$$E_{I(SOLIDS)} = PS*C*F*DU*SS \quad (5)$$
$$E_{I(LIQUIDS)} = PS*C*EV \quad (6)$$
$$E_{I(VAPOURS)} = PS*C \quad (7)$$

The actual dermal exposure estimate for each body part will be calculated by multiplying the potential exposure with its clothing protection factor for hands (O_{HA}) or for other body parts (O_{BP}) (Equation 8). The clothing protection factors for hands and other body parts (Equations 9 and 10) influence by the type of material (M) covering the skin (i.e. woven, non-woven, non-permeable) and the protection factor of the clothing material (PFM), as well as the clothing replacement frequency (RF). In addition to material and frequency of replacement, the clothing protection factor of hands (O_{HA}) depended on: whether the gloves connect well to the clothing of the arms (GC), percentage of task duration that the gloves were being worn (GD), the use of a second pair of gloves (UG) under the outer-gloves with its replacement frequency (URF), and the use of a barrier cream (BC).

$$Skin{-}A_{BP} = Skin{-}P_{BP} * O_{HA/BP} \quad (8)$$
$$O_{HA} = M*PFM_{HA}*RF*GC*GD*UG*URF*BC \quad (9)$$
$$O_{BP} = M*PFM_{BP}*RF \quad (10)$$

For estimation of each body part, the total potential ($Skin{-}P_{TASK}$) and actual dermal exposure ($Skin{-}A_{TASK}$) estimates will be calculated for a specific task by summing individual body part values (Equations 11 and 12). Weighting of each of the nine body parts by its body surface factor (BS_{BP}) before summing results in weighted total exposure ($Skin_w{-}P_{TASK}$, $Skin_w{-}A_{TASK}$ Equations 13 and 14). The body part factor is the surface area of an individual body part divided by the mean surface area of the nine body parts (Equation 12).

$$Skin{-}P_{TASK} = \Sigma_{BP}=1{-}9\ Skin{-}P_{BP} \quad (11)$$
$$Skin{-}A_{TASK} = \Sigma_{BP}=1{-}9\ Skin{-}A_{BP} \quad (12)$$
$$Skin_w{-}P_{TASK} = \Sigma_{BP}=1{-}9\ (BS_{BP} \cdot Skin{-}P_{BP}) \quad (13)$$
$$Skin_w{-}A_{TASK} = \Sigma_{BP}=1{-}9\ (BS_{BP} \cdot Skin{-}A_{BP}) \quad (14)$$

Time-weighted estimates ($Skin_W{-}P_{TASKW}$, $Skin_W{-}A_{TASKW}$) will be calculated by multiplying the total dermal exposure of a task by its relative task duration estimate (RTD). The relative task duration is defined as the total time of the task performance (task frequency multiplied by task duration, assessed per day, week, month or year) divided by total working time (assessed on the same timescale). To be able to compare the contribution of several tasks with a dermal exposure estimate for a working day, or at job level, the time-weighted task estimates will be summed and subsequently multiplied by the workers' hygiene estimate (WH), the hygiene estimate of the work environment (EH) and the continued exposure estimate (CE).

2.2 Dermal Exposure Ranking Method (DERM)

DERM is a model in which specific determinants of dermal exposure are assessed based on two factors: the type of transport process (T) and the area of the body surface (as a percentage) potentially affected by the determinant (A) (Blanco et al., 2008). In addition, clothing-related determinants (C) are evaluated as a protection factor.

The type of transport process (T) is evaluated following the conceptual model for dermal exposure proposed by Schneider et al. (1999), stated that contaminant can reach the skin through emission, deposition or transfer. A score (1–5) will be assigned once the transport process is characterized. In order to define the scores for transport processes, it is assume that transfer processes lead to low exposure, deposition processes lead to a medium exposure and emission processes lead to high exposure. A score of 1 will be assigned to low exposure (transfer process), 3 or 4 to medium exposure (transfer from recently contaminated surfaces and deposition, respectively) and 5 to high exposure (emission processes).

Body surface area (A) expected to be contaminated by a particular determinant will be ranked from 1 to 5, representing percentage ranges of the total body surface as follows: 0–20, 21–40, 41–60% and so on. The ranges and scores will be defined arbitrarily, with the only assumption that within a category the level of exposure is approximately the same. To estimate the percentage of body surface, the percentages proposed by Lund and Browder (1944) is used as guidelines to estimate the proportion of body surface affected in burned patients.

Small-scale subsistence farmers usually spraying pesticides in normal clothing without any personal protective equipment. Since normal clothing can provide some degree of protection (Stewart, 1999) and

different types of fabrics can reduce exposure to different extents, it is necessary to assess the different types of clothing worn by farmers and take this into account as a protection factor. Thus, the degree of protection provided by normal clothing can be described as a clothing protection factor (C) (Stewart et al., 2001), which defined as the complement of the reduction in the exposure level (1 exposure reduction) that occurred due to the clothing worn. It is assumed that maximum reduction in the intensity of exposure of 50% when the best clothing available was worn (long-sleeved shirt and long pants), thus giving a clothing protection factor of 0.5 (C = 1 - 0.5).

On the contrary, a 0% protection will be assumed for the worst clothing available (old/overused/torn shirt, old/overused/torn pants and being barefoot), thus yielding C = 1. Because of the different types of clothing that these farmers may be used to wear during pesticide applications, a proportional clothing protection factor will be assigned to different pieces of clothing, so the total protection should be defined by adding the reduction in exposure provided by each piece of clothing (long/short-sleeved shirt and long/short pants).

To define the corresponding proportion in exposure reduction for a piece of clothing (not old/overused/torn), it is assumed that each piece of normal clothing reduced in 50% the intensity of exposure on that body surface it was covering and that this is equivalent to a 50% reduction in the covered area. Thus, the 50% of the area of the body surface (in percentage) that might be covered by each piece of clothing will be used as the proportion. In order to simplify the figures to be added while using the method in the field, the figures will be rounded. It is also assumed that shoes provided better protection than clothing (because of the material in shoes: leather or rubber) and used the total area of the feet as a protection factor (also rounded).

For example, if we wanted to know the clothing protection factor for a farmer who wore a short-sleeved shirt and short pants, which were in good condition, but no shoes, we will add the assumed exposure reductions for short-sleeved shirt (0.15) and short pants (0.10); thus, C = 1 - 0.25 = 0.75.

2.3 Whole Body Dosimetry Method

Quantification of dermal exposure to pesticide establishes the level of health risk faced by pesticide operators. Patch and whole body sampling are the commonly used methods to estimate dermal exposure (García-Santos et al., 2011). However, whole body dosimetry sampling has an advantage over the patch sampling as it does not rely on uniform distribution of the contaminant over large section of the body (Soutar et al., 2000).

The pesticide fractioning on the body quantified by the whole body dosimetry method is using the tracer uranine (Fluorescein Sodium Salt; $C_{20}H_{10}Na_2O_5$) as pesticide surrogate. Uranine mixed with 20 L of water in the tank will be collected before spraying to measure the initial tracer concentration. Workers who participate are required to accomplish the spraying task by spraying within the experimental sub-area that has been set using manual and motorized sprayer in his usual way, with a solution of water and tracer uranine.

The assessment can be carried out during three pesticide management activities (i.e. preparation, application and cleaning). Tyvek garments and cotton gloves are used as sampling media. Prior to the evaluation, Tyvek garments need to be labeled according to each body part; such as arms, thighs, legs (left, right, frontal and dorsal), chest, abdomen and back (upper and lower back) (García-Santos et al., 2011; Lesmes-Fabian et al., 2012).

The garments then cut according to the parts previously labelled immediately after the evaluation activities finish (**Fig.1**). They were packed together with gloves and conserved in the dark plastic bag. The tracer solution in 100-L container is sampled in 10 ml flask and also conserved in the dark place until the measurement in the laboratory.

The whole body dosimetry method measures the potential dermal exposure (PDE) and the actual dermal exposure (ADE) during pesticide preparation, application and cleaning. The measurement for PDE requires the operators to wear the Tyvek garment over the work clothing together with the cotton gloves. While the measurement for ADE requires the operator to wear the Tyvek garment under the work clothing.

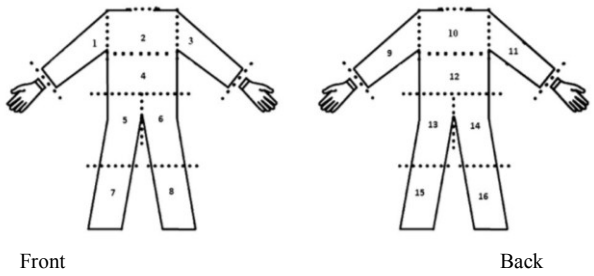

Figure 1: Tyvek cutting scheme
(Source: Lesmes-Fabian et al.,2012)

2.3.1 The Analytical Method

Following proposed protocol and method by García-Santos et al. (2011), the amount of uranine in tyvek sections and gloves is extracted by shaking all pieces in glass bottles with 200 or 400 ml of ultrapure water. Small tyvek sections from arms, legs, thighs and gloves are shaken in bottles with 200 ml ultrapure water and large tyvek sections from chest, abdomen and back in bottles with 400 ml. Afterwards, aliquots of 2 ml of the extraction solution together with aliquots from the samples in the tracer solution in the 100-L container taken in cuvettes and 3 drops of 1 mol NaOH is added. Finally, the measurement of uranine is performed with the Luminescence Spectrometer PERKIN ELMER LS 50-B at an excitation wavelength of 491 nm, emission wavelength of 520 nm, excitation slit of 10 nm, emission slit of 10 nm, integration time of 1 second, and an emission filter cut-off at 515 nm. A series of standard concentrations is prepared measured for the calibration of the equipment at 0.05, 0.1, 0.5, 1, 3, 5 and 10 ppb. The detection limit of the instrument is in the range of 0.05 and 30 ppb. When concentrations are above the detection limit, dilutions need to be made to 50x or 2500x.

2.3.2 The Calculation of Dermal Exposure

The amount of uranine deposited on the tyvek pieces and gloves can be obtained by multiplying the measurements from the luminescence spectrometer (µg/L) by the volume of extraction (0.2 or 0.4 L) following the guidelines for dermal exposure (USEPA, 2007). In the same way, the total amount of uranine applied can be obtained by multiplying the measurements from the luminescence spectrometer (µg/L) obtained from the samples of the solution taken in the 100-L container by the total amount of solution applied (80L).

The PDE is calculated as the ratio of the amount of uranine measured in the tyvek garment used over the work clothing ($U_{T.O}$) plus the amount of uranine measured in the gloves (U_G), over the total amount of uranine applied measured in the 100-L container (U_A), according to (Equation 1).

$$PDE = (U_{T.O} + U_G) / U_A \quad (1)$$

Where $U_{T.O}$ is calculated as the sum of the amount of uranine measured on the different tyvek pieces (Equations 2 to 4).

$$U_{T.O} = \Sigma\,(U_{T.Frontal} + U_{T.Dorsal}) \quad (2)$$

$$U_{T.Frontal} = \Sigma\,(U_{Front.Right.Arm} + U_{Front.Left.Arm} + U_{Front.Right.Thigh} + U_{Front.Left.Thigh} + U_{Front.Right.Leg} + U_{Front.Left.Leg} + U_{Chest} + U_{Abdomen}) \quad (3)$$

$$U_{T.Dorsal} = \Sigma\,(U_{Dorsal.Right.Arm} + U_{Dorsal.Left.Arm} + U_{Dorsal.Right.Thigh} + U_{Dorsal.Left.Thigh} + U_{Dorsal.Right.Leg} + U_{Dorsal.Left.Leg} + U_{Upper.Back} + U_{Lower.Back}) \quad (4)$$

ADE is calculated as the ratio between the amount of uranine measured in the tyvek garment (used under the work clothing) ($U_{T.U}$) over the total amount of uranine applied measured in the 100-L container (U_A) (Equation 5).

$$ADE = U_{T.U} / U_A \quad (5)$$

Where $U_{T.U}$ is calculated as the sum of the amount of uranine measured in the different tyvek pieces according to Equations 2 to 4.

The PDE and ADE of each pesticide applied are calculated based on the PDE and ADE measured with the tracer and the real amount of herbicides commonly applied in study area (Equations 7 and 8).

$$PDE_{Pesticide} = PDE_{Uranine} * Pesticide_{Applied} \quad (7)$$
$$ADE_{Pesticide} = ADE_{Uranine} * Pesticide_{Applied} \quad (8)$$

Where, $PDE_{Uranine}$ and $ADE_{Uranine}$ are the values of PDE and ADE to the tracer obtained with Equation 1 and 5. $Pesticide_{Applied}$ is the amount in kg of pesticide applied during one day of application. Considering an average corporal weight of 70 kg and calculating the exposure for a working time of 8 h, the PDE and ADE results were compared with the dermal median lethal doses (Dermal LD_{50}) of each herbicides commonly used during the pest management in the study area.

2.3.3 The Protection Factor (PF)

The protection factor of work clothing (PF) during pesticide application is defined as the fraction of pesticide retained by the barrier of the work clothing layer. It is calculated as the ratio of the ADE over the PDE (Equation 6).

$$PF = (ADE / PDE) * 100 \quad (6)$$

2.4 Salivary Cholinesterase Activity

The measurement of cholinesterase (ChE) levels in blood is the conventional method to assess the degree of occupational exposure among workers exposed to OP pesticides. Since acetylcholinesterase (AChE) catalytic activity has been detected in saliva, the procedure of determination salivary AChE is more readily acceptable for biological monitoring as saliva collection is less invasive as compared to blood samples collection (Ng et al., 2009).

In order to minimize the possibility of diurnal variation effects on enzyme activity, saliva is best taken in the morning. Respondents need to be asked not to smoke 1 hour prior to sample collection. The respondents saliva is collected through spitting into a tube, five minutes after rinsing their mouth with 100 ml of still mineral water. Saliva samples need to be refrigerated immediately and centrifuged at 15,000 rpm at 4°C for 3 min to precipitate any particulate matter. Aliquots of supernatants are frozen at -20°C until use. Determination of enzyme activity can be determined with a 96-well microtiter plate by colorimetric assay system. ChE activity is determined from the capacity of the saliva to hydrolyze acetylthiocholine, according to Ellman et al. (1960). The reaction temperature should be 30°C. The activity need to be normalized to the sample protein content (Lowry et al. 1951), as practiced in Bulgaroni et al. (2012).

4. Conclusions

This paper takes as its starting point the large and relatively recent literature on the health risk assessment of pesticide use in oil palm plantation. The literature was analysed to include the understanding of the methodology used in the assessment. This allows us to incorporate a comprehensive assessment framework through both semi-quantitative and quantitative methods.

This paper has highlighted the semi-quantitative method used; the DREAM and DERM models to assess occupational dermal exposure to chemical agents. These models have been partially validated in several case studies with different characteristics. It is an easy-to-use method of exposure assessment based on determinants of dermal exposure. The feasibility of these methods to be implemented on palm oil plantation system in a developing country becomes necessarily assessed.

The second part of this paper highlights the quantification of the pesticide fractioning on the body from the exposure to pesticide through the whole body dosimetry method. The main mechanism of action for organophosphorus (OP) and carbamate pesticides is the inhibition of cholinesterase activity is assessed through salivary AChE. It is a less invasive method as compared to blood samples analysis.

The advantage of analysing the pesticide exposure and the health risk provides the information on level of health risk. Its enable the stakeholders for the improvement of the risk assessment scheme, optimization of factors influence level of exposure and development of programs to aware workers on the appropriate use of pesticides.

While literature in this area is limited, the authors draw as widely as possible on a variety of sources and empirical studies from around the world. Importantly, this paper has provided an overview of the semi-quantitative and quantitative assessment framework for the pesticide exposures.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in the publication of this research.

ETHICAL ISSUES

Ethical approval was obtained from the Ethical Committee for Research involving Human Subjects of Universiti Putra Malaysia.

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