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Original Article

Chemical health risk assessment for calcium carbide (CaC_2) used as fruits ripening agent among farmers and fruits sellers

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Abstract

Calcium carbide (CaC_2) is used as a chemical fruits ripening agent. A specific amount of phosphine gas (PH_3) released from the CaC_2 reaction with moisture is known to be toxic to respiratory system. This study was carried out to evaluate the potential risk of the CaC_2 and PH_3 among mango farmers and fruit sellers. The sample size was 200 respondents recruited by universal sampling in Perak, Kedah and Perlis. The procedure to perform chemical health risk assessment (CHRA) was based on the Use and Standard of Exposure of Chemical Hazards to Health Regulations 2000. The permissible exposure limit for PH_3 is 0.3 ppm 8. The average TWA for carbide wrapping and ripening in the farm (C) and at the fruit stall (D) was 0.033 ppm while for sales activities at the fruit stall (E) was 0.017 ppm. Thus, the magnitude rating for C and D was $\geq$ 0.1 O.E.L but < 0.5 O.E.L and for E was < 0.1 O.E.L. It was found that for respondents who were directly involved with the ripening process, the risk is significant for both CaC_2 and PH_3 and the risk were also found significant for those who were not involved directly with these chemicals such as staffs who only involved in sales especially in fruit stall. This study will be beneficial to famers where it can be used for them to understand the effect of carbide to human health and to increase awareness on the health impact of the use of CaC_2 to workers.

Keywords: Calcium carbide, phosphine, Risk assessment

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Introduction

CaC_2 or also known as carbide among farmers has been used as chemical fruits ripening agent in Asian country since olden times (Rohani, 1999). Malaysia is still using carbide extensively for fruits ripening purposes especially mango (Siddiqui and Dhua, 2009). Carbide has been used widely because the cost is minimal and easily accessible (Siddiqui and Dhua, 2010). CaC_2 used in fruits ripening is the industrial grade type which contains the elements of arsenic and phosphorus hydride (Rahman et al., 2008). It reacts with water vapor in the air to produce acetylene gas that acts as a ripening agent (Rohani, 1999). Artificial fruits ripening become dubious in recent years when various health -related issues began to arise (Fattah and Ali, 2010). Acetylene gas released from the CaC_2 reaction contains phosphine at a concentration of 95

ppm (Bingham et al., 2001) and this concentration exceeds the life and health value (IDLH) set by NIOSH which is 50 ppm (National Institute of Occupational Safety and Health, 2003). Generally, acetylene gas is not considered to be a major contributor to a serious toxic hazards to human but the association of the impurities, which is one of it is phosphine contained therein causes health problems (Public Health England, 2009) especially to pulmonary system and cardiovascular system (Agency for Toxic Subtances and Disease Registry, 2002). Inhalation of phosphine by farmers cause cough, chess tightness and may lead to lung damage (Agency for Toxic Subtances and Disease Registry, 2002) while excessive exposure may cause pulmonary edema (New Jersey Department of Health, 2013)

Risk assessment is an essential approach to evaluate the potential risk of the impurities produced by CaC_2 as a result of emission from a known and linked source. CHRA is one of a tool utilised to protect workers from the chemical's adverse effects and according to Occupational Safety and Health Act (1994), it has become the employer's responsibility to safeguard their employees by performing an assessment on chemicals used that has a potential to conceive health risk. In addition, under the Use and Standard of Exposure of Chemical Hazards to Health Regulations 2000 or USECHH Regulations 2000, the health risk ascending from the used of hazardous chemicals at the workplace shall be assessed (DOSH Malaysia, 2000).

Material and Methods

The study populations were mango farmers, mango farm workers and fruit traders in Perak, Kedah and Perlis. This study was conducted in mango farms operated by farmers on a land provided by the government agencies, mango farms operated by government agencies and mango farms operated by individual farmers on private land. For fruit traders, the respondents were among the entrepreneurs who were registered with Fresh Fruit Stall program under the Federal Agricultural Marketing Authority (FAMA) and also individual fruit traders who were not registered with any government agencies. All respondents in each location was invited to participate in the study. There were 200 respondents involved with 118, 56 and 26 respondents from Perak, Kedah and Perlis respectively. The number of respondents was small in each location. They were scattered in different locations throughout Perak, Perlis and Kedah.

The procedures to perform CHRA in this study was based on the Use and Standard of Exposure of Chemical Hazards to Health Regulations 2000 or USECHH Regulations 2000 (DOSH Malaysia, 2000). All individuals who might be exposed to phosphine released from CaC_2 reaction were identified. These individuals included personnel who handled CaC_2 directly and personnel who worked near or passed through the ripening process area. Then, work units and their working hours were identified. There were three work units assessed at the mango farms and two work units at the fruits stall. However, in most farms or fruits stalls, the same staffs/workers worked in all units. Table 1 shows the work units assessed and their working hours.

Table-1: Work unit assessed and their working hours

Mango farms			Fruits stall		
Code	Work unit	Working hours	Code	Work unit	Working hours
A	Harvesting staff	9 am-12 pm	D	Carbide wrapping and ripening staff	2 pm -3 pm
B	Cleaning staff	12 pm – 1 pm	E	Staff in charge of sales	10 am – 5 pm
C	Carbide wrapping and ripening staff	4 – 7 pm	-	-	-

The process flow identified in the farms started from the immature mango harvesting stage. Mangoes then were washed with water and wiped dry using cloth. Then, carbide was wrapped with newspaper and placed at the bottom of a fruit basket. Fruits were then loaded into the baskets and the baskets were covered with newspaper and the ripening process accelerated by chemical agent started and last for 48 hours. For mango farmers, the risk of CaC_2 exposure started when farmers opened the carbide packaging then wrapped the carbide using newspaper and after ripening process (within 24 to 48 hours). Staffs who were in charged on wrapping process were exposed directly to carbide and coded as C (as in Table 1) while harvesting and cleaning staff were excluded in the assessment because the activity was carried out far from the exposure source.

Table-2: Hazard rating (HR) based on risk phrases

Effect	Acute/ chronic	Routes of exposures					HR
		Inh.	Dermal		Ing	Not specified	
			Sk	Ey			
Very toxic	Acute	R26	R27		R28	R39	5
	Chronic	-	-		-	-	
Toxic	Acute	R23	R24		R25	R39	4
	Chronic	-	-		-	R48, R39	
Harmful	Acute	R20	R21		R22	R40	3
	Chronic	-	-		-	R48, R40	
Corrosive	Acute		R35				4
			R34				3
Irritant	Acute	R37	-	R41			3
		-	R38	R36			2
Sensitizing	Acute	R42	-				3
		-	R43				2
Carcinogenic	Chronic	R49 (1)				R45(1)	5
		R49 (2)				R45(2)	4
		-				R40(3)	3
Mutagenic						R46(1)	5
						R46(2)	4
						R40(M2)	3
Teratogenic						R47(1)	5
						R47(2)	4
Exposure assessment required		Inh	Sk	Ey	Ing	All routes	

*Inh = inhalation, Sk = skin, Ey = eye, Ing = ingestion

While for fruits sellers, the process flow initiated from the receiving of immature fruits (mango, papaya, banana) from farmers. Carbide then was wrapped with newspaper and placed at the bottom of the enclosed chamber. At the fruits stall, enclosed chamber and basket is the favorable container used by fruit sellers. The fruits were then loaded into the enclosed chamber and basket for the ripening process to take place. Staffs who were in charged on sales (coded as E in Table 1) were included in the assessment because they were located near to the exposure source due to space constraints.

Hazard rating was done based on the health effect description or based on the risk phrases obtained from CSDS (DOSH Malaysia, 2000). Hazard is rated based on scale from 1 to 5 where 1 indicating non- hazardous condition and 5 for the greatest harmful to health (DOSH Malaysia, 2000). For this study, hazard rating is determined based on risk phrases or hazard categories as in Table 2 (DOSH Malaysia, 2000).

Next, the exposure evaluation was carried out. The exposure was rated through the evaluation of the possible of the hazardous chemical pass into the body through diverse routes of entry which caused systemic effects or localized effects (DOSH Malaysia, 2000). The frequency of exposure was assessed from the work units and their working hours and also from the survey conducted towards respondents. The rating of the frequency of exposure was established using the frequency rating table as in Table 3 (DOSH Malaysia, 2000).

Table-3: Frequency rating

Rating	Description	Definition
5	Frequent	Potential exposure one or more time per shift or per day
4	Probable	Exposure greater than one time per week
3	Occasional	Exposure greater than one time per month
2	Remote	Exposure greater than one time per year
1	Improbable	Exposure less than one time per year

The magnitude of exposure was determined quantitatively through the estimation of the 8-hour exposure of work units towards phosphine. The formula used for calculation of 8-hour exposure using direct reading instrument is as below (DOSH Malaysia, 2000):

$$TWA = \frac{(D_1 \times C_1) + (D_2 \times C_2) + \ldots (D_n \times C_n)}{D_1 + D_2 + \ldots + D_n}$$

Where,

n = tasks involving exposure to the assessed chemical

D = average duration for each task exposure

C = average concentration for each task

The magnitude of exposure for phosphine was determined using the magnitude rating table, while for CaC_2, the magnitude rating was determined using the degree of release and degree of chemical contact. The magnitude rating for CaC_2 also referred to the magnitude rating table proposed by the DOSH (DOSH Malaysia., 2000). Based on the frequency of the exposure rating and the magnitude of exposure rating, the exposure rating was determined using exposure rating table proposed by the DOSH (DOSH Malaysia, 2000).

As for conclusion of the assessment, the evaluation of risk is based on the term "significant' or "not significant". Risk rating was determined using the risk matrix table proposed by the DOSH (DOSH Malaysia, 2000). Referring to the risk decision and the evaluation of existing control measures, the risk was summarized based on the table for the conclusion of the assessment provided by the DOSH (DOSH Malaysia, 2000).

Results

Hazard rating and exposure rating determination of CaC_2

The CSDS used for hazard rating of CaC_2 was obtained from New Jersey Department of Health webpage (New Jersey Department of Health, 2003). From the CSDS, CaC_2 is irritant to eyes, skin and inhalation (New Jersey Department of Health, 2003). The hazard rating of CaC_2 for farmers, fruit traders, farm workers and stall workers were rated 3 as in Table 4. For the determination of frequency of exposure, the frequency rating for CaC_2 was rated 4 (exposure greater for one time per week) for C, rated 3 (exposure greater for one time per month) for D and rated 2 (exposure greater than one time per year) for E.

The degree of chemical release for CaC_2 was "Moderate" for C and D and "Low" for E while for degree of absorption for CaC_2 were "Moderate" for C and D and "Low". Thus, the magnitude rating of CaC_2 for C, D and E were rated 3, 3 and 1, respectively. The exposure rating of CaC_2 was determined and the rating for C, D and E were 4, 3 and 2, respectively as shown in Table 4.

Table-4: Determination of hazard rating and exposure rating for farmers, farm workers, fruit traders and fruit stall workers for CaC_2

Work unit code	Description	Chemical involved	Risk phrase	Hazard Rating	Exposure Rating
*C	Carbide wrapping and ripening staff	CaC_2	R37/R41/R 38	3	4
**D	Carbide wrapping and ripening staff	CaC_2	R37/R41/R 38	3	3
**E	Staff in charged of sales	CaC_2	R37/R41/R 38	3	2

***** farmers and farm workers

** fruit trader and stall workers

Hazard rating and exposure rating determination of phosphine (PH_3)

The safety data sheet (SDS) for PH_3 was attained from Airgas website. PH_3 is a flammable gas with acute toxicity to inhalation, cause skin corrosion and eye irritation. The hazard rating for PH_3 is 4 as in Table 5. For the determination of frequency of exposure, the frequency rating for PH_3 was rated 4 (exposure greater for one time per week) for C, rated 3 (exposure greater for one time per month) for D and E.

The magnitude of exposure was determined quantitatively through the estimation of the 8-hour exposure of work units towards phosphine. For average personal exposure, the TWA reading was 0.033 ppm while for average ambience exposure, the TWA reading was 0.017 ppm. The calculations of TWA for both exposures were based on the below formulation (DOSH Malaysia., 2000):

$$TWA = \frac{(D_1 \times C_1) + (D_2 \times C_2) + \ldots (D_n \times C_n)}{D_1 + D_2 + \ldots + D_n}$$

Where,

n = tasks involving exposure to the assessed chemical

D = average duration for each task exposure

C = average concentration for each task

Table-5: Inhalation exposure based on airborne exposure measurement for phosphine

Time- weighted average (TWA) or maximum concentration	Magnitude rating
≥ 0.0	5
≥ 0.3 but < 0.9	4
≥ 0.15 but < 0.3	3
≥ 0.03 but < 0.15	2
< 0.03	1

The TWA values were then referred to Table 5 for magnitude rating determination. The permissible exposure limit for PH_3 is 0.3 ppm 8 hours (DOSH Malaysia., 2000). The average TWA reading for C and D was 0.033 ppm while for E was 0.017 ppm. Thus, the magnitude rating for C and D was 2 and for E was 1. The exposure rating of PH_3 for C, D and E were 3, 3 and 2 respectively as shown in Table 6.

Table-6: Determination of hazard rating and exposure rating for farmers, farm workers, fruit traders and fruit stall workers for PH_3

Work unit code	Chemical involved	Risk phrase	Hazard Rating	Exposure Rating
*C	PH_3	R23/R35/R41	4	3
**D	PH_3	R23/R35/R41	4	3
**E	PH_3	R23/R35/R41	4	2

*****farmers and farm workers
**fruit trader and stall workers

Discussion

There are three work units that have a possibility to be exposed to carbide and phosphine. They are carbide wrapping and ripening staffs at the farm (C), carbide wrapping and ripening staff at the fruit stall (D) and staff incharge of sales at the stall (E). The risk was found significant for those who work directly and indirectly with CaC_2. The existing control measure was not to eat and drink during wrapping activity and it was found not sufficient for respondents who did carbide wrapping and ripening for both site base on suitability, use and effectiveness (DOSH Malaysia, 2000).

For those who were exposed indirectly to this chemical such as sales staff at the fruit stalls, the control measures was found to be adequate because most of them was positioned at the front of the stall and far from the carbide wrapping area which is at the back of the stall but the risk could increase in the future if a person who conducted carbide wrapping is also act as a sales staff.

Thus, it is crucial for them to have information on the impurities that exist in the carbide that lead to the phosphine released, route of entry, the suggested or recommended quantity of carbide used, the carbide effect to human health and the type of PPE that can be used.

Conclusion

Based on the risk rating conclusion, the appropriate actions that need to be taken in order to control the risk that could rise in the future can be established. There is a need to conduct risk assessment of the CaC_2 used in agricultural sector and exploring its effects towards farmers and farm workers.

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Contribution of Authors

Ismail NS: Conceived idea and write up of article
Rasdi I: Data collection and article write up and approval
Abidin EZ: Data analysis and literature search
Praveena SM: Data analysis and literature search

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