UNIVERSITI PUTRA MALAYSIA

RISK ASSESSMENT OF CALCIUM CARBIDE USE IN FRUIT RIPENING AMONG FARMERS, FARM WORKERS AND FRUIT TRADERS IN THE NORTHERN REGION OF MALAYSIA

NOOR SHAEDA ISMAIL

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By

NOOR SHAEDA ISMAIL

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Chair : Associate Professor Irniza Rasdi, PhD
Faculty : Medicine and Health Sciences

Introduction: Ripening agent is a material that is used to accelerate the fruit ripening activity and calcium carbide (CaC_2), a chemical ripening agent, is widely used since antiquity for seasonal fruits ripening purposes. Artificial fruits ripening become dubious in recent years when various health related issues began to arise. Therefore, workplace risk assessment related to CaC_2 use is crucial to protect the safety and health of workers from the hazardous impurities. **Objective:** The general objective of this study is to analyze the potential risks of CaC_2 to occupational safety and health (CHRA). **Method:** This study was performed through the delegation of questionnaires and face to face survey. Pulmonary test and phosphine exposure measurement was also carried out. There were two groups involved in this study which were the exposed groups (172 respondents) and non-exposed group (172 respondents). The study location was conducted in mango farms and fruits stall that used CaC_2 as a ripening agent in Perak, Kedah and Perlis. **Results:** The response rate for exposed respondents was 100% (n = 172). For HIRARC, there were 4 hazard categorized as high risk and medium risk and 1 hazard categorized as low risk while for CHRA analysis, the risk was found significant for those who work directly (work unit A and work unit B) and indirectly with CaC_2 (work unit C). The most prevalence respiratory symptom reported for exposed respondent was phlegm (37.8%). It was found that the most contributable factor towards exposed respondent's lung function was education level (OR = 2.545, p=0.026) while the most contributable factors towards exposed respondent's respiratory symptoms were marital status for wheezing (OR = 3.428, p=0.002) and chest tightness (OR = 4.876, p=0.000), employment duration (OR = 3.011, p=0.004) for shortness of breath and race for cough (OR = 3.416, p=0.03) and phlegm (OR = 3.241, p=0.024). **Conclusions:** It is essential to determine the CaC_2 exposure towards farmers and fruits trader in order to improve the existing handling of CaC_2 and to recover the current method towards a safer approach in order to enhance farmer's quality of life.

Keywords: Calcium carbide, phosphine exposure, chemical fruits ripening

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah ijazah Doktor Falsafah

PENILAIAN RISIKO UNTUK KALSIUM KARBIDA YANG DIGUNAKAN DALAM PEMERAMAN BUAH-BUAHAN DI KALANGAN PETANI, PEKERJA LADANG DAN PENIAGA BUAH DI NEGERI UTARA MALAYSIA

Oleh

NOOR SHAEDA ISMAIL

Mei 2019

Pengerusi : Professor Madya Irniza Rasdi, PhD
Fakulti : Perubatan dan Sains Kesihatan

Pengenalan: Agen pemasakan merupakan satu bahan yang digunakan bagi mempercepatkan aktviti pemasakan buah dan kalsium karbida (CaC_2) telah digunakan secara meluas sejak berkurun lamanya bagi tujuan mempercepatkan pemasakan buah bermusim. Namun, kaedah ini menjadi keraguan pada tahun kebelakangan apabila pelbagai isu berkaitan kesihatan mula timbul. Maka, penilaian risiko di tempat kerja berkaitan dengan penggunaan CaC_2 adalah penting untuk melindungi keselamatan dan kesihatan pekerja dari bahan berbahaya. **Objektif:** Objektif umum adalah untuk menganalisis kemungkinan risiko CaC_2 terhadap keselamatan dan kesihatan pekerja.. **Metodologi:** Kajian dilaksanakan melalui agihan borang kaji selidik dan survei secara bersemuka, Ujian pulmonari dan pengukuran pendedahan gas fosfin turut dilakukan. Dua kumpulan responden terlibat dalam kajian ini iaitu mereka yang terdedah secara lansung (172 orang) dan mereka yang tidak terdedah dengan CaC_2 (172 orang). Lokasi kajian adalah di ladang mangga dan gerai buah di Perak, Kedah dan Perlis. **Keputusan:**Kadar respon kumpulan yang terdedah adalah 100% (n=172). Bagi HIRARC, terdapat 4 bahaya yang dikategorikan sebagai risiko tinggi dan risiko sederhana dan 1 bahaya yang dikategorikan sebagai risiko rendah manakala untuk analisis CHRA, risiko didapati signifikan bagi mereka yang bekerja secara langsung (unit kerja A dan unit kerja B) dan secara tidak langsung dengan CaC_2 (unit kerja C). Simptom pernafasan yang paling lazim yang dilaporkan untuk responden yang terdedah adalah kahak (37.8%). Faktor yang paling meyumbang ke arah fungsi paru-paru responden ialah tahap pendidikan (OR = 2.545, p = 0.026) manakala faktor yang paling menyumbang kepada simptom pernafasan responden adalah status perkahwinan untuk bunyi berdehit (OR = 3.428, p = 0.002) dan sesak dada (OR = 4.876, p = 0.000), tempoh pekerjaan (OR = 3.011, p = 0.004) untuk sesak nafas dan bangsa untuk batuk (OR = 3.416, p =0.03) dan kahak (OR = 3.241, p=0.024). **Kesimpulan**: Kajian pendedahan CaC_2 terhadap petani dan penjual buah adalah penting untuk menambahbaik pengendalian semasa CaC_2 dalam menjadi lebih selamat bagi meningkatkan kualiti hidup petani.

Kata kunci: Kalsium karbida,pendedahan fosfin, pemasakan buah kimia

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I certify that a Thesis Examination Committee has met on 31 May 2019 to conduct the final examination of Noor Shaeda Ismail on her thesis entitled "Risk Assessment of Calcium Carbide Use in Fruit Ripening Among Farmers, Farm Workers and Fruit Traders in the Northern of Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy

Members of the Thesis Examination Committee were as follows:

Kulanthayan a/l K.C. Mani @Subramaniam, PhD
Associate Professor
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

Karmegam a/l Karuppiah, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Internal Examiner)

Sharifah Norkhadijah Syed Ismail, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Internal Examiner)

Noor Hassim Ismail, PhD
Professor
Faculty of Medicine
Universiti Kebangsaan Malaysia
Malaysia
(External Examiner)

_____
NOR AZOWA IBRAHIM, PhD
Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 6 December 2019

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Irniza Rasdi, PhD
Associate Professor
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

Sarva Mangala Praveena, PhD
Associate Professor
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

Emilia Zainal Abidin, PhD
Associate Professor
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

_____
ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature : _____
Name of
Chairman of
Supervisory
Committee : Associate Professor Dr Irniza Rasdi

Signature : _____
Name of
Member of
Supervisory
Committee : Associate Professor Dr Sarva Mangala Praveena

Signature : _____
Name of
Member of
Supervisory
Committee : Associate Professor Dr Emilia Zainal Abidin

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LIST OF ABBREVIATIONS

HIRARC	Hazard identification, risk assessment and risk control
DOSH	Department of Safety and Health
OSHMP	Occupational Safety and Health Master Plan
GTP	Government Transformation Programme
ETP	Economic Transformation Programme
NKEA	National Key Economic Area
EPP	Entry Points Projects
OSHA	Occupational Safety and Health Act
IDLH	Immediately Dangerous to Life or Health
ppm	Part per million
PEL	Permissible exposure limit
OEL	Occupational exposure limits
TWA	Time-weighted average
STEL	Short-term exposure limit
OEHHA	Office of Environmental Health Hazard Assessment
CHRA	Chemical health risk assessment
GBBS	Fresh Fruit Stall Entrepreneur Program
DOA	Department of Agriculture
FAMA	Federal Agricultural Marketing Authority
MARDI	Malaysia Agricultural Research and Development Institute
MADA	Muda Agriculture Development Authority
PAC	Protective Action Criteria
NIOSH	National Institute of Occupational Safety and Health
ACGIH	American Conference of Governmental Industrial Hygienists
IFOAM	International Federation of Organic Agriculture Movements
FVC	Force vital capacity
FEV1	Force expiratory volume-one second
COPD	Chronic obstructive pulmonary disease
OHSAS	Ocupational Helath and SafetyAsesmen Series
MSDS	Material safety data sheet

CHAPTER 1

INTRODUCTION

Calcium carbide (CaC_2) is widely used in Asian countries since antiquity for ripening purposes (Rohani, 1999). Ripening agent is a substance used to accelerate ripening activities and it is derived from many types, includingCaC_2. CaC_2 can stimulate ripening within 24 hours and under the circumstance that it can be attained at very low price, makes it a very admired substance among farmers (Singal, Kumud and Thakral, 2010). Globally, $CaC_2$is used by a number of countries for the ripening of a broad range of fruits (Sy and Wainwright, 1990) as shown in Table 1.

Table 1.1: Countries that use CaC_2 as fruit ripening agent

Fruits	Countries
Banana	Australia, Egypt, India, Philippines, South Africa, Sudan, Taiwan, USA, Yemen
Mango	Brazil, Costa Rica, India, Malaysia, Philippines, Senegal, South Africa
Citrus	Australia, Philippines, South Africa
Tomatoes	Australia, Morocco, Philippines, USA
Plums	South Africa
Peaches	South Africa

Malaysia is one of the countries using CaC_2 in fruit ripening especially mangoes (Siddiqui and Dhua, 2009) and it is still a preferred choice until now. CaC_2 that is used for fruit ripening can be found in the form of small blocks or powder. In Malaysia, small blocks of CaC_2 are often used. The industrial type of $CaC_2$is used in the ripening activity which contains arsenic and phosphorus; hazardous to human health if consumed (Rahman et al., 2008).

Mango is one of the seasonal fruits mainly grown in tropics and sub-tropics countries. In Malaysia, the total area planted with mangoes is 5.816.4 hectare (Department of Agriculture, 2016). The main area of mango plantation is on the Northern Region of Peninsular Malaysia including Perak, Perlis, and Kedah where total production (metric tons) in 2016 were 6377.1, 1388.1, and 298.6 respectively (Department of Agriculture, 2016). Mangoes are considered as seasonal fruits and like many other seasonal fruits, they cannot be attained at all times. Naturally ripened fruits do not ripen uniformly and this situation makes it difficult for marketing and distribution purposes. Thus, farmers use chemical ripening agents such as CaC_2, ethanol, methanol, ethylene glycol, and

ethephon (Goonatilake, 2008)to accelerate the ripening process and provide a high return to the seller. In Malaysia, mangoes are picked slightly unripe and then CaC_2 is applied.

This artificial method of fruit ripening has become dubious in recent years when various health-related issues begin to arise(Fattah and Ali, 2010). The use of carbide has a bad effect on human health through inhalation. Health effects triggered by CaC_2 include skin irritation which can cause rash and redness; and lung irritation which can initiate cough and/or shortness of breath (SOB) (New Jersey Department of Health, 2016). Pulmonary oedema with acute SOB may occur with high and recurrent exposure; it can cause bronchitis with coughing, phlegm, and/or shortness of breath (New Jersey Department of Health, 2016). When $CaC_2$is applied on fruits, it will react with moisture and released acetylene which has ripening attributes analogous to ethylene, a natural/biological ripening agent (Rahman et al., 2008).

Acetylene is colourless and odourless; and is an extremely flammable gas(Public Health England, 2009). In common industrial exercise, acetylene is not deemed an intense lethal hazard but in an occupational situation, exposure to acetylene does have harmful health effects which is linked with the existence of toxic impurities(Public Health England, 2009). Common impurities include ammonia, arsine, and phosphine(Public Health England, 2009).

Therefore, workplace risk assessment related to CaC_2 use is crucial to protect the safety and health of workers from hazardous impurities. Hazard identification, risk assessment and risk control (HIRARC) is a process or approach in evaluating hazards and their related risks that will impart a system to restrain the risks(DOSH Malaysia, 2008). The process involves several steps starting with work activities classification, followed by hazard identification, risk assessment, and the final step is selecting a control (DOSH Malaysia, 2008). Hierarchy of controls is one of the tools that can be used to manage risks originating from CaC_2. The process involves the assessment of existing controls whether it is necessary to make any changes to the current control mechanism or to initiate a new control procedure. The elements of hierarchy of controls include elimination, substitution, isolation, engineering controls, administrative controls, and personal protective equipment(Basiran, Baharudin and Anwar, 2016).

From economic perspective, detailed information of the usage of CaC_2 among Malaysian farmers is needed to indirectly contribute to Malaysia's economic growth through the implementation of Occupational Safety and Health Master Plan 2020 (OSHMP). It is expected to improve current application to refer to the OSHMP towards a safer fruit ripening method as an effort to improve the farmers' quality of life. Its goal is to improve the quality of workers' life through reduction of occupational disease rate in the workplace. A safe and conducive working environment

produces healthier and more productive workers. A healthy and productive worker is very important in order to support national development policies such as Eleventh Malaysia Plan, Government Transformation Programme (GTP), and Economic Transformation Programme (ETP). This, in turn will contribute to an increase in productivity and to create competition among fruit producers.

The impact and involvement of productive and healthy workers in Malaysia economy can be demonstrated through a government project known as National Key Economic Area (NKEA) which is under the Ministry of Agriculture. Under the Agriculture NKEA there are 16 Entry Points Projects (EPP). One of the EPP known as EPP7 is focusing on fresh fruits. With the reduction of occupational illness and disease rate at the workplace, more fruits can be processed and exported. This will support the NKEA goal which is to increase gross national income (GNI) amounting to RM21.44 billion by 2020. Not only do the occupational illness and disease cause farmers to lose their source of income, it also gives a significant impact to the nation's labour sources in the long term. On top of that, economy, productivity, and nation competitiveness are also affected.

Whilst from food security view, although it is engaged on the risk evaluation and assessment of farmers on the usage of CaC_2, nevertheless, during the evaluation process, important information such as potential hazards of CaC_2, guideline values for CaC_2, route of exposure, and quantity of CaC_2 applied onto fruits can be obtained. This information can be used as supplementary reports in order to support the national food security policy especially when the fruits are exported to other countries that are very demanding when it comes to food safety issues.

Despite of few but limited evidence available on the hazardous effects of CaC_2 from ripening activities to workers health, data on the amount of CaC_2exposure and its related health impact among Malaysian farmers are unknown due to the absence of research and data on this particular area. Moreover, in Occupational Safety and Health Act (OSHA), there is no permissible exposure limits available for workers dealing with CaC_2. Although several researches have been done previously in other countries, several factors may differentiate the findings. These factors might include working culture, method of applying CaC_2, working duration, awareness level, and biological factors such as age, sex, race, and even the climate. Furthermore, most studies tend to focus on CaC_2 effects on fruit texture, taste, and nutritional contents but not to farmers. Therefore, there is no baseline data and insufficient evidence to describe the occupational health risk related to the application of CaC_2 among Malaysian workers which prelude for any necessary control and prevention measures for postulated health impact of CaC_2. Thus, this study aims to address these knowledge gaps by investigating the potential health risks of CaC_2 to occupational safety and health among farmers, identifying the predictors contributing to farmers' health related to CaC_2 exposureandto imply controls in deliberation to lowering the risks.

1.1 Problem Statements

The extensive use of CaC_2 in fruit ripening among farmers is due to its cheaper price and easy availability. Besides its lower price factor, other elements that may contribute to the workers' health quality and the selection of fruit ripening method are sociodemographic, work characteristic and the knowledge, attitude and practice (KAP). There are several sociodemographic factors such as age, marital status, education level, ethnic of origin, and smoking status that may contribute to influencing farmers to choose carbide as the only source for ripening. The work characteristic factors such as employment duration, working status and exposure duration to carbide can also contributed to the farmer's health quality. Equivalently with KAP where the KAP study associated with CaC_2 use among farmers and agricultural workers will reveal the increase or decrease in knowledge on the health hazards posed by this chemical and its impurities, attitude changes towards the safer method application, and changes in the variety of practice with regard to management of CaC_2 and its impurities exposure.

Due to the present of impurities in the CaC_2, HIRARC need to be conducted when there is an indication of significant threat posed by substantial hazards or where there is a need to evaluate if the current controls are sufficient. HIRARC is considered as preventive measures since control is applied when hazard has been identified and analysed, and its associated risk are assessed (DOSH Malaysia, 2008).

Risk assessment is an essential approach to evaluate potential risks of the impurities produced by CaC_2 as a result of emission from known and linked sources. CHRA is one of the tools utilized to protect workers from chemicals' adverse effects. The CHRA for this study is crucial in order to protect farmers and their workers from the adverse effects of chemical used at the workplace. According to USECHH Regulations 2000, it is compulsory to perform assessment of the chemicals that is hazardous to health at the workplace; employees are not allowed to use and handle any hazardous chemicals before the assessment is conducted (DOSH Malaysia, 2000). CHRA conducted in this study would be a pioneer evaluation for all farmers and agricultural workers that use CaC_2 as fruit ripening agent in Malaysia. The conclusion from this assessment will determine whether the use of this chemical in ripening process in Malaysia should be banned permanently or strictly controlled through several control measures as suggested in CHRA.

Calcium carbide reaction released acetylene gas, which act as a reducing agent (New Jersey Department of Health, 2016). It has the same fruit ripening attributes with ethylene (Hossain, Akhtar and Anwar, 2015). The reaction between CaC_2 with moisture will produce acetylene and consequently lead to ripening as shown in the following equation (Sy and Wainwright, 1990):

$$CaC_2 + 2H_20 = Ca(OH)_2 + C_2H_2$$

Acetylene generated from CaC_2 reaction contains a trace of arsine and phosphine at a concentration of 3ppm and 95ppm, respectively (Bingham, Cohrssen and Powell,

2001). The existence of these impurities gives rise to the CaC_2 toxicity (Public Health England, 2009) especially if high amount of CaC_2 is applied on raw fruits. However, phosphine was chosen to be studied due to its high concentration in carbide compared to arsine. Furthermore, the phosphine concentration exceeds the life and health value (IDLH) set by NIOSH which is 50 ppm (NIOSH, 2003) compared to the IDLH value for arsine which is 3ppm (National Response Team, 2012). However, it was unknown on how much the quantity of CaC_2 is used to generate 95 ppm of phosphine.

The work process in fruits ripening using CaC_2 involved several steps from harvesting stage until storage of fruits. The individual who might be exposed to phosphine included workers/farmers who handled CaC_2 directly and those who worked near or pass through the ripening process area. At the farm, after harvesting, mangoes were washed with water and were wiped using cloth. Then, carbide was wrapped with newspaper and placed at the bottom of the fruit basket. Mangoes were then loaded into the baskets and the basket was covered with newspaper. While at the fruit stall, most of the fruit sellers used wood chamber to store the fruits or ripening process especially banana while for other fruits, fruit baskets were used. Carbide was wrapped with newspaper and placed at the bottom of the enclosed wood chamber. Then, bananas were loaded into the chamber and the chamber was closed. Figure 1.1shows the work process involving the carbide use at the farms and fruit stall.

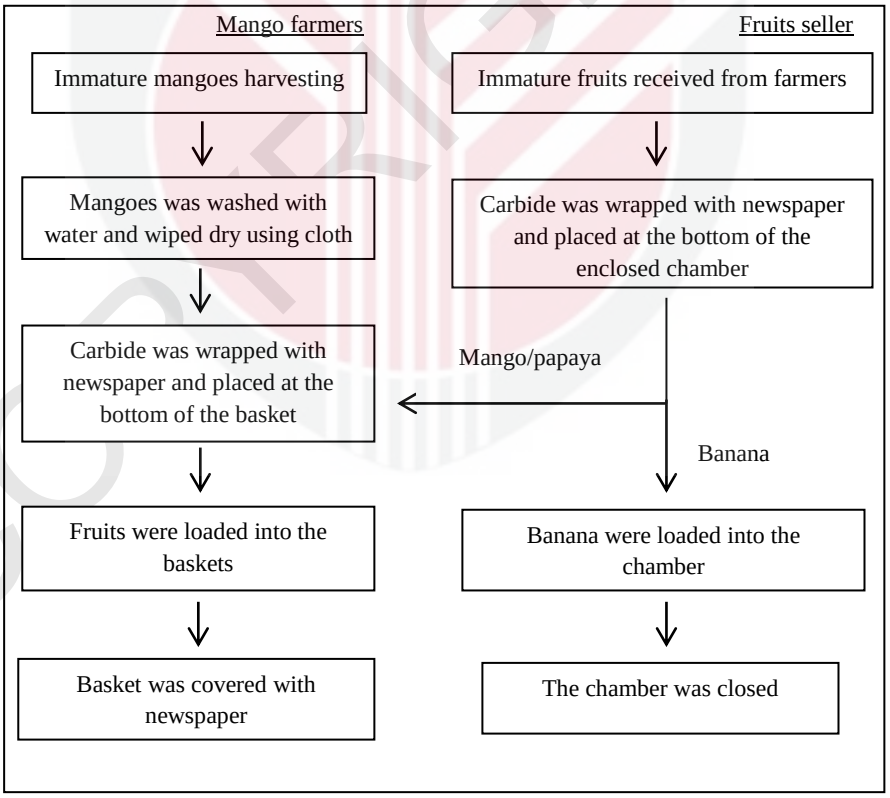

Figure 1.1: The work process involving the use of carbide in fruits ripening

The exposure of CaC_2 to workers can arise from multiple ways such as during wrapping of carbide block using newspaper where the carbide dust may accumulate on workers' mucous membrane (Elkem, 2006) or when the ripening process takes place chemically within 24–48 hours where acetylene gas is released from the reaction between CaC_2 and moisture (Bingham, Cohrssen and Powell, 2001). The risk among workers is intensified if they use CaC_2 excessively because the more immature the fruits, the more CaC_2 are applied in order to ripen them(Smith and Thompson, 1987) and the more exposure of this chemical to those handling it.

Generally, acetylene gas released from the carbide reaction is not considered to be a major contributor to serious toxic hazards to humans but the association of the impurities contained therein, where one of it is phosphine causes health problems (Public Health England, 2009) especially to pulmonary system and cardiovascular system (Agency for Toxic Substances and Disease Registry, 2014). Phosphine is a colourless gas with garlic scent and it can enter the body through inhalation. Phosphine is categorized as a lung damaging agent (NIOSH, 2015). Inhalation of phosphine by farmers can cause cough, chest tightness, and may lead to lung damage (Agency for Toxic Substances and Disease Registry, 2014) while excessive exposure may cause pulmonary oedema (New Jersey Department of Health, 2016).

When phosphine is inhale, phosphoric acid is produced and reacts with moisture in the lungs and subsequently damages the alveolar membrane (NIOSH, 1999). Moreover, the pulmonary toxicity may also be caused through the inhibition of mitochondrial cytochrome C oxidase by phosphine where the inhibition disrupts the mitochondrial morphology and instigates the oxidative respiration to be reduced by 70% (Proudfoot, 2009); consequently causes the cells to perish rapidly(Singh and Sharma, 1991).While for arsine, the exposure towards high level of arsine may experience nausea, vomiting, diarrhoea, anaemia and low blood pressure (Asif, 2012).

The magnitude of the problem from the phosphine exposure is shown via several human epidemiology studies of occupational exposure to phosphine. Findings of a previous study showed that out of 121 cases of phosphine poisoning derived from aluminium phosphide as grain fumigant, 78 (64.4%) cases showed signs of dyspnoea(Singh, Saharia and Sharma, 1990). A similar study on phosphine poisoning originated from aluminium phosphide as grain fumigant was also carried out. This study indicated that out of 32 cases, 25 cases (78%) exhibited symptoms of dyspnoea (Singh and Rastogi, 1989). There were evidences that pulmonary oedema, necrosis of individual hepatic cells, and anoxic change in purkinje cells of the cerebellum were amid the human cases of death from acute exposure to phosphine (Price and Chambers, 1990).A histopathology analysis on rat tissues has revealed that the rats' lungs showed augmentation in weight when different concentration of CaC_2 was given orally to them every day for one month (Patoare et al., 2007).

Several other studies related to exposure of phosphine involving animals have also been carried out in order to estimate the safe occupational exposure levels (WHO, 1988). A study on rats, cats, and guinea pigs showed that when these animals were exposed to phosphine at 5 ppm for 31.5 hours, 5 ppm for 41.5 hours and 5 ppm for 26.6 hours respectively, all the test subjects were found dead with inner organ congestion and pulmonary oedema (Klimmer, 1969).There was a recent physiochemical study on Wistar rats conducted by Essien, Onyegeme-Okerenta and Onyeme, 2018 where 56 Wistar rats were fed with mango ripened with CaC_2 and some of the parameters such as hormonal parameters, oxidative stress enzymes, haematology indices, histopathology and semen analysis were observed and from this study it was found that eating fruits ripened with carbide may weaken the immune system and caused hormone imbalance and this may lead to sterility (Essien, Onyegeme-Okerenta and Onyeme, 2018). However, there are very limited numbers of recent studies on CaC_2 exposure towards workers.

Calcium carbide is not only used in the agricultural setting as a chemical fruits ripening agent but it is also useful in steel making industry (Jamie, Stefan and Goro Toki, 2004), fertilizer production (calcium cyanamide) (Asif, 2012), acetylene production for plastic manufacturing (Asif, 2012) and the making of carbide light (Asif, 2012). Malaysia is one of the countries still using CaC_2 extensively for fruit ripening. Until now, there are no acts and regulations governing the use of CaC_2 in post-harvest phase in agricultural sector either related to occupational safety or food safety. Besides, there are very limited studies conducted in Malaysia regarding the effects of CaC_2 use as a fruit ripening agent on workers and also consumers. Therefore, the mindfulness of the health effects of this chemical in Malaysia may not initiate an interest to legislate or ratify a specific regulation on this chemical even though there are involvement of NGOs such as Consumers Association of Penang urging the ban of CaC_2.

In Malaysia, there is no act and regulation that specializes in determining the level of human exposure towards CaC_2. In OSHA, there is no permissible exposure limit (PEL) available for workers dealing with CaC_2.Based on the International Chemical Safety Cards (ICSC) provided by International Labour Organization, the occupational exposure limit (OEL) for CaC_2 is also not established (International Labour Organization, 2017). Referring to the Hazardous Substance Fact Sheet provided by New Jersey Department of Health, the OEL for CaC_2 is not determined too although it may jeopardize human health (New Jersey Department of Health, 2016). The only PEL's establishment related to this chemical is the PEL for phosphine where the 8-hour time-weighted average (TWA)is 0.3ppm (DOSH Malaysia, 2000); with 15-minute short-term exposure limit (STEL) of 1ppm (NIOSH, 1997). Nevertheless, according to Malaysia Occupational Safety and Health Acts and Regulations, the ceiling limit for phosphine and the15-minute short-term exposure limit (STEL) have not been established. While for arsine, the 8-hour time-weighted average (TWA)is 0.05ppm (DOSH Malaysia, 2000).

In Malaysian Food Act and Regulations (1983), under Rules 225 which is for raw and fresh fruits, there is no specific standard for artificially-ripened fruits using chemicals. However, there is a recommendation value that can be used which is 0.3–10g of carbide for each kilogram of yields (Rohani, 1999). However, not all farmers abide by the recommendation because there is no explicit enforcement on the quantity or amount of CaC_2 to be used in fruit ripening practice. If farmers applied this substance excessively exceeding the recommended value, not only does it impact their health but the consumers' too. This is because the impurities in the CaC_2 are soluble to fat and they can diffuse into the fruit's flesh; consequently triggering health problems (Haturusihghe, De Silva and Wimlasena, 2004).

However, the use of CaC_2as a ripening agent is prohibited in many countries such as the USA (Giacomini, 2012), India (Islam et al., 2015), Bangladesh (Mursalat et al., 2013) and Nepal (Siddiqui and Dhua, 2010). However, it is still being used in Malaysia. This is probably because safer alternatives such as ethylene and methyl jasmonate are somewhat costly (Rahman et al., 2008). Moreover, fruits ripened naturally on trees are not evenly ripe (Hossain, Akhtar and Anwar, 2015). By using carbide, the fruits can be ripened uniformly. In addition to the cost factor, for fruit traders, the damage of unripe and immature fruits can be minimized during transportation as the fruits are ripened chemically at the stalls (Hossain, Akhtar and Anwar, 2015).

Thus, the research questions that need to be highlight in this study are:

a) What are the hazards, risks and recommended control for CaC_2 handling in fruits ripening among farmers?
b) How do farmers and workers come into contact with phosphine and how much the exposure is likely to happen?
c) What is the substance and its concentration released from the CaC_2 reaction that has a prospective to initiate undesirable health effect?
d) How does CaC_2 possibly harmful to farmer's respiratory symptoms and lung function?
e) What are the possibly factors that might affect farmer's respiratory symptoms and lung functions from the use of CaC_2 as fruits ripening agent?

1.2 Study Justification

As there has been no research on CaC_2 exposure in Malaysia, the present study will provide novel data on the exposure level of CaC_2 among Malaysian fruit farmers. This data will be compared to the standards used in other countries and it will determine whether Malaysian farmers are exposed to acceptable or hazardous level of CaC_2. Furthermore, data on the exposure level of CaC_2 will be analysed on its health effects among Malaysian farmers. Other than providing novel data on its health effects among Malaysian fruit farmers, this study will calculate the health risks of CaC_2 in every step of ripening process of Malaysian fruits particularly mangoes. It should be noted that the ripening process in Malaysia might not be the same with those practiced in other countries. By scrutinizing every step of ripening process, it will be clear as to how

exposure happens. Results from the risk assessment will give answers on how CaC_2health risk is impacted by factors such as age, race, and sex. This information can be used for the development of guideline on the safety and health precautions of CaC_2 handling among Malaysian fruit farmers.

Moreover, this data can be used as a base line on the determination of PEL for CaC_2 which is regulated under OSHA (1994). It will also be useful for policy makers for their reference and for the development of standard operating procedures (SOP) which are not yet available in Malaysia. The SOP that may be generated by government agencies related to agriculture may include information such as the MSDS of $CaC_2$and phosphine, route of exposure, PEL or OEL for CaC_2 and phosphine, the recommended quantity of CaC_2 for ripening, and the use of protective personal equipment (PPE) when handling CaC_2.

Besides, the findings from this study will be beneficial to public where they can be used to create public awareness on the effects of hazardous chemicals to human health and how to minimize the associated risks. The findings also serve to increase awareness on the health impact of CaC_2 to workers, to encourage workers to use PPE when handling CaC_2, and to provide knowledge and information on alternative methods such as ethylene gas for fruit ripening. The importance of awareness among farmers and fruit sellers is essential in order to reduce the knowledge gap and practice gap.

The outcome of this study may enhance the farmers' per capita income, average household income, and Malaysia's prosperity index through improved quality of life by ensuring compliance of safety precautions when handling hazardous chemicals and abiding by the recommended amount of CaC_2 used in fruit ripening process. This is consistent with the government's direction towards the establishment of a high-income developed nation and to transform the nation by implementing 'Preventive culture' to strengthen safe and healthy work culture among workers and employers by 2020.

Other than that, by providing supplementary information on potential hazards of CaC_2, guideline values for CaC_2, route of exposure, and the quantity of CaC_2 applied on fruits along with the associated enforcement, this study will assist the government to increase the production of higher quality fruits that adhere to food safety standards, thus, enabling access to premium markets especially Middle East and Europe. With the ASEAN Free Trade Area (AFTA), it has initiated a huge rivalry in Malaysian agriculture scene through the increase of local and international investment thus, creating more job opportunities. Subsequently, this study will act as preventive measures that can be utilized by authorities and related government agencies such as Department of Occupational Safety and Health, Ministry of Agriculture, Ministry of Health, SIRIM, and Ministry of International Trade and Industry in ensuring occupational safety and consumer well-being.

In conclusion, there is a need to conduct risk assessment of the CaC_2 used in agricultural sector and explore its effects on farmers and farm workers. It is important to investigate and review the current handling of this chemical by farmers. Findings of this research are expected to improve current application towards a safer method in efforts to improve the quality of life of workers and consumers. It is anticipated that these will provide reference to the policymakers to enact rules and regulations either to ban the use of this chemical or to come out with the standard operating procedures (SOP) on dosing rate, safe worker exposure level, and specific safety precautions for all farmers in Malaysia.

1.3 Study Objectives

The general objective of this study is to analyse the potential risks of CaC_2 to respiratory health among farmers and fruit traders and potential control mechanism in CaC_2 handling. The specific objectives are stated as below:

1) To identify hazard, risk and recommended control mechanism for CaC_2 handling through Hazard Identification and Risk Control technique (HIRARC).
2) To identify the chemical hazard rating and risk rating of CaC_2 handling among respondents through Chemical Health Risk Assessment (CHRA).
3) To determine the socio-demographical data, work characteristics, Knowledge, Attitude and Practice theory (KAP) among exposed and non-exposed groups, and the exposure levels of phosphine (personal and ambience) on the use of CaC_2.
4) To assess the prevalence of respiratory symptoms among exposed and non-exposed groups.
5) To assess the prevalence of lung capacity among exposed groups
6) To measure the association between socio-demographical data, KAP, phosphine concentration, and work characteristics with the prevalence of respiratory symptoms (exposed and non-exposed groups), and lung function (exposed groups).
7) To determine the most significant factors contributing to lung capacity and respiratory symptoms.

1.4 Hypothesis

1.4.1 There is no significant association between socio-demography with the prevalence of respiratory symptom and lung function among exposed group

1.4.2 There is no significant association between work characteristic with the prevalence of respiratory symptom and lung function among exposed group

1.4.3 There is no significant association between KAP with the prevalence of respiratory symptom and lung function among exposed group

1.4.4 There is no significant association between phosphine concentration with the prevalence of respiratory symptom and lung function among exposed group

1.5 Conceptual framework

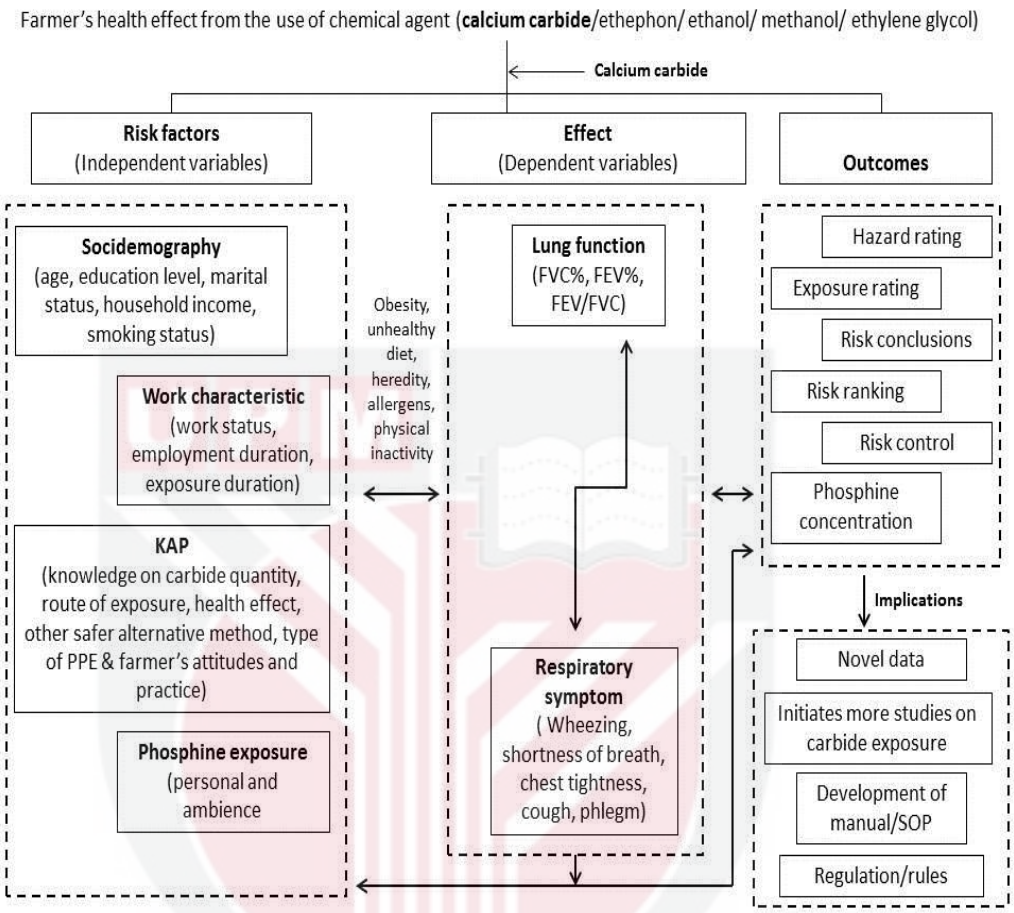

Figure 1.2: The conceptual framework for Risk Assessment of Calcium Carbide Use in fruit Ripening among Farmers, Farm Workers and Fruit Traders in the Northern Region of Malaysia

Based on the framework, this study had identified four independent variables and two dependent variables. The target organ for phosphine gas is pulmonary system (OEHHA, 2002). Exposure above the limit set by OSHA which is 0.3 ppm for an 8-hour work shift can lead to pulmonary oedema and shortness of breath (Agency for Toxic Substances and Disease Registry, 2014). Therefore the lung function and respiratory symptom were categorized as dependent variables.

Increasing risks of respiratory symptoms and lung functional deficiency among agricultural workers are considered crucial and have become public health issues globally (Stoleski et al., 2015). A previous study conducted by Stoleski et al. in 2015 on chronic respiratory symptoms and lung function in agricultural workers showed that

airway changes are affected independently by exposure duration, smoking, and age. Thus, for this study, sociodemographic factors, work characteristics and phosphine concentration levels were incorporated as independent variables in order to evaluate the impact of age, race, household income, education level, smoking status, exposure duration, employment duration, occupational status and phosphine exposure (ambience and personal) towards respiratory impairment.

The KAP model was also included as one of the independent variables in this study in order to assess its influence on respiratory impairment. Furthermore, it may reveal the increase or decrease in knowledge on the health hazards posed by this chemical and its impurities, attitude changes towards the application of safer method as well as changes in the variety of practice with regards to management of CaC_2 and its impurities exposure.

Due to CaC_2 health effects on humans, Chemical Health Risk Assessment (CHRA) was performed with the intention to protect the health of farmers and agricultural workers who have the potential to be exposed to CaC_2 and its impurities at work. The identification of hazards produced by CaC_2, the evaluation of workers' degree of exposure, the sufficiency of current control measures, and the health risk significance were the dependent variables used to evaluate the potential risks of phosphine emitted from a known source. Similarly with HIRARC, it is conducted when there is an indication of significant threats posed by substantial hazards or when there is a need to evaluate if the current controls are sufficient (DOSH Malaysia, 2008). Thus, relative risks and risk analysis were performed as dependent variables in order to come up with suitable corrective or preventive measures and to ensure that the risks are satisfactorily controlled.

1.6 Conceptual Definition

Conceptual definitions for variables are listed as below:

1) Lung function — is referring to how good the lungs operate and how well the oxygen circulation when air is inhaled into respiratory system (Fahy, Sockrider and Lareau, 2014)
2) Respiratory symptoms — are referring to the lung conditions which include wheezing, chest tightness, shortness of breath, attack of coughing, phlegm of chest, trouble with breathing, and asthma (Burney et al., 1989).
3) Phosphine — is referring to a colourless gas with garlic scent which endures in acetylene derived from the reaction of CaC_2 and water vapour; it can enter the body through inhalation (NIOSH, 2015).
4) Sociodemography – is referring to a community or group outlined by its social and demograhic characteristic.
5) Work characteristic — is referring to an aspect specific to a job such as the exposure duration, the use of personnel protective equipment, work position, and work department.

6) KAP – is referring to an instructive analysis to discover vicissitudes in knowledge, attitude and practice of a particular community on certain matters (Kaliyaperumal, 2004).

1.7 Operational Definition

Operational definitions for variables are listed as below:

1) Lung function – The value of how much air is exhaled out of the lungs vigorously after taking a deep breath using spirometer in order to discover the well-being of the lungs. Two decisive value are force vital capacity (FVC) and force expiratory volume-one second (FEV1) (The Worer Health Protection Program, 2013).
2) Respiratory symptom – The detection of risk factors for conditions where lungs are affected by breathing complications such as rapid breathing, shallow breathing, diffulty breathing, deep breathing and absence of breathing (William, 2016) using IUATLD Bronchial Symptoms Questionnaire (Burney. Chinn, Britton, Tattersfield and Papacosta, 1989).
3) Phosphine concentration – The real time measurementfor personal and ambience of exposure levels of phosphie with continous data logging using ToxiRae Pro.
4) Sociodemography – The determination of social and demographic factors (age, marital status, education level, smoking status and household income) and its relation with respondent's health using a newly developed questionaires and the type of questions used were Yes or No type and multiple choice questions.
5) Work characteristic – The determination of aspects specific to a job and working condition and its relation with respondent's health using a newly developed questionaires and the type of questions used were Yes or No type and multiple choice questions.
6) KAP – The measurement of respondent's knowledge, attitude and practice using a newly developed questionaires and the type of questions used were Yes or No type and multiple choice questions.

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BIODATA OF STUDENT

Born in Ipoh on July 30, 1977, Noor Shaeda completed her secondary school in Sekolah Menengah Raja Perempuan Kelsom, Kuala Kangsar, Perak. She pursued her studies in Universiti Kebangsaan Malaysia (UKM) and graduated with a Bachelor Science (Hons.) in Molecular Biology (Microbiology) at the end of 1999. She was offered to join MARDI in 2000 and then went on to serve as Research Officer. After 7 years of service, she continued her studies at the Master's level. She then graduated with a Master's Degree in 2009 in Food Science from UKM.

She has experience for 10 years as a microbiologist in the field of food analysis and served as Technical Manager for 5 years in Food Microbiological Analysis Laboratory, MARDI. After serving for almost 11 years in the laboratory, she continued her service at the field and has involved in several ministry's project such as Azam Tani, My Kampung My Future (MKMF) and National Blue Ocean Strategy (NBOS).

Then in 2015, she was offered to pursue a doctorate degree in Universiti Putra Malaysia (UPM) and has chosen the occupational safety and health field. During her PhD studies, she has successfully produced 4 articles which were published in local and international journals. Previously, she also had several other publications including chapter in book (1 publication), articles in proceeding (6 publications), magazines (3 publications) and MS ISO/IEC 17025 quality manuals (3 manuals).

LIST OF PUBLICATIONS

Hazard identification, risk assessment and risk control (HIRARC) for the use of calcium carbide (CaC2) as ripening agent among mango farmers in northern region of Malaysia. International Journal of Agriculture, Forestry and Plantation, Volume 8 (June 2019), ISSN 2462-1757.

Calcium carbide exposure from fruit ripening process and health effects among fruit farmers: A research review. International Journal of Public Health and Clinical Sciences, e-ISSN: 2289-7577, Vol 5: No.2

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Respiratory symptoms and sociodemographic factors among agricultural workers exposed to calcium carbide as fruits ripening agent in Kuala Kangsar, Perak: A Preliminary study. Annals of Tropical Medicine and Public Health, DOI: 10.4103/1755-6783.208693.

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