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Calcium carbide (CaC_2) exposure from fruit ripening process and health effects among fruit farmers: A research review.

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ABSTRACT

Background: The use of CaC_2 in fruits ripening is common in some countries because it is readily available and can easily be purchased at very low prices. However, the health effects from its occupational exposure is rarely being documented. This paper provides a review on the potential health risks of CaC_2 exposure among workers in fruit plantation.

Materials and Methods: Online manuscripts were sought from databases including the Science Direct, PubMed and Google Scholar. The main keywords used for the search were calcium carbide, chemical fruits ripening and phosphine exposure and health effects.

Result: Overall, a total of 9 articles on CaC_2 and its health effects were selected. These articles were published in 1991 to 2013 and there were five studies from India, two studies from Bangladesh, one study from United Kingdom and one study from Germany. Study designs reported in those articles were experimental and non-experimental (general article, editorial, case study and case report). From the review, four articles focus on the health effects instigated by CaC_2 whereas five articles emphasize on the effect of phosphine not only to pulmonary and cardiac system but also to cellular level.

Conclusion: In summary, findings from nine studies agreed that CaC_2 and phosphine exposure were related to pulmonary symptoms. It is important to review the current handling of this chemical by farmers and this research is expected to improve the current application towards a safer method in effort to improve the quality of life of workers and also consumers.

Keywords: Calcium carbide health effect, chemical fruits ripening, phosphine exposure

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1.0 Introduction

CaC_2 is a grey-black substance and has a garlic scent. It has been used enormously in steel industries and agriculture (New Jersey Department of Health, 2003). In agriculture, CaC_2 is used as a source of acetylene gas which acts as a reducing agent (New Jersey Department of Health, 2003) and it has the same fruits ripening attributes with ethylene (Hossain, Akhtar, & Anwar, 2015). CaC_2 reacts with moisture and produces acetylene which is responsible for fruits ripening. CaC_2 is hazardous to human health due to the presence of impurities in the acetylene which are phospine and arsine (Rahman, Chowdhury, Rabbi, & Alam, 2008). Bingham, Cohrssen, & Powell (2001) reported that the concentration of phospine found in acetylene is 95ppm and the concentration of arsine is only 3ppm. Phosphine (PH3) is a colourless gas with a garlic scent which is disseminated in outdoor air and indoor air and it can be absorbed to human body via inhalation (National Institute of Occupational Safety and Health, 2015).

In agricultural setting, phosphine is primarily used as fumigant where it is generated from the reaction of aluminium, magnesium or zinc phosphide with moisture (OEHHA, 2002). In fruit processing, CaC_2 makes the fruit's peel colour more appealing while the fruits stay raw (Smith & Thompson, 1987). This substance has been used extensively in Asian for fruits ripening (Rohani, 1999) and as for mango, it has been used in countries such as Brazil, Costa Rica, India, Malaysia, Pakistan, Philippines, Senegal and South Africa (Rahman et al., 2008). The extensive use of this chemical is due to its cheap price and easily availability (Siddiqui & Dhua, 2010). In Malaysia for example, it can easily be purchased from rural shops for RM5.50 / kg (USD1.24/kg) (Consumers Association of Penang, 2011). The dose recommended for CaC_2 to be applied onto fruits is 0.3-10g for each kilogram of yields (Rohani, 1999). Though, not all farmers adhere to this recommended level because of higher amount of CaC_2 is required to ripen the completely unripe fruits (Smith & Thompson, 1987).

There are several methods of applying CaC_2 on fruits for ripening purposes. For countries that are still using CaC_2 for ripening purposes, some farmers or dealers placed fruits in an enclosed compartment together with the huge amount of CaC_2 block and before the compartment is closed, water is sprinkled into the compartment (ICAR, 2013). Some of them put a small packet of carbide in a fruits container and then carbide powder is spread onto the fruits surface (ICAR, 2013). It was also discovered that CaC_2 block was placed concurrently with the immature banana in a box and all the bananas were ripened within 24 hours (Consumers Association of Penang, 2011). In India, CaC_2 is packed together with the mango fruits and water is sprinkled onto the fruits before it was covered with newspaper (Mann, 1974). Two gram of carbide were used to ripen a 4-5 kg of mango (Mann, 1974). There are two methods for CaC_2 application on fruits have been used commercially in India. (Sy & Wainwright, 1990). For the first approach, amass of fruits is positioned in a room. Next, CaC_2 is strewed in some areas in the room and then craft paper is used to cover the fruits (Sy & Wainwright, 1990). In another approach, CaC_2 is wrapped in a paper or cloth and then it is placed at the bottom of the palm leaves baskets. Then, a heap of fruits is loaded into the basket. The baskets then covered with craft paper in order to increase temperature and to maintain the humidity. The baskets then were kept in a closed room for 3-4 days (Sy & Wainwright, 1990). In Malaysia, based on a survey conducted by Consumers Association of Penang (2011), mango farmers use newspapers to wrap a block of carbide and they located it in an enclosed container full of mangoes (Consumers Association of Penang, 2011). It is uncertain however, whether these practices of applying CaC_2 are safe for the workers' health.

The concentration of phosphine found in acetylene (95 ppm) (Bingham et al., 2001) exceeds the life and health value (IDLH) set by the United States NIOSH which is 50 ppm (National Institute of Occupational Safety and Health, 2003). IDLH is a condition indicating a threat to life either immediately or delayed or that would cause permanent undesirable health outcomes that would restrict the person capability to elude unassisted (National Institute of Occupational Safety and Health, 1994). Although the concentration of acetylene gas released from CaC_2 can be estimated, how much CaC_2 inhaled by workers involved with the ripening process is rarely documented.

In developing and developed countries, the prohibition of the use of CaC_2 is quantified in their act and regulations. However, the injunction of this chemical are more focus on the health effect that this chemical may pose to consumer's health and fruit's quality instead of occupational safety. The developing countries in South and East Asia like Bangladesh, India and Nepal have laws specific in prohibiting CaC_2 being used as a ripening agents either in preparing or selling and distributing of fruits ripened with this chemical. There are several factors that may contribute to the enactment of such laws in those countries. One of them is the active involvement of their researchers, policymakers, government agencies, farmers and consumers. The collaboration between agencies is very crucial and it safeguarding the prohibition of chemicals such as CaC_2 used for fruits ripening and any people who violate the rules and regulations will face the penalty. The enacted laws in Bangladesh included Pesticide law 2007, Pure Food Rules and Act 1967 and 2005, Quarantine Rules 1968, Mobile Court Act 2009 and Penal Code 1869 (FAO, 2010). Similarly in India, there are laws regarding the banned of CaC_2. The relevant laws are Food safety and Standards Act 2006, Prevention of Food Adulteration Rules (1955) and Food Safety and Standards Regulations (2001) (Islam, Rahman, Mursalat, Rony, & Khan, 2015). Similarly, in Nepal where according to Food Rules, 2007 (1970), under Chapter 7 rule number 19(d) clearly stated that fruits ripened with carbide shall not be sell or hold for the sale (Siddiqui & Dhua, 2010).

These fruits are exported to other countries including the developed countries. In Bangladesh, in 2007-2008 the value of fruits exported was worth USD$8.64 million and even now is expanding (Bangladesh Horticulture Export Development Foundation, 2013). In developed country such as the USA, the screening policy for fruits imported from other countries are focused on pests (Ganesan, 2014), irradiation and fungicidal treatments but does not stipulate a policy for fruits treated with CaC_2 (Agricultural & Processed Food Products Export Development Authority, 2007). However, there is a recommendation made to the Organic Program (NOP) from the United States National Organic Standard Board (NOSB) to use ethylene, a natural ripening agent for tropical fruits ripening purposes (Giacomini, 2012). The use of ethylene is also supported by the International Federation of Organic Agriculture Movements (IFOAM) where according to IFOAM only ethylene can be used to ripened fruits as in IFOAM Indicative List of substance for Organic production and Processing (Mursalat et al., 2013).

In a perspective of occupational safety and health, there is no permissible exposure limit (PEL) available for workers dealing with CaC_2. Although some research has 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 and races and even the climate. Despite of all the laws, regulations and enactment commenced in those countries, there are some farmers and fruits traders still using it due to high demand and high profit (Mursalat et al., 2013). Therefore, the

mutual involvement of several agencies and ministries is so important to ensure the monitoring of such activities can be done effectively and systematically.

Malaysia is one of the countries that allow the use of CaC_2 for fruit ripening. There are no act and regulations governing the use of CaC_2 in postharvest phase in agricultural sector either related to occupational safety or food safety. However, there is a regulation on phosphine exposure limit where the 8 hour-time-weighted average airborne concentrations value is 0.3 ppm as stated in the Occupational Safety and Health (Use and Standards of Exposure of Chemical Hazardous to Health) Regulations 2000. However, the ceiling limit is not indicated in the regulations nad no PEL is suggested for CaC_2 (DOSH Malaysia., 2000). In addition, under the Malaysian Food Act and Regulations, Rules 225 which is for raw and fresh fruits, there is no specific standard for artificially ripened fruits using chemicals. Therefore, studies on the use of CaC_2 for fruit ripening process and the potential human health effects from its exposure appeared to be essential to protect human health. Hence, this paper reviews the existing facts about CaC_2 and health as an initial effort in further understanding the health risk of CaC_2 exposure.

2.0 Materials and Methods

The research review on CaC_2 and its exposure is based on previous studies conducted by researchers mainly from India and Bangladesh. This is because most research and studies on the health effects of CaC_2 to human worldwide was carried out by researchers from those countries. The search for journals was carried out through online sources included but not limited to database accessed from the UPM's library website. The database included Science Direct, PubMed and Google Scholar. The articles sought were in English and Malay language published in the last thirty years. The main keywords used for the search were calcium carbide, chemical fruits ripening and phosphine exposure and health effects.

3.0 Result

The total journal searched for this review was 1,015 articles and 999 articles were excluded due to several reasons such as the articles is not related to CaC_2 used for the purpose of fruits ripening and some of the articles were not accessible. A total of 57 articles were screened and 41 articles were rejected because those studies only focussed on the effects of CaC_2 to fruits quality and not human health. From 16 journals selected, only 9 journals fulfil the purpose of this review which is to explore the effects of CaC_2 and phosphine exposure to human health. All the nine journals selected are in English. The results for journal screening and selection are shown in Figure 1.

This paper review nine selected articles on the exposure of CaC_2 and phosphine plus its health effects to human. These articles were published in 1991 to 2013. There were five studies from India (Siddiqui & Dhua (2010); Jindal, Tarsem, Agrawal , Nitika, Sangwan (2013); Arora, Punia, & et al, (1995); Singh & Sharma (1991) and (1991)), two studies from Bangladesh (Mursalat et al., (2013) and Patoare et al., (2007), one study from United Kingdom (Proudfoot, 2009) and one study from Germany (Popp, Mentfewitz, Gotz, & Voshaar, 2002).

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The types of studies conducted in the nine selected articles were non-experimental (8 articles) and experimental (1 article). The non- experimental types of articles included editorial, general article, case report and case study. Four articles written by Siddiqui & Dhua, (2010), Mursalat et al., (2013), Patoare et al., (2007) and Jindal et al., (2013) are focussing on the health effects instigated by CaC_2 whereas five articles are emphasized on the effect of phosphine not only to pulmonary, respiratory and cardiac system but also to cellular level and these articles were written by Popp et al., (2002), Proudfoot, (2009), Arora, Punia, & et al, (1995), Chugh et al., (1991) and Singh & Sharma, (1991).

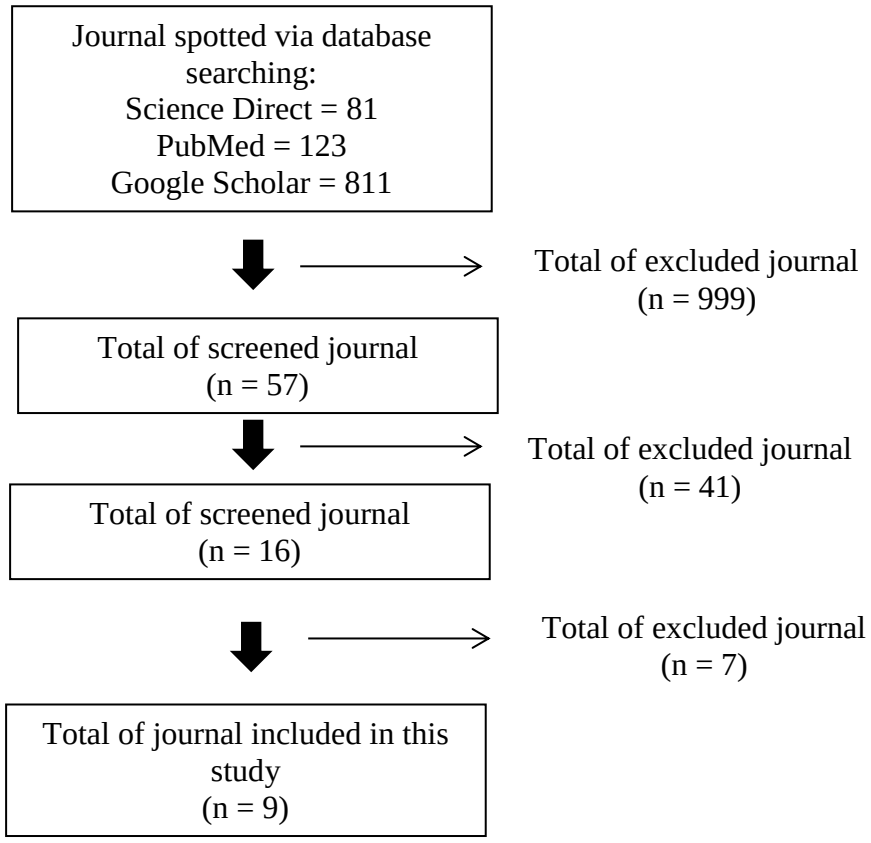

Figure 1. The process involved in journal screening and selection.

3.0 Discussion

The reaction between CaC_2 and water generates acetylene gas which contains hazardous impurities, phospine and arsine (Siddiqui & Dhua, 2010). According to Bingham et al., (2001), this gas contains 3 ppm of arsine and 95 ppm of phospine. Fruit farmers are exposed to phospine and arsine through inhalation while applying CaC_2 for ripening process. Since

phospine is a major element in acetylene gas, its potential on posing hazardous health effect to fruit farmers become a great concern. Popp et al., (2002) stated that phosphine is known to be venomous to respiratory system where at a concentration of 20:100,000 part of phosphine in air is reported as lethal. Phospine which enters into lungs attacks the respiratory and cardiovascular system and set off pulmonary oedema and cardiac arrest (Agency for Toxic Subtances and Disease Registry, 2014).

Furthermore, the histopathological studies conducted by Arora (1995) on thirty cases of phosphine poisoning in 1995 revealed that there were evidence of varying degrees of congestion, oedema and leucocytic infiltration, changes suggestive of cellular hypoxia in lungs, kidneys and adrenals (Arora et al., 1995). The pulmonary toxicity effect may caused by the inhibition of mitochondrial cytochrome C oxidase by phosphine where the inhibition disrupt the mitochondrial morphology and instigated the oxidative respiration to be reduced by 70% and consequently cause the cell to perish hastily (Singh & Sharma, 1991).

The health effects of phospine on human beings are also supported by evidence from an in-vivo study. Patoare (2007) found that when a different concentration of CaC_2 were given orally to *long evans* rat once daily for 30 days, there was an increment in weight and a presence of red-brown to red colour at the main areas of consolidation. Several studies related to exposure of phosphine involving animal has 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). Patoare et al., (2007) also claimed that CaC_2 exposure may lead to cancer. The researchers mentioned that free radicals released from CaC_2 may alter the coding of DNA basic information via the interaction with the gene which subsequently result in cancer. The cancer causing effect explained in the article was comparable with the study conducted by Kjuus et al. (1986) where colonic and prostatic cancer were triggered from the CaC_2 exposure.

Acetylene generated from CaC_2 is found to be irritating to respiratory system (Jindal et al., 2013; Mursalat et al., 2013; Siddiqui & Dhua, 2010;). Chugh et al., (1991) stated that the common features of pulmonary toxicity are tachypnea, dyspnoea, crepitation and rhonchi. Siddiqui & Dhua (2010) stated that acute and chronic respiratory health effects can be resulted from CaC_2 exposure and this includes shortness of breath, wheezing and cough and sore throats. In workers who deal directly and exposed at higher concentration of CaC_2, fluids may be built up in the lung and cause pulmonary oedema (Mursalat et al., 2013; Siddiqui & Dhua, 2010).

A few studies found that CaC_2 were related to general symptoms like headache, sleepiness and dizziness (Siddiqui & Dhua, 2010). The symptoms exhibited from the CaC_2 exposure was due to the phosphine poisoning where neurological system is affected and subsequently cause headache, dizziness, mood disturbance and sleepiness (Rahman et al., 2008). Moreover, it was also reported that CaC_2 exposure caused permanent skin damage, difficulty in swallowing, dizziness, frequent thirst, irritation in mouth, vomiting, skin ulcer and weakness (Siddiqui & Dhua, 2010). Siddiqui & Dhua, (2010) concluded that these symptoms arised due to the direct contact of workers with CaC_2 while using this chemical on the fruits. The review of the selected articles on the effect of CaC_2 to human health and in biological system is summarized in Figure 2.

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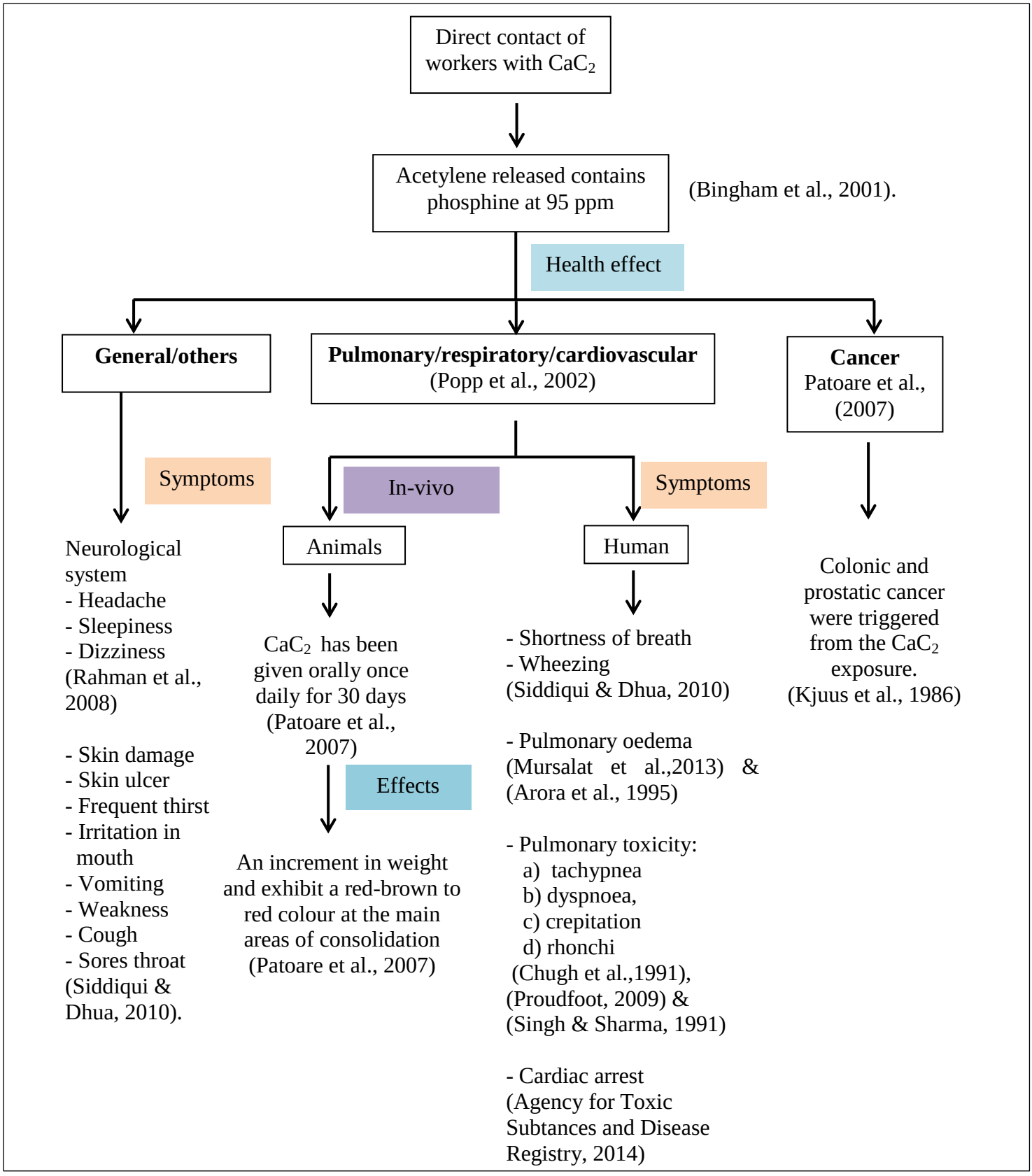

Figure 2: The effect of CaC_2 to human health and in biological systems

4.0 Conclusion and recommendation

In conclusion, there are some though limited studies, showing that exposure to CaC_2 via inhalation is hazardous to human health. Although, some research has 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 and races and even the climate. Furthermore, most studies tend to focus on CaC_2 effects to fruits texture, taste and nutritional contents. Therefore, there is no baseline data and insufficient evidence to urge for prompt control and prevention measures of CaC_2 handling among Malaysian.

In Malaysia, it is essential to establish act and regulation that specializes in determining the level of human exposure towards CaC_2 and permissible exposure limit available for workers dealing with CaC_2 since the most extensively used chemical ripening agent in Malaysia is CaC_2. In Malaysian Food Act and Regulations, under Rules 225 which is for raw and fresh fruits, there is no specific standard for artificially ripened fruits using chemicals but there is a recommendation value that can be used where 0.3-10g of carbide for each kilograms of yields (Rohani, 1999). However, not all farmers abide by the reference because there is no explicit enforcement on the quantity or amount of CaC_2 shall be used in fruits ripening practise.

Furthermore, a guideline on the use of CaC2 and permissible exposure limit available for workers dealing with CaC2 in agricultural setting in Malaysia need to be defined. If the farmers applied this substance excessively exceeding the recommended value, the health impacts is not only affect the agricultural workers but it also affect consumers since the impurities in the CaC_2 are soluble to fat and it can diffuse into the fruit's flesh and consequently cause health problems to consumers (Haturusihghe, De Silva, & Wimlasena, 2004). Study conducted by Haturusihghe showed that the impurities level in mango's peel and flesh was increased with the increment of the amount of CaC_2 used for mango ripening (Haturusihghe et al., 2004). It indicates that enforcement play an important role in ensuring the quality of human health is in a good condition.

Findings of this review of the health effects of CaC_2 to human is valuable to create awareness on the effect of CaC_2 exposure to human health and how to minimize the risk. More studies are therefore necessary to further exploring the health effect of CaC_2 from workplace exposure particularly on work task and methods of applying CaC_2.

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Declaration

Author(s) declare that the ethical approval of this study was obtained from Ethic Committee, Universiti Putra Malaysia (reference number: **FPSK (exp16) p100**).

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