COMPARISON BETWEEN THE OCCUPATIONAL EXPOSURE OF PADDY FARMERS TO PESTICIDES APPLIED IN GRANARY AND OUTSIDE GRANARY AREAS

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Sustainable Science) with Honours

FACULTY OF EARTH SCIENCE

UNIVERSITI MALAYSIA KELANTAN

2019

DECLARATION

I declare that this thesis entitled "Comparison between the Occupational Exposure of Paddy Farmers to Pesticides Applied in Granary and Outside Granary Area" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : _________________________

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ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to Dr. Wong Hie Ling, my research supervisors, for the patient guidance, enthusiastic encouragement and useful critiques of this research work.

I would also like to thanks all lecturer of the sustainable science program that had gave me knowledge that I can use to fulfil this final year project.

I would also like to express my thanks to all the paddy farmers in Tanah Merah and Pasir Mas that provided me the data needed for the study.

My fellow undergraduate students should also be recognized for their support. Finally, I wish to thank my parents for their support and encouragement throughout my study.

ABSTRACT

Comparison between the occupational exposure of paddy farmers to pesticide applied in granary and outside granary areas

The study investigates major differences of pesticide exposures between paddy farmers in granary and outside granary areas in Kelantan, using survey data collected in Pasir Mas and Tanah Merah as case studies, respectively. A total of 11 farmers were analyzed for their exposure to pesticides using the exposure algorithms from the Generic Risk Assessment Model for Indoor and Outdoor Space Spraying of Insecticides developed by the World Health Organization. The predicted exposures were assessed against the Acceptable Agricultural Operator Levels (AOEL). Overall, the predicted daily exposures of single active substances that exceeded the respective AOELs were higher in Tanah Merah compared to Pasir Mas, mainly due to the higher number of pesticide applications in Tanah Merah. All six farmers from Tanah Merah had at least one application with estimated exposure greater than the AOEL while in Pasir Mas only one farmers had exposures greater than the AOELs. There were six active substances contributed to the exceedances, comprising propanil, bentazone sodium, MCPA dimethylammonium and imidacloprid due to their relatively larger amount applied while chlorpyrifos and lambda-cyhalothrin due to their relatively higher toxicity. Results also indicate that older farmers (≥ 55 years old) and farmers with longer working experience (≥ 10 years) had higher number of pesticides application. The higher pesticide exposure estimation in Tanah Merah compared to Pasir Mas was also influenced by the irrigation systems because the major irrigation system increases the production output for the paddy field. Study findings indicate that farming experience, age and irrigation system as major factors of pesticide exposure among the farmers.

ABSTRAK

Perbandingan antara pendedahan dari tempat kerja bagi petani padi terhadap racun perosak yang digunakan di jelapang dan luar kawasan jelapang padi

Kajian menunjukkan perbezaan bagi pendedahan terhadap racun perosak antara petani padi di dalam dan luar kawasan jelapang padi di Kelantan dengan menggunakan data kaji selidik yang dikumpul di Pasir Mas dan Tanah Merah sebagai kajian kes. Seramai 11 orang petani dianalisis untuk pendedahan terhadap racun perosak menggunakan “Generic Risk Assessment Model for Indoor and Outdoor Space Spraying of Insecticides” dari “World Health Organization (WHO)”. Anggaran pendedahan terhadap racun dibandingkan menggunakan “Acceptable Agricultural Operator Levels (AOEL)”. Secara keseluruhan, anggaran pendedahan harian yang melebihi AOEL lebih tinggi di Tanah Merah berbanding Pasir Mas disebabkan oleh jumlah penggunaan racun perosak yang tinggi di Tanah Merah. Kesemua enam petani di Tanah Merah mempunyai sekurang-kurangnya satu penggunaan dengan anggaran pendedahan yang lebih tinggi berbanding AOEL manakala cuma seorang petani mempunyai pendedahan yang lebih tinggi berbanding AOELs di Pasir Mas. Terdapat enam bahan aktif yang menjana anggaran pendedahan terhadap racun perosak yang lebih tinggi berbanding nilai AOEL iaitu propanil, bentazone sodium, MCPA dimethylammonium dan imidacloprid kerana jumlah digunakan adalah tinggi manakala, klorpirifos dan lambda-cyhalothrin kerana ketoksikan yang tinggi. Keputusan menunjukkan petani yang lebih tua (≥ 55 tahun) dan petani dengan pengalaman bekerja yang lebih lama (≥ 10 years) mempunyai penggunaan racun yang lebih tinggi. Anggaran pendedahan terhadap racun perosak yang lebih tinggi di Tanah Merah juga disebabkan oleh perbezaan sistem pengairan di Tanah Merah dan Pasir Mas kerana system pengairan yang lengkap di jelapang padi boleh meningkatkan hasil tanaman. Penemuan kajian menunjukkan pengalaman bertani, umur dan sistem pengairan sebagai faktor utama pendedahan terhadap racun perosak dalam kalangan petani.

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LIST OF ABBREVIATIONS

DOA	Department of Agriculture Malaysia
MADA	Muda Agricultural Development Authority
KADA	Kemubu Agricultural Development Authority
IADA	Integrated Agricultural Development Area
US HHS	U.S. Department of Health and Human Services
NPIC	National Pesticide Information Centre
WHO	World Health Organization
EFSA	European Food Safety Authority
PHED	Pesticide Handlers Exposure Database
AOEL	Acceptable Agricultural Operator Level
PPE	Personal protective equipment
PPDB	Pesticide Properties Database
NPIC	National Pesticide Information Center

LIST OF SYMBOLS

%	Percentage
×	Multiply
≥	Greater and equal than
<	Less than

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Pesticides are chemicals that are intended to kill and control pests and crop diseases. Pesticides are typically classified based on their functions and target pests, modes of entry and chemical compositions (Yadav & Devi, 2017). For classification based on the functions of pesticides and the organism they kill, the name of the pesticides comes from the combination of the type of pest they kill and the word -cide such as fungicides for fungi, algaecides for algae and insecticides for insect. There are also pesticides that are categorised based on their functions and their names are not ended with –cide, including defoliants, chemosterilants and repellent (Yadav & Devi, 2017).

For classification based on the modes of entry, pesticides are classified based on how they come in contact with their target and enter their body, namely repellents, fumigants, non-systemic, systemic and stomach poisoning (Yadav & Devi, 2017). The repellents drive the pests away but do not kill them. Fumigants produce poisonous vapours that kill the pests. Non-systemic pesticides are chemicals that come into contact and enter the epidermis of the pests while systemic pesticides are absorbed by animals or plants. Stomach poisoning occurs when the pests ingest pesticides.

For classification based on chemical compositions, pesticides can be classified as pyrethroids and pyrethrin, organophosphates, carbamates and organochlorines (Jayaraj et al., 2016). Pyrethroids and pyrethrin have the same organic compound. Organophosphates are made from esterification process and are the most widely used pesticides. Carbamates are structurally similar to organophosphates that derived from carbamic acid while organophosphates are derived from phosphoric acid. For organochlorines, there are five or more chlorine atoms that are attached to the organic compound and are mostly used as insecticides. Organochlorine is one of the Persistent Organic Compound, which has now often replaced by organophosphates and carbamate esters (Stadlinger et al., 2011; Yadav & Devi, 2017).

In Peninsular Malaysia, the rice paddies can be categorised based on their irrigation schemes, namely granary areas with major irrigation schemes and outside granary areas with minor or outside irrigation schemes. According to the DOA (2016), irrigation scheme refers to as irrigation projects that are already completed, commissioned, fully operational and declared as irrigation area by the authority whereas outside irrigation scheme usually depends on rainwater. The granary area is recognised by the National Agriculture Policy as the main paddy producing area with three strata of paddy parcel area (0.4 - 201 ha, 202 - 4,046 ha and 4,047 ha and above) under the management of Muda Agricultural Development Authority (MADA), Kemubu Agricultural Development Authority

(KADA), Integrated Agricultural Development Area (IADA) Kerian, IADA Barat Laut Selangor, IADA Pulau Pinang, IADA Seberang Perak, IADA KETARA, IADA Kemasin Semerak, IADA Pekan and IADA Rompin. Meanwhile, outside granary area comprises a mukim as the administrative unit like the Department of Agriculture (DOA) in a district with four strata of paddy parcel area (0.4 - 39 ha, 40 - 201 ha, 202 - 404 ha and 405 ha and above) (DOA, 2016).

In Kelantan, there are two granary areas with a larger planted area called KADA and a smaller granary area called IADA Kemasin Semerak, with total planted areas of 25,332 ha and 4,835 ha, respectively (DOA, 2016). Meanwhile, outside granary areas are supported by each district's DOA such as the DOA of Tanah Merah.

Paddy farmers can experience from occupational exposure to pesticides during a typical working day. The U.S. Department of Health and Human Services (HHS) defines occupational exposure as the contact with a potentially harmful physical, chemical, or biological agent at work (HHS, 2019). National Pesticide Information Centre (NPIC, 2012) states that pesticides can be classified from low to high toxicity and that pesticides with low toxicity can lead to high risk when the exposure is high. This is because the level of risk depends on both the level of toxicity and the amount of exposure (Equation 1.1; NPIC, 2012).

$$Risk = Toxicity \times Expoure \tag{1.1}$$

In developed countries, measurement of farmers' exposure to pesticides is an integral part of the decision-making procedure with no product authorisation is granted unless adequate data or the predictive models indicate that the exposure is acceptable (EFSA, 2014; Cao et al., 2017). In developing countries, however, there are no national systems to monitor pesticide risk (Schreinemachers et al., 2015). Typically, exposure models are used to predict the levels of exposure during typical activities due to the limitations and complexities in measuring doses via different routes of exposure and in biological monitoring, together with the very wide range of climatic and working conditions that need to be considered in the field measurements (Colosio et al., 2012).

In characterising pesticide risk, reference values are usually used to quantitatively describe risk of adverse health effects for single active substances (Atabila et al. 2017). The Acceptable Agricultural Operator Levels (AOELs) is the European regulatory limit for which the predicted total absorbed doses of individual farmers should not be exceeded in a single working day (Regulation EC No 1107/2009). That is, AOEL is a health-based exposure limit with the toxicological properties of an active substance are used as the basis for the establishment without causing any adverse health effects (EU Commission, 2006). The AOELs that derived from the results of human tests when scientifically and ethically acceptable are more precise, while the most sensitive no observed adverse effect levels (NOAELs) for relevant endpoints of test animals are usually used to establish the maximum exposure limit (EFSA, 2006). Countries that have no own national reference values usually depend on the reference values derived by international and other organisations for health risk assessment (Atabila et al., 2018).

1.2 Problem Statement

Pesticides can protect and thus improve the production of crops, which in turn can help to maintain food security (Popp et al., 2013). However, intrinsic toxicity properties of pesticides can pose risks to human health including the deterioration of reproductive, neurological and gastrointestinal systems (Maipas et al., 2016). Pesticides with carcinogenic property can also trigger cancer formation in human body (Alavanja et al., 2004).

In agricultural activities, farmers often handle large amount of pesticides and thus represent a vulnerable group for pesticide exposure and thus health risk. While the management of paddy fields in granary and outside granary areas is different due to the scheme of irrigation, the major factors of farmers' exposure towards pesticides in two areas may be different. Identification of the major factors of farmers' exposure to pesticides applied in the paddy fields can be used to reduce pesticide risks in the future.

1.3 Objectives

1) To compare the levels of exposure of paddy farmers to pesticides applied in granary and outside granary areas over a cropping season.
2) To investigate the major factors that contribute to farmers' exposure to pesticides applied in the selected paddy fields.

1.4 Scope of Study

This study investigates the agricultural use of and levels of paddy farmers' exposure to pesticides applied in the granary and outside the granary areas under two different irrigation schemes, with or with no irrigation systems. To do this, pesticide application data are collected via face-to-face interview (approximately 20 minutes per individual) and questionnaire surveys (approximately 3 months for a cropping season), with the consents of the selected paddy farmers. A range of data are collected including individuals' demographic data, agricultural practices and spraying equipment, use of personal protective equipment (PPE), and pesticide application data. Simultaneously, pesticide packages are also collected during the entire cropping season as an efficient and rapid assessment method to obtain baseline information about pesticide application (Sattler et al. 2018). The amount of pesticide active substance applied on a single spraying day (kg active substance applied per hectare, kg a.s. ha^{-1}) is the key input parameter in exposure modelling based on the exposure algorithms derived from the Generic Risk Assessment Model for Indoor and Outdoor Space Spraying of Insecticides (WHO, 2018). The exposure algorithms are used to predict the levels of paddy farmers' exposure to pesticides handled on a daily basis. Then, predicted exposure estimates are assessed against the Acceptable Agricultural Operator Levels (AOELs) for single active substances, for which predicted total absorbed doses of individual farmers should not be exceeded in a single working day (Regulation EC No 1107/2009). The survey data are analyzed using the Microsoft Office Excel for the exposure modelling and descriptive analysis, both qualitatively and quantitatively. This study involves a total of 11 paddy farmers as the study subjects, comprising five individuals from the KADA granary area in Pasir Mas and six individuals from the DOA outside of granary area in Tanah Merah, Kelantan.

1.5 Significance of Study

Pesticides have unfavourable effects to the environment and human health due to their intrinsic toxicity properties. Farmers is often very vulnerable to the risk of pesticide exposure due to their intensive use of pesticides, thus assessment towards their pesticide exposure in both granary and outside granary paddy field deems important. There are a range of factors may influence the farmers' exposure to pesticides under real-working conditions in paddy fields, with exposure model is generally used to predict levels of exposure during typical activities rather than measurement due to the limitations in biological monitoring together with the very wide range in climatic and working condition that need to be considered and complexities in measuring dose via different routes (Colosio et al., 2012).The identification of the major factors that contribute to farmers' exposure to pesticides applied in the selected paddy fields can be used to determine the mitigation methods for pesticide exposure and risk more effectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Common Pests and Pesticides Use in Paddy Field

Pest is the main factor for the usage of pesticides in rice planting. *Chilo polychrysus* is one of the most common rice borer insect that causes damage to the stem as it perforates into the stem (Watson et al., 1995). *Spodoptera Mauritia* (also known as paddy swarming caterpillar) is also common in rice field which cuts the leaf and wilt the tips causing the paddy plant to look unhealthy (Tanwar et al., 2010). *Scotinophara coarctata* usually feeds on the rice plants causing the loss of plant sap and thus growth stunt for some plants just after a day of its attack. *Nymphula depunctalis* usually damages the leaves of young paddy plants. *Leptocorisa oratorius* eats the developing rice grain causing the loss of yield and produces unpleasant odour if it is disturbed (Van Den Berg, 2000). *Nephotettix virescens* (familiarly known as *penyakit merah*) is a vector for tungro can cause stunting in plant growth (Azzam & Chancellor, 2002).

Pesticides that are commonly used in the paddy fields comprising paraquat, imidacloprid, chlorpyrifos, malathion, thiodan (Horstkotte, 1999; Bradford et al., 2010; Anyusheva et al., 2012; Fuad et al, 2012; Phung et al., 2012)

For instance, paraquat is a herbicide that is commonly used to kill weed in Malaysia (Sazaroni et al., 2011). Imidacloprid is designed to be effective by contact or ingestion by insects (NPIC, 2019). Chlorpyrifos is an organophosphate insecticide and used to control many types of pests which include termites, mosquitoes and roundworms (NPIC, 2019). Thiodan (also known as endosulfan) is an organochlorine insecticide that used to control many insects such as termites, beetles and aphids (Mnif et al., 2011). Malathion is an organophosphate insecticide that acts as acetylcholinesterase inhibitor (National Research Council, 1989). Thus, it can bind to the acetylcholinesterase at nerve ending and damage the function of insects' nervous system.

2.2 Routes of Occupational Exposure to Pesticides

Generally, humans can be exposed to pesticides via dietary and non-dietary routes of exposure. Dietary exposure refers to as where pesticides enter through the mouth whereas, non-dietary routes of exposure refers to as pesticides that come in contact with the skin and the respiratory system via dermal contact and inhalation (Damalas & Koutroubas, 2016).

Occupationally, farmers who often handle large amount of pesticides in single working days are mainly exposed to pesticides via dermal and respiratory exposure (MacFarlane et al., 2013). Non-dietary exposure deems more important to farmers' exposure to pesticides under field conditions because they are less likely to eat at work.

Dermal exposure occurs when pesticides spill and splash during handling activities such as mixing or loading and spraying. During application, the highest exposure is predicted to be powder, followed by liquid and then granule (GroBkopf et al., 2013). If the solid pesticides are dissolved in solution for spraying, all formulations (liquid, powder and granule) will have similar influence on the level of exposure.

2.3 Pesticide toxicities and associated health effects

Pesticides can cause acute and chronic effects to human health due to different durations of exposure. Acute toxicity is a single negative health effect from a single exposure and causes acute poisoning at different severity grades, including minor effects with mild and transitory health symptoms, moderate effects with prolonged and noticeable symptoms, life threatening and fatal (Persson et al., 1998). In contrast, chronic health effects occur when farmers exposed to low doses of pesticide for long period and that pesticides can slowly accumulate in the body.

For minor poisoning, pesticides can cause irritation of the throat, eye and skin, breathlessness because of the effect to the respiratory system and the affected gastrointestinal tract will cause diarrhoea and vomiting (Cornell University, 2012).

Moderate pesticide poisoning severity have a few symptom of prolonged vomiting, ulcerative transmucosal lesions from endoscopy and difficulty in swallowing (dysphagia), prolonged coughing and low concentration of oxygen in the blood (hypoxemia), effects on the nervous system (e.g. hallucinations, generalized seizures, auditory and visual disturbances), and the muscular system might experience pain and cramping (Cornell University, 2012).

For severe pesticides poisoning, the affected gastrointestinal tract may experience perforation or massive haemorrhage, the affected respiratory system may cause inability to breath, the nervous system may be in extreme agitation and thus frequent seizure, the cardiovascular system may be in hypertensive crisis, the kidney may experience renal failure, the muscular system may experience immense cramping and extreme pain, the skin area may experience second degree burn on more than 50% of body surface and third degree burn on more than 2% of body surface, and deafness and blindness (Casey et al., 1998).

A growing body of evidence has associated pesticide exposure with a range of health effects including infertility, neurotoxicity, disruption of endocrine system and carcinogenicity (Nordby et al., 2005; Sabarwal et al., 2018). Infertility causes damages to sperm or testicular function or change in sperm genetic material in farmers (Meeker et al., 2004), while take-home pesticide toxins may lead to infertility for their wife (Nordby et al., 2005). Endocrine disrupting pesticides can change the functions of endocrine system including immune dysfunction and reproductive defects (Combarnous, 2017). For instance, thiodan can cause negative developmental and reproductive effects as an endocrine disruptor (Mnif et al., 2011). The chemical classes of pesticides that related to the non-Hodgkin's lymphoma disease are benzoic acid and phenoxy herbicides, amide fungicides and carbamate and organophosphate insecticides, while prostate cancer can be caused by organochlorine and methyl bromide (Alavanja et al., 2003). Exposure towards 2,4-D can negatively affect the fertility and increase the risk of non-Hodgkin lymphoma, which is a cancer of the lymphatic system (Pohanish, 2015; Liaw et al., 2017). Carcinogenicity is the tendency of chemical in inducing tumors with a variety of diseases have been associated with pesticide exposure including non-Hodgkin's lymphoma, leukaemia, soft-tissue sarcoma, multiple myeloma, and cancers of lung, prostate and ovarian (Alavanja et al., 2004).

Fungicides exposure has been associated with the increase number of pancreatic cancer (Andreotti et al., 2015). There is also a linkage of Parkinson’s disease with herbicides and insecticides (Marianne et al., 2012). In a study conducted by Fernandez et al. (2011), occupational use of paraquat had been associated experimentally to pathophysiological mechanisms implicated in human Parkinson’s disease. Meanwhile, organochlorines, organophosphates, fumigants, sulfallate and creosote have been associated with neurological diseases including Parkinson’s disease, Alzheimer’s disease and dementia. That is, different types of pesticides can cause similar toxicological endpoints and thus health diseases.

2.4 Factors That Influence Farmers’ Exposure to Pesticides

Exposure of farmers to pesticides usually occur during pesticides handling activities including preparation of pesticide solution, spraying process and machine cleaning. During the preparation, exposure of farmers is affected by the formulation types, with relatively larger exposure for wettable powder pesticides, intermediate for liquid pesticides and relatively smaller for granule pesticides (GroBkopf et al., 2013). During the spraying process, there is higher chance of pesticide exposure to due to the type of spraying equipment used. For instance, the use of backpack sprayers can cause higher exposure compared to the use of truck or aerial sprays (Phung et al., 2012).

The improper use of personal protective equipment (PPE) is one of the major drivers to cause higher exposure and health risk on farmers (Keifer, 2000). There are a few types of PPE to protect different parts of body including those for eye, hand, foot, body and respiratory system. The PPE use can protect the routes of exposure where the pesticide can enter the body (Hansen & Walker, 2015). For instance, long sleeves shirt, gloves and boots can prevent dermal exposure while mask can minimise inhalation exposure. Nevertheless, a range of drivers may influence PPE use and compliance among the farmers. Rivas and Rother (2015) proposed that farmers who do not receive pesticide-handling training often have low compliance in PPE usage, female workers have better use in PPE compared to male, and uncomfortable working condition such as hot weather can causes discomfort due to PPE use. Sharifzadeh et al. (2017) also proposed that lack of PPE usage by other colleagues, low availability of PPE and expensive price as the factors of PPE use. Meanwhile, farmers with risk-accepting properties had much lower PPE compliance because of their susceptibility to seek out harmful behaviour compared to those that are risk-averse (DellaValle et al., 2012).

Lack of training on how to properly handle pesticides and lack of awareness on safety precaution when handling pesticide are also factors that can influence farmers' exposure to pesticides (Miller et al., 2013), that may in turn affect their perceptions on pesticide risks (Hou & Wu, 2010). Studies have also indicated that younger generation perceived pesticide risk better than the older generation, which can reduce their exposure to pesticides (Damalas & Hashemi, 2010).

2.5 Methods to Reduce Exposure to Pesticide

To reduce farmers' exposure to pesticides, they need to read and understand the product label properly especially the precautions and warning to minimise risk from the usage of the product (NPIC, 2018). It is important to apply pesticide product according to the recommended rate and method of application. Farmers should not re-enter the treated field after pesticide application to avoid any risk of exposure due to skin contact with pesticide residue on the treated surfaces. Farmers need to do regular medical check-ups to find out any health symptoms due to pesticide exposure to ensure early treatment (Sarwar, 2015). Safety trainings on pesticide handling can give awareness to individual farmers in mitigating their exposure to pesticide (Peres et al., 2003).

In regulatory risk assessment, the use of PPE is an important method in reducing pesticide exposure and thus risk. For instance, gloves is used to protect the farmers from hand exposure, mask is used to protect them from inhalation exposure and google is used to protect their eyes (Macfarlane et al., 2013). The type of PPE used is depending on the type of pesticides, the preference of farmers and the circumstance of exposure (Damalas & Koutroubas, 2016).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

In this study, two study areas were selected to represent the granary area and outside granary area in Pasir Mas and Tanah Merah Kelantan, respectively. The granary paddy field is located at Tendong in Pasir Mas while the outside granary area paddy field is located at Kampung Bendang Keladi in Tanah Merah. The areas were chosen because of their proximities from Universiti Malaysia Kelantan, Jeli, with easier access to the study areas.

Figure 3.1: The study area at the paddy field in Kampung Bendang Keladi, Tanah Merah

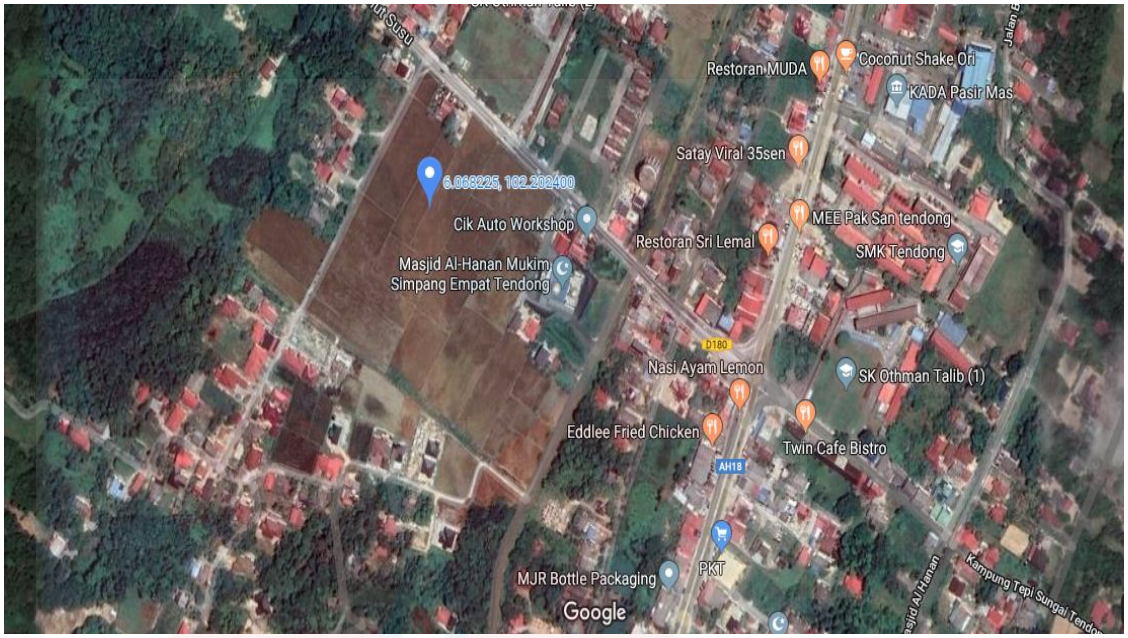

Figure 3.2: The study area at the paddy field in Tendong, Pasir Mas.

3.2 Research Instruments

The main research instrument for this research comprising interview and questionnaire forms and mathematical modelling. The interview and questionnaire forms consists of questions regarding the information of the farmer, paddy field, pesticide, pesticide spraying equipment, pesticides handling activities, PPE and pesticides used information. The WHO Generic Risk Assessment Model for Indoor and Outdoor Space Spraying of Insecticides was used to estimate maximum daily systemic dose for dermal exposure during mixing and loading, inhalation exposure during pesticide application and dermal exposure during application, washing and maintenance. The WHO mathematical model was used to predict farmers' exposure to liquid pesticides based on the model assumptions.

3.3 Data Collection

Data was collected from the paddy farmers at Tanah Merah and Pasir Mas area. Before the collection of data, informed consent was distributed to the farmers as part of the requirement for human ethics assessment. The data was collected via face-to-face interview with duration of approximately 20 minutes per individual and questionnaire surveys with the data of approximately 3 months for a cropping season after getting consent from the paddy farmers. Pesticide packages was also collected to obtain some baseline information about pesticide application. The interview was conducted for 12 farmers from Pasir Mas but only 5 of them completed the questionnaire surveys. For Tanah Merah, the interview was conducted for 9 farmers but only 6 people completed the questionnaire surveys.

The personal survey during face to face interview was divided into seven parts comprising section A, section B, section C, section D, section E, section F and section G (Appendix B). Section A collected farmer's basic information and demographic data including name, age, gender, body weight, education level, working experience as farmer, contact details and information regarding pesticide-related training. Section B collected information regarding the paddy field including the area of paddy field, type of paddy, ownership of paddy field and reason for pesticide usage. In the section C, the questions focused on pesticide use information including source of pesticide, government subsidy, location of pesticide storage, location of preparation for pesticide solution and disposal method for empty pesticide container, and to lesser extent pesticide-related health issues. In the section D, information regarding pesticide machine were collected including type of pesticide sprayer, model name for the machine, tank capacity and the location for pesticide storage. Section E collected information on the average durations and number of activities of mixing or loading, spraying and cleaning sprayer activities were collected for single working days, while section G collected information regarding the use of PPE during mixing or loading, spraying and cleaning activities. The farmers also filled a questionnaire survey to provide information for pesticide usage that completed in approximately 3 months for the whole cropping season (Appendix C). This was used to collect information of actual pesticide use in paddy fields, including date of application, pesticide name, pesticide distributor, formulation type, amount of pesticide used, amount of water that mixed together, sprayed area and time of spraying activities.

3.4 Data Analysis

3.4.1 Quantification of Farmers' Exposure to Pesticide

The exposure algorithms in the Generic Risk Assessment Model for Indoor and Outdoor Space Spraying of Insecticides from World Health Organization (WHO) was used to predict farmers' exposure to pesticide active substances formulated in liquid form, comprising scenarios of dermal exposures during mixing and loading and during application, washing and maintenance and inhalation exposure during application. The inhalation exposure during mixing/loading liquid pesticides deems not significant by the generic model and thus excluded in this study. While the model algorithms require the key input parameter, that is, the concentration of active substance to be expressed in the unit of g L^{-1}, the surveyed pesticide products comprised the unit of % w/w. Therefore, label of similar pesticide product with the same formulation type and proportion of active substance were referred in this study.

During mixing/loading activities, the dermal maximal daily systemic dose ($SysD_{M/L}$, mg kg bw^{-1} day^{-1}) of paddy farmers' exposure to pesticides is calculated as eq. (3.1):

$$SysD_{M/L} = \frac{UE_{LIQ} \times PPE \times CF \times ABS_D}{BW} \tag{3.1}$$

where UE_{LIQ} is maximal daily systemic dose (mg kg bw^{-1}; the unit exposure for a liquid formulation is 0.01 mL/operation for container with volume of 1 litre for any neck aperture), PPE is PPE efficacy (0.1 in guideline scenario and 1 in lax standard scenario; the guideline scenario refers as the sprayer is fully leak-proof, protective clothing and appropriate gloves are used), CF is the concentration of formulation are referred to the pesticide label (mg mL^{-1}), ABS_D is the dermal absorption of the spray. Default dermal absorption values of 25% and 75% are used for pesticide products with the content of active ingredient < 5% and ≥ 5%, respectively. BW is the farmer's body weight.

During application, the inhalation maximal daily systemic doses ($SysI_{Ap}$, mg kg bw^{-1} day^{-1}) is calculated by:

$$SysI_{Ap} = \frac{TAR \times RPE \times BV \times ED \times ABSp}{(HSC \times BW)} \tag{3.2}$$

where TAR is target application rate (mg active ingredient per m^2). RPE is the respiratory protection factors (0.1 for the guideline scenario and 1.0 for the lax standard scenario), BV is the breathing volume (1.25 m^3 hr^{-1}; default value for an adult moderate activity), ED is the exposure duration (default value of 0.5 hr day^{-1}), $ABSp$ is respiratory absorption value (default value of 100%), HSC is the height of spray cloud (m), which based on average plant height at different growth stage (Singh et. al, 2014). BW is the farmer's body weight.

During application, the dermal maximal daily systemic dose ($SysI_{Ap}$, mg kg bw^{-1} day^{-1}) is calculated as:

$$SysD_{Ap} = \frac{VLH \times Cspray \times PPE \times ABS_D}{BW} \tag{3.3}$$

where VLH is the volume of liquid on hand (default value of 8.2 mL for an adult), $Cspray$ is the concentration of the active ingredient in the spray (mg mL^{-1}; derived from the concentration of the active ingredient in the formulation and its dilution for spraying), ABS_D is the dermal absorption value (default value of 75%for diluted solution with assumption of and < 5% of active ingredient).

The total maximum daily systematic dose for single active ingredient applied on a single working day ($total\ exposure_{a.i.}$ mg kg bw^{-1} day^{-1}) is the sum of dermal exposure during mixing/loading activities and application and the inhalation exposure during application as:

$$Total\ exposure_{a.i.} = SysD_{M/L} + SysI_{Ap} + SysD_{Ap} \tag{3.4}$$

3.4.2 Risk Characterization of Predicted Exposure

The Acceptable Agricultural Operator Levels (AOELs) were used to assessed the predicted daily exposures for single active substances, for which predicted total absorbed doses of individual farmers should not be exceeded in a single working day (Regulation EC No 1107/2009). The AOEL values were extracted from the Pesticide Properties Database (PPDB, 2019), which is an international database for pesticide risk assessments and management that is endorsed by the International Union of Pure and Applied Chemistry and promoted by major organizations including the Food and Agricultural Organization (Lewis et al., 2016). In the regulatory risk assessment, predicted total pesticide exposure of agricultural operators to pesticides should not be greater than the AOEL for an individual active substance or combination of active substances formulated into a single product. According to Regulation (EC) No 1107/2009, the AOEL is used as a limit in the authorization process of the use of any active substances, and further work or ultimately no authorization is triggered if the exposure estimate exceeds the AOEL (Aprea et al., 2016; Thouvenin et al., 2016).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Farmers' Basic Information

Table 4.1 shows basic information for six paddy farmers from Tanah Merah (TM01 – TM06) and five paddy farmers from Pasir Mas (PM01 – PM05). The name of the farmers is not revealed following research ethics, that their identity is only available to the persons who are directly involved with the study to ensure confidentiality (Žukauskas et al., 2018).

Overall, paddy farmers from Tanah Merah comprised of ages between 25 to 60 years old, with an average ages of 48 years old. Meanwhile, paddy farmers from Pasir Mas comprised of ages between 37 to 76 years old with an average of 55 years old, who were generally older than those from Tanah Merah. Generally, the number of younger farmers (3 farmers < 40 years old) were lower compared to older farmers because young people tend to migrate from rural to urban area, leaving older people to involve in farming activities (Liangxin et al., 2013). Meanwhile, older farmers tend to exhibit improper safety behaviour towards pesticide use because of their incapability and difficulty in following label's instruction (Fan et al., 2015). Older farmers generally have insufficient knowledge on pesticide risk and they are often not willing to change their behaviour towards pesticide use and associated risk (Fan et al., 2015). Of eleven selected farmers, they were all males who working in paddy fields either as full-time (7 individuals) or part-time (4 individuals) workers.

For the spraying experience, paddy farmers from Tanah Merah involved in paddy farming aged from 2 to 27 years, with the average spraying experience of 9 years (Table 4.1). For Pasir Mas, the spraying experience of farmers ranged from 1 to 46 years, with the average spraying experience of 22 years (Table 4.1), which was comparatively generally longer than Tanah Merah. Studies have proposed that the increase in farming experience will cause an increase in pesticide use (Ayinde et al., 2013; Adejumo et al., 2014)

For Tanah Merah, only two out of six selected farmers had a nationally recognized certification and for Pasir Mas, two out of five selected farmers had a nationally recognized certification (Table 4.1). Farmers who are trained generally have improved knowledge in pesticide usage, safety behaviour and belief in pesticide hazard control (Mubushar et al., 2019). This is important to reduce farmers' exposure towards pesticide risk.

Table 4.1 shows more than half of the farmers (8 farmers) rented the paddy fields whereas only three of them owned the fields. Muhammad et. al (2019) proposed that land ownership has positive influence on the knowledge of pesticides usage safety measures because farmers who own their agricultural land are generally more concerned and knowledgeable on pesticides effects towards human health, but farmers who renting the land are often more focused on how to maximize profits from the lnd.

Table 4.1: Basic information of the selected paddy farmers from Tanah Merah (outside granary area) and Pasir Mas (granary area)

Farmer	Age	Gender	Job status	Spraying Experience	Certificate	Most recent year of training	Farm ownership
Tanah Merah (TM)							
TM01	25	M	FT	4	N	-	R
TM02	57	M	FT	10	Y	2016	R
TM03	53	M	FT	2	N	-	R
TM04	39	M	FT	8	N	-	R
TM05	60	M	PT	5	N	-	R
TM06	56	M	PT	27	Y	2015	O
Mean	48			9			
Pasir Mas (PM)							
PM01	41	M	FT	9	Y	2010	R
PM02	58	M	FT	46	Y	2014	R
PM03	62	M	PT	12	N	-	R
PM04	76	M	FT	40	N	-	O

Table 4.1 (Continued)

PM05	37	M	PT	1	N	-	O
Mean	55			22			

FT - full time; PT - part time; N – with no nationally recognized certification; Y – with nationally recognized certification; O - self-ownership; R – renting

4.2 Education Level and Total Maximum Daily Systemic Exposure

The education level can be grouped as primary school (PS), high school (HS), college (C) and university (U). For the education level of farmers from Tanah Merah, four of six selected farmers were graduated from high school, one graduated from the university and one from the primary school. For Pasir Mas, only one farmer graduated from the university, two from the high school and only one from the primary school. Mustapha et al. (2017) proposed that the higher the farmers' education level, the tendencies for them to wear PPE will increase. This is because they have greater access to information and knowledge regarding pesticide risk, which can reduce their systemic dose of pesticide exposure (Mustapha et al., 2017). Mubushar et al. (2019) also proposed that education level is one of the most significant factor on the knowledge of pesticide safety measures.

Figure 4.1 shows that farmer with the highest education level from Tanah Merah at the college level had lower total maximum daily systemic dose (0.216 mg kg bw^{-1} day^{-1}) than those graduated from the high school (0.278 mg kg bw^{-1} day^{-1}– 2.875 mg kg bw^{-1} day^{-1}) but higher than farmer graduated from the primary school (0.072 mg kg bw^{-1} day^{-1}). Figure 4.2 shows that the farmer with the highest education level from Pasir Mas had intermediate level of total maximum daily systemic dose (0.098 mg kg bw^{-1} day^{-1}), compared to those from the high (0.135 mg kg bw^{-1} day^{-1} and 0.067 mg kg bw^{-1} day^{-1}) and primary schools (0.113 mg kg bw^{-1} day^{-1} and 0.088 mg kg bw^{-1} day^{-1}). Overall, the analysis of this study indicates no association between farmers' education level and the total maximum daily systemic dose.

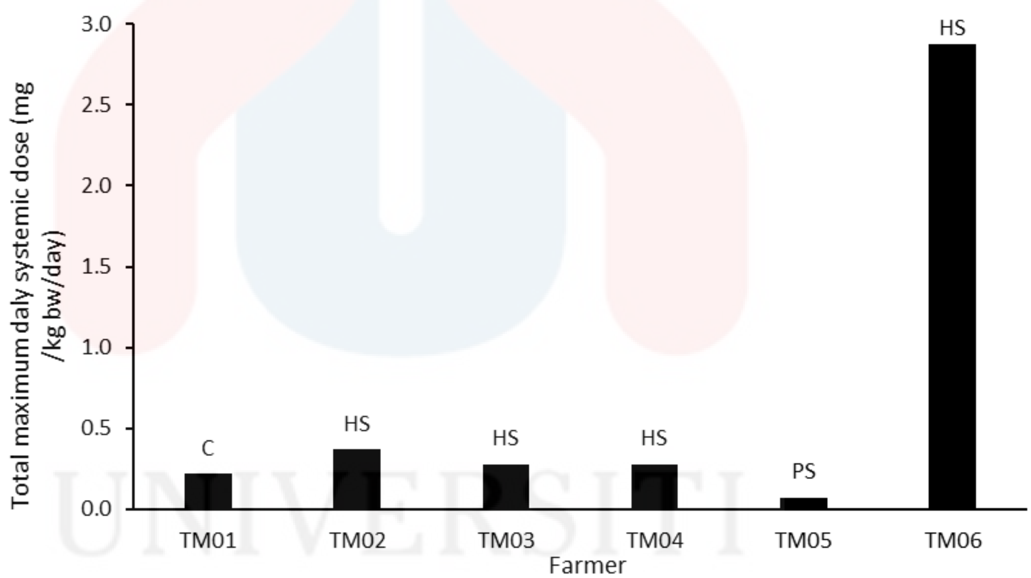

Figure 4.1 : Graph of total maximum daily systemic dose vs education level in Tanah Merah.

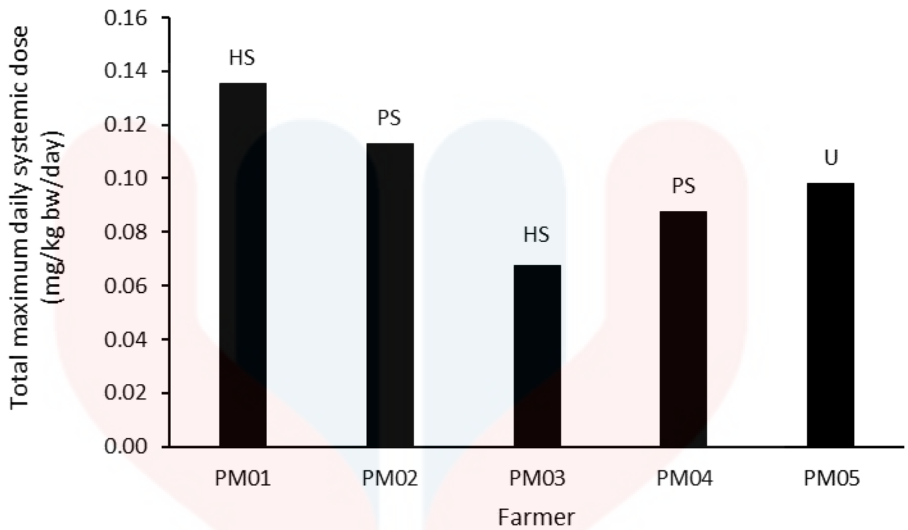

Figure 4.2: Graph total maximum daily systemic dose vs education level in Pasir Mas.

4.3 Comparison of Total Maximum Daily Systemic Dose between Tanah Merah and Pasir Mas

Figures 4.3 and 4.4 show that Tanah Merah farmers had higher total maximum daily systemic dose compared to Pasir Mas with 0.072 mg kg bw^{-1} day^{-1} – 2.875 mg kg bw^{-1} day^{-1} and 0.067 mg kg bw^{-1} day^{-1} – 0.135 mg kg bw^{-1} day^{-1}, respectively. This might be because of the shorter spraying experience among farmers from Tanah Merah (mean of 9 years) compared to those from Pasir Mas farmers (mean of 22 years). This is supported by the research by May et al. (2011) which stated that farmers who are more experienced in agricultural activities tend to reduce pesticide use, which is opposite from the studies conducted by Adejumo et al. (2014) and Ayinde et al. (2013). Another reason for the higher exposure in Tanah Merah is because of minor or outside irrigation schemes compared to Pasir

Mas with major irrigation schemes (Namar et al., 2005). Benjamin and Joseph (2015) proposed that irrigation influences pesticide use in rice production where the study showed that paddy field that used major and proper irrigation system have lower pesticide use compared to paddy field that does not have major and proper irrigation system. Since the irrigation can increase the production output for the paddy field, the farmers typically does not feel the need to use excessive pesticide compared to farmer with minor or outside irrigation scheme.

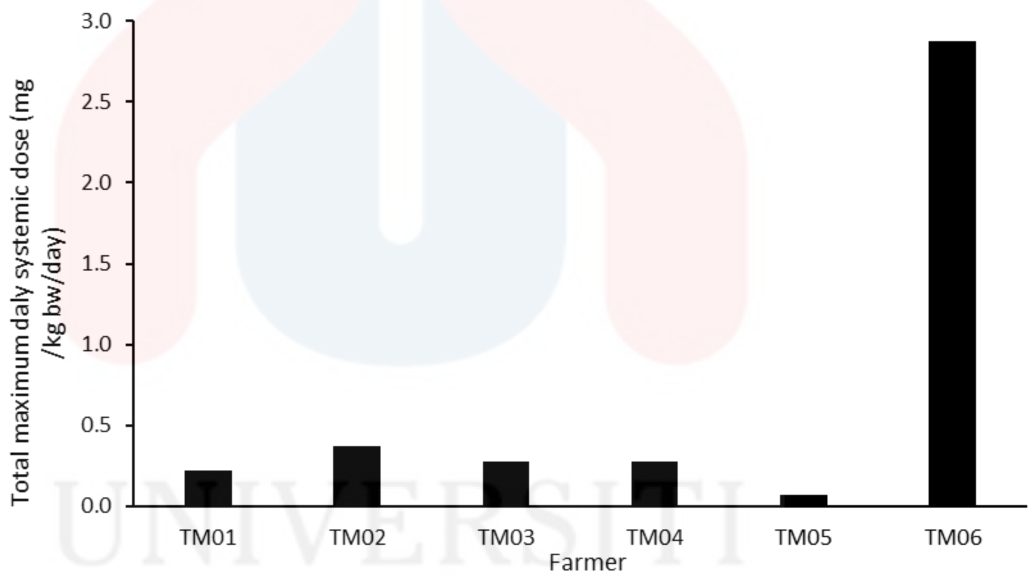

Figure 4.3: The total maximum daily systemic dose of the selected farmers from Tanah Merah..

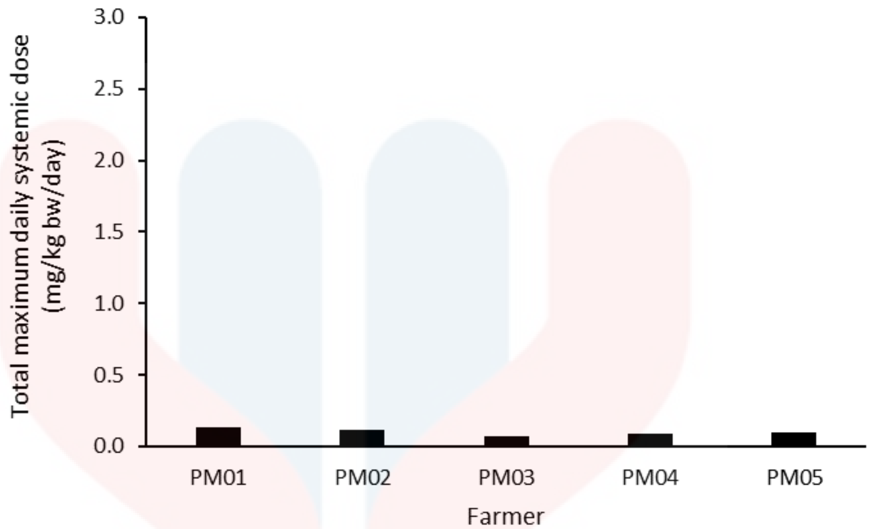

Figure 4.4: The total maximum daily systemic dose of the selected farmers from Pasir Mas.

4.4 Comparison of Exposure Estimates with Respective AOEL for Single Application

Figures 4.5 and 4.6 show the ratios between the predicted exposure and the respective AOEL for each active substance handled on a single working day. The AOEL is the maximum amount of an active substance to which a farmer may be exposed internally without causing any adverse health effects (Marrs & Ballantyne, 2004). Here, the same substance applied several times on the same working day is considered as one application whereas the same active substance applied on successive days counts as two applications.

Figure 4.5 shows the six farmers from Tanah Merah had number of applications ranged from 4 to 34 applications across the whole season and 2 to 6 applications for the five farmers from Pasir Mas (Fig. 4.6). The figures also show that older farmers (≥ 55 years old) have higher total number of pesticides application compare to younger farmers (<55 years old) in both study areas. For Tanah Merah, older farmers (≥ 55 years old) had 63 total numbers of pesticides application while younger farmers (<55 years old) had 30 total numbers of pesticides application. For Pasir Mas, older farmers (≥ 55 years old) had 11 total numbers of pesticides application while younger farmers (<55 years old) had 9 total numbers of pesticides application. Younger farmers often have higher level of risk perception compared to older farmers and they prefer to use alternative pests control such as integrated pest management practices because of their higher concern on pesticide use and risk (Damals & Hashemi, 2010). High perception towards pesticide risk and positive impact towards alternative use of pest control are factors for the lower number of application among younger farmers.

Figures 4.5 and 4.6 also show that farmer with longer working experience (≥ 10 years) have higher total number of pesticides application compare to farmers with shorter working experience (<10 years) in both study areas. For Tanah Merah, farmers with longer working experience (≥ 10 years) had 59 total numbers of pesticides application while farmers with shorter working experience (<10 years) had 41 total numbers of pesticides application. For Pasir Mas, farmers with longer working experience (≥ 10 years) had 11 total numbers of pesticides application while farmers with shorter working experience (<10 years) had 9 total numbers of pesticides application. The result is in line with the findings of Idris et al. (2013) and Denkyirah et al. (2016) where the farmer with longer working experience had higher pesticide used compared to those with shorter working experience. The level of awareness on health implications of pesticides use decrease as the experience of farmers in pesticide usage increases which resulting in lower total number of pesticide application for farmers with shorter working experience (Mabe et al., 2017).

For outside granary area in Tanah Merah, all farmers had at least one application with pesticide exposure exceeded the respective AOEL (Figure 4.5), indicating potential negative adverse health effects. Active substances with predicted exposures exceeded the respective AOELs including propanil, bentazone sodium, MCPA dimethylammonium and imidacloprid which due to larger amount applied (AOEL values: 0.02 mg kg bw^{-1} day^{-1} – 0.13 mg kg bw^{-1} day^{-1} while chlorpyrifos and lambda-cyhalothrin with their relatively high toxicity (AOEL values of 0.001 mg kg bw^{-1} day^{-1} and 0.00063 mg kg bw^{-1} day^{-1}, respectively).

For granary area in Pasir Mas, only one farmer had application with predicted exposure exceeded the respective AOEL because of the usage of imidacloprid active substance with AOEL value of 0.08 mg kg bw^{-1} day^{-1}. The reason is due to larger usage of this pesticide for certain spraying days.

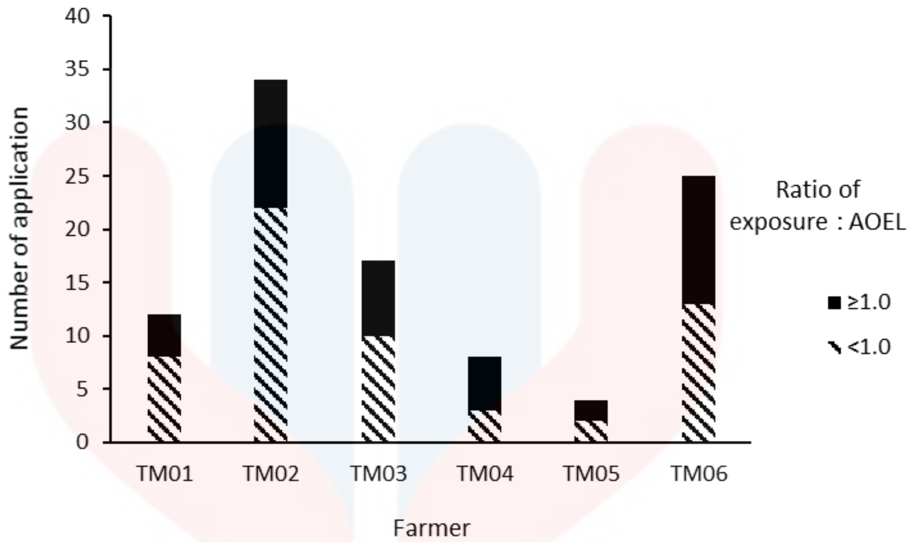

Figure 4.5: Total number of application with predicted exposures assessed against the AOEL values for six selected farmers from Tanah Merah. Single applications refer to one active substance applied on a spraying day.

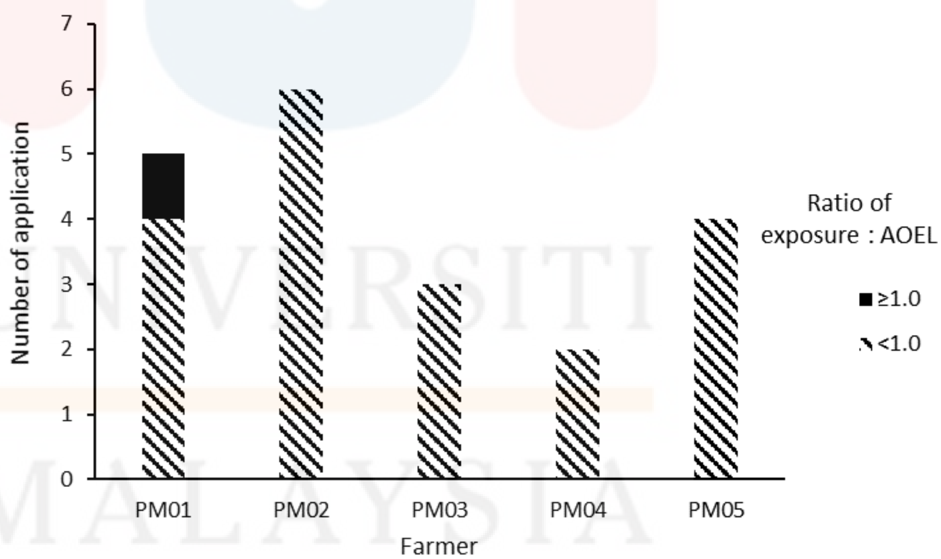

Figure 4.6: Total number of application with predicted exposures assessed against the AOEL values for five selected farmers from Pasir Mas. Single applications refer to one active substance applied on a spraying day.

4.5 Study Limitations

Limitations of the study include the use of WHO Generic Risk Assessment Model for Indoor and Outdoor Space Spraying of Insecticides for only liquid formulations, where non-liquid pesticides cannot be assessed for additional pesticide exposures. Next, the product labels provide information of active substance content in the unit of % w/w which cause the actual content for single active substances in the formulation is not clear. The WHO exposure algorithms also require the concentration of active substance in a product in $g\ L^{-1}$ as the key input parameter to calculate the application rate and thus, exposure level.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study assessed paddy farmers' exposure to pesticide active substances formulated in liquid formulations using WHO Generic Risk Assessment Model for Indoor and Outdoor Space Spraying of Insecticides across a whole cropping season, where data was available. Overall, the model predicted relatively higher levels of exposure and larger number of applications that exceeded AOELs for farmers from outside granary area in Tanah Merah compared to those from granary area in Pasir Mas. Results indicate the influences of farming experience, age and irrigation system as major factors of pesticide exposures among the farmers. All farmers from Tanah Merah and only one farmer in Pasir Mas had predicted daily exposure that exceeded AOEL, indicating potential adverse health effects to the farmers.

5.2 Recommendations

The recommendation for further study is to develop a specific exposure model or algorithms for paddy scenarios when data become available. This is because currently there is no such exposure model developed for paddy field scenarios. The model need to consider the use of % w/w of active substances as the key input parameter to calculate the estimate pesticide exposure because all pesticide labels in Malaysia provide information on the concentration of pesticides active substance in % w/w instead of g L^{-1}, which is required by the existing model algorithms. Another possibility is the switch of local government to use the concentration unit of g L^{-1} instead of % w/w on all pesticides products since the unit % w/w does not really give the actual content of active substances. This can also ensure the uniformity with other countries since most developed countries are using the unit g L^{-1} for the active substance concentrations on their product labels. This would allow the uses of exposure algorithms that are developed by those countries. The product database for pesticides also need to be improved to facilitate and ease the public in finding information regarding pesticides.

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APPENDIX A

Informed Consent

BORANG PERSETUJUAN MENJADI RESPONDEN

Assalamualaikum dan salam sejahtera,

Saya Nurul Najiah binti Norman, mahasiswa dari Universiti Malaysia Kelantan Jeli ingin menjalankan kajian yang bertajuk "Perbandingan antara Pendedahan di Tempat Kerja bagi Petani Padi terhadap Racun Perosak yang Digunakan di Jelapang Padi dan Luar Jelapang Padi". Saya ingin meminta kebenaran Encik/Puan/Cik untuk bekerjasama dengan saya bagi memberi maklumat yang berkaitan dengan kajian ini.

Tujuan kajian ini dibuat ialah untuk membandingkan tahap pendedahan petani padi terhadap racun perosak yang digunakan di jelapang padi dan luar jelapang padi di bawah dua system pengairan yang berbeza. Kajian ini juga mengkaji factor pendedahan petani terhadap racun perosak yang digunakan di sawah padi tertentu. Maklumat mengenai kajian ini adalah seperti berikut:

i) Responden akan diwawancara selama 20 minit. Responden juga diminta mengisi boring kaji selidik selama 3 bulan untuk kesuluruhan musim tanaman.

ii) Penyertaan responden adalah secara sukarela dan responden dibenarkan menarik diri bila-bila waktu tanpa sebarang denda dan hukuman.

iii) Maklumat dari responden adalah sulit dan hanya akan digunakan untuk kajian ini. Rekod maklumat diri responden tidak akan didedahkan kepada umum.

iv) Responden dibenarkan untuk mengetahui keputusan penyelidikan mengikut kemahuan responden sendiri.

Penyelidik,

Nurul Najiah binti Norman

Saya seperti yang dinyatakan di bawah :

Nama :

No. kad pengenalan :

Alamat :

Dengan ini saya bersetuju menjadi responden untuk kajian yang dijalankan oleh Nurul Najiah binti Norman, pelajar Universiti Malaysia Kelantan Jeli yang bertajuk "Perbandingan antara Pendedahan di Tempat Kerja bagi Petani Padi terhadap Racun Perosak yang Digunakan di Jelapang Padi dan Luar Jelapang Padi". Saya faham akan kesan yang akan berlaku dari penglibatan saya dalam kajian ini dan saya akan memberi kerjasama dengan penyelidik sewaktu kajian dijalankan.

Tandatangan reponden :

………………………

Tarikh :

APPENDIX B

Face-to-face interview

Nama Kampung: Nama Daerah:

(A) Maklumat pesawah padi	
1. Nama:	2. Koordinat GPS (rumah):
3. No. telefon:	4. Jantina:
5. Umur:	6. Berat badan (kg):
7. Taraf pendidikan (bulatkan yang berkenaan): ○ Sekolah rendah / Sekolah menengah / Kolej / Universiti / Tidak pernah bersekolah	
8. Bekerja sebagai: ○ Pesawah padi sepenuh masa ○ Kerja sambilan (sila nyatakan): ____________________	
9. Pengalaman bekerja sebagai pesawah padi: __________ tahun	
10. Kursus/latihan: i. Tahun terkini menghadiri kursus/latihan: __________ ii. Kursus/latihan dianjur oleh: ____________________ iii. Jenis kursus yang dihadiri: Theori / Praktikal / Kedua-duanya	
(B) Maklumat racun perosak	
1. Sumber racun:	2. Tempat simpan racun:
3. Aktiviti *mixing/loading:* i. Tempat campur racun: ____________________ ii. Penggunaan penyukat waktu campur: Ada / Tiada	
4. Cara pelupusan bekas kosong racun:	
5. Masalah kesihatan yang disebabkan racun:	

i. Nyatakan jenis penyakit: ____

ii. Cara sembuh: ____

(C) Maklumat mesin penyembur racun

1. Jenis penyembur (bilangan tahun):

   ○ Manual knapsack: ________ tahun

   ○ Motorised knapsack: ________ tahun

   ○ Lain (nyatakan): ____ tahun

2. Nama model mesin:	3. Kapasiti tangki (Liter):

4. Tempat simpan mesin:

(D) Purata masa diperlukan untuk aktiviti:

1. *Mixing/loading* (min/day):
2. *Spraying* (min/day):
3. *Cleaning sprayer* (min/day):

(E) Purata bilangan aktiviti dijalankan pada hari pakai racun:

1. *Mixing/loading* (no. of activity/day):
2. *Spraying* (no. of activity/day):
3. *Cleaning sprayer* (no. of activity/day):

(F) Penggunaan PPE

1. *Mixing/loading activit*y (bulatkan yang berkenaan):

   i. Tangan: sarung tangan kain / sarung tangan plastik / tidak memakai

   ii. Badan: baju lengan panjang / baju lengan pendek / seluar panjang / seluar pendek /apron

   iii. Kaki: kasut but / kasut getah / tidak memakai

   iv. Hidung: topeng kain atau kapas / topeng buatan sendiri / tidak memakai

2. *Spraying activity* (bulatkan yang berkenaan):

   i. Tangan: sarung tangan kain / sarung tangan plastik / tidak memakai

   ii. Badan: baju lengan panjang / baju lengan pendek / seluar panjang / seluar pendek /apron

   iii. Kaki: kasut but / kasut getah / tidak memakai

   iv. Hidung: topeng kain atau kapas / topeng buatan sendiri / tidak memakai

3. *Sprayer cleaning* (bulatkan yang berkenaan): i. Tangan: sarung tangan kain / sarung tangan plastik / tidak memakai ii. Badan: baju lengan panjang / baju lengan pendek / seluar panjang / seluar pendek /apron iii. Kaki: kasut but / kasut getah / tidak memakai iv. Hidung: topeng kain atau kapas / topeng buatan sendiri / tidak memakai
4. Berapa kali guna PPE sebelum dilupuskan? Jelaskan:

APPENDIX C

Maklumat penggunaan racun

Tarikh	Nama racun	Syarikat Pengeluaran Racun	Perumusan	Jumlah Racun Diguna (g/ml)	Jumlah Air Dicampur (litre)	Keluasan tanah disembur