

## HEALTH RISK DUE TO CARBAMATE EXPOSURE IN COMMUNITIES AROUND PADDY FIELD AREAS

Maksuk Maksuk<sup>1\*</sup>, Sherli Shobur<sup>1</sup>, Suzanna Suzanna<sup>2</sup>

<sup>1</sup>Department of Environmental Health, Health Polytechnic Palembang Ministry of Health, South Sumatera 30121, Indonesia.

<sup>2</sup>Center for Environmental Health Engineering and Disease Control Palembang, South Sumatera 30961, Indonesia.

**Corresponding Author:**

\*) [maksuk@poltekkespalembang.ac.id](mailto:maksuk@poltekkespalembang.ac.id)

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### Abstract

**Introduction:** Carbamate is one of the most widely used pesticides in paddy field areas, which causes environmental pollution and human health problems. Therefore, this study aims to analyze the health risks of carbamate exposure in communities around paddy fields areas. **Methods:** This was an observational analysis study conducted using the health risk assessment approach. There were 20 samples of waterway streams from 10 sites observed in the morning (at high tide) and evening (at low tide) taken using a grab sampling method. The parameters of the waterway streams river, such as pH and temperature, were measured on-site using a pH meter and portable thermometer, while the carbamate concentration was analysed in the laboratory using High-Performance Liquid Chromatography (HPLC). **Results and Discussion:** The active ingredients of carbamate pesticides that observed as follows: aldicarb (0 – 0.05 mg/l), carbaryl (0 – 0.01 mg/l), carbofuran (0-0.005 mg/l), and propoxur (0-0.001 mg/l). While the pH (6.4 – 7.5) and temperature (22.1 – 32.4oC). The potential exposure of Aldicarb in grown-up and kids were 0.042 and 0.077 mg/kg bodyweight-day, respectively. Furthermore, the potential exposure of carbofuran in Grown-ups and kids were 0.004 and 0.01 mg/kg bodyweight-day, respectively. Only the carbofuran exposure in kids has a rate of RQ > 1, which is unsafe or can cause non-carcinogenic effects in the next 30 years. **Conclusion:** Although the carbamate concentrations in waterway streams around paddy field areas were below the quality standard, it is not safe. Therefore, it is necessary to carry out risk management and communication with local policymakers.

## INTRODUCTION

Pesticides compounds have been used widely in the agricultural sector to kill pests, weeds and increase harvests productivity (1–5). The use of pesticides is the basis of agriculture intensification developed in the middle of the 20<sup>th</sup> century (6-7) to improve the productivity and quality of farming commodities (4,8-9). Based on the results in China, the total pesticides emissions increased from 165.47 tons in 2004 to 179.77 tons in 2017 (10).

Currently, the pesticides mostly used in the agricultural sector include organophosphate and carbamate (11). In Indonesia, approximately 3,207 pesticides have been legally registered (12–14). Moreover, carbamate is structurally and mechanistically similar to organophosphate and is N-methyl Carbamate derived from carbamic acid that will inhibit acetylcholinesterase at neuronal synapses and neuromuscular junction. These pesticides are effective due to their ability to inhibit acetylcholinesterase in the nervous system and other esterases (15-16).

In developing countries, pesticide poisoning and toxicity incidences gradually increase due to

acetylcholinesterase inhibition (17) and have become a public health problem (18). Meanwhile, the poisoning was most common among farmers, farming families, and communities around agricultural areas (19). A study in China stated that organophosphate and carbamate insecticides were the cause of most poisonings in children amount 1130, which lead to 34 deaths (20).

The overuse and misuse of pesticides contaminate the environment, soil, and water media (2). Although carbamate is very persistent in the environment and contains highly soluble compounds in water (16), the contamination in the surface water is caused by improper application and inappropriate spraying, sewage of rice milling factories, and other agricultural activities (2,9).

Based on a previous study, the carbamate concentration was detected in Bangladesh's Savar and Dhamrai Upazilas waterways (21). However, carbofuran residues were detected in water Kalisat River, Malang Regency (22-23). It is showed that the presence of carbamate pesticides in the water basin, river, and surface water varies due to aerial spraying, erosion, sewage from factories, wastewater disposal, and agriculture runoff (1-2).

Carbamate is widely used to kill insects in South Sumatra's agricultural areas, including Pegayut Village, Ogan Ilir Regency. Pegayut is among the villages in Pemulutan District, along the waterway streams in the rice farming area. The river is the primary source of clean water for Pegayut Village communities and the source of irrigation for agricultural lands. The most widely used pesticides in the rice farming area of Pegayut Village are organophosphates and carbamate of various types to kill insects. These pesticides enter and contaminate the village's waterway streams through agricultural activities, rice milling factories, and equipment washing after application. Therefore, there is a need to monitor the presence of carbamate in the waterway streams in agricultural areas through risk assessment and management. This is because water contamination from exposure to pesticides is harmful to farmers, families, communities, and the environment (24). Furthermore, health risk assessment is needed for the early diagnosis of diseases caused by pesticides exposure, health surveillance, and reporting systems for worker protection in terms of safety and health in the agriculture area (5). The required health risk assessment for the estimated values for hazard quotient (HQ) and hazard index (HI) for non-carcinogenic risk was below the targeted value, which indicated no non-carcinogenic risk through dermal contact and non-intentional ingestion of water (25).

In Indonesia, the environmental health risk assessment method has existed since 2012, even though the application is still not optimal (26). Although environmental health is an essential program at the public health center, the health risk assessment program has not been carried out optimally, especially studies on pesticides exposure in waterway streams used by communities around paddy field areas. Therefore, this study aims to analyze the health risks of carbamate exposure in waterway streams used by communities around paddy fields.

**METHODS**

This observational study was conducted at a residential area along waterway streams around paddy field areas in Pegayut village, Pemulutan, Ogan Ilir, which used the health risk assessment approach. The study was conducted from October to December at Pegayut Village Pemulutan, Ogan Ilir Regency. Furthermore, 20 water samples from 10 waterway streams would be taken in the morning (at high tide) and evening (at low tide). These samples were collected using the grab sampling

method at a depth of 30 cm from the surface of the waterway streams (27) by BTKLPP Palembang officers and stored in a cold box before sending to the laboratory. Before being analyzed at the laboratory, all samples were saved in a refrigerator at 25°C. The test parameters include temperature and pH of the water, which were checked in situ using a portable multifunction analyzer, and the active ingredient Carbamate was examined in the laboratory using HPLC by method 3510 from the US EPA. Meanwhile, the potential dose was calculated using the formula by Louvar and Louvar below (28):

$$I = \frac{C \times R \times TE \times FE \times Dt}{Wb \times tavg} \tag{1}$$

The explanation of the equation above is as follows:

- Potential Intake (I) Dose/ : The potential dose of the agent enters the body (mg/kg-day)
- Concentration (C) : The examination results of the active ingredient Carbamate in water (mg/l)
- Rate (R) : average daily water consumption (for grown-up = 2 liter/day, children = 1 liter/day)
- Time of Exposure (t<sub>E</sub>) : exposure time daily for 24 hours (hour/day) for the residential area)
- Frequency of Exposure (f<sub>E</sub>) : length of exposure daily for 350 days (days/year)
- Duration Time (D<sub>E</sub>) : The duration of exposure to non-carcinogenic substances is 30 years (years)
- Weight (W<sub>b</sub>) : Average weight for asian (for grown-up =55 kg and kids=15 kg)
- Time of average (t<sub>avg</sub>) : The average exposure time to non-carcinogenic substances is 30 years each day (30 years × 365 days/year)

**Risk Management**

This study carried out a risk management scenario for carbofuran for kids because the RQ was over 1. The calculation was carried out using the formula by Louvar and Louvar, as shown below (28):

Acceptable Carbofuran Concentration:

$$Acceptable\ Concentration = \frac{I \times Wb \times tavg}{R \times TE \times FE \times DT}$$

Acceptable Consumption Rate

$$Acceptable\ Consumpsion\ Rate = \frac{I \times Wb \times tavg}{C \times TE \times FE \times DT}$$

Acceptable Frequency of Exposure

$$Acceptable\ Frequency\ of\ Exposure = \frac{I \times Wb \times tavg}{C \times R \times TE \times DT}$$

Acceptable Time of Duration

$$Acceptable\ Time\ of\ Duration = \frac{I \times Wb \times tavg}{C \times R \times FE \times TE}$$

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**RESULTS**

**Hazard Identification**

Hazard identification is the first stage to determine the kinds of active pesticide ingredients and their effect on humans and environmental media (29-30). In Pegayut Village, organophosphates and carbamates are pesticides mostly used in paddy fields areas. In this study, the primary data from water sampling showed the concentrations of carbamate active ingredient, pH, and temperature, as shown in Table 1.

**Table 1. The Carbamate Pesticide Levels, Temperature, pH, and The Length of The Stream in Rice Fields Zones of Pegayut Waterway Streams**

Variables	Average	Range	Maximum Limit Values (36,37)
Aldicarb	-	0 - 0.05 mg/l	0.1 mg/l
Carbaryl	-	0 - 0.01 mg/l	
Carbofuran	-	0 - 0.005 mg/l	
Propoxur	-	0 - 0.001	
Temperature	29.9 °C	22.1 - 32.4 °C	± 3 °C
pH	6.9	6.4 - 7.5	6 - 9
The length of the stream to rice field zones	161.2 m	50 - 500 m	

**Dose-Response Assessment of Carbamate Active Ingredient**

The dose-response assessment focused on four active carbamates (Aldicarb, Carbaryl, Carbofuran, and Propoxur), categorized as active ingredients of non-carcinogenic pesticides (31) with the reference dose values of the four active ingredients of Carbamate and can be seen on the IRIS - EPA website.

**Exposure Assessment of Carbamate Active Ingredient**

The exposure assessment was carried out after the first and second steps to calculate the potential dose of the risk agent. Exposure assessment determines potential dose or intake value using several variables, including measurement of carbamate concentration, consumption rate, time and frequency of exposure, time duration, bodyweight, time average (32). Furthermore, some variables used to calculate the potential dose are the bodyweight of grown-ups 55 kg and kids 15 kg, the level of water consumption for grown-ups of approximately 2 liters daily, and kids of almost 1 liter daily with a lifetime exposure of 30 years (32). The potential dose results were different for each carbamate active ingredient, as described in Table 2. The potential dose

of Aldicarb obtained more than the reference dosage for both grown-ups and kids, while the potential dose of carbofuran in grown-ups was below and kids was over reference dosage.

**Table 2. The Potential Dose of Carbamate Pesticide for Grown-ups and Children in Rice Fields Zones of Pegayut Waterway Streams**

Active Ingredient	Reference Dose (mg/kg-day)	Potential Dose (mg/kg-day)	
		Grown-ups	Children
Aldicarb	0.001	0.042	0.077
Carbaryl	0.1	0.008	0.015
Carbofuran	0.005	0.004	0.01
Propoxur	0.004	0.001	0.002

**Risk Characterization of Carbamate Active Ingredient**

RQ (Risk Quotient) is estimated by dividing the potential dose with the reference dosage of Carbamate active ingredients. Based on the results, the RQ of Carbamate active ingredient in waterway streams was less than 1 for grown-ups, while RQ of Carbofuran for kids was over 1. This showed that Carbofuran in waterway streams was risky for kids. Furthermore, the total RQ of Carbamate active ingredient in waterway streams for grown-ups and kids was over 1. The RQ results of Carbamate active ingredient in waterway streams river were different, as described in Table 3.

**Table 3. The RQ (Risk Quotient) and RQ Total Calculation Results of Carbamate Active Ingredient for Grown-ups and Kids in Rice Fields Zones of Pegayut Waterway Streams**

Active Ingredient	RQ (Risk Quotient)		Risk Quotient Criteria	
	Grown-ups	Children	Grown-ups	Children
Aldicarb	0.024	0.01	Acceptable	Acceptable
Carbaryl	0.08	0.15	Acceptable	Acceptable
Carbofuran	0.84	1.53	Acceptable	Unacceptable
Propoxur	0.21	0.38	Acceptable	Acceptable
RQ Total	1.15	2.07	Unacceptable	Unacceptable

**Risk Management**

This study carried out a risk management scenario for carbofuran for kids because the RQ was over 1.

Acceptable Carbofuran Concentration:

The result of the equation over, the maximum acceptable concentration of carbofuran for kids was 0.003 mg/l for 30 years

Acceptable Consumption Rate:

The result of the equation is that the maximum acceptable consumption rate of carbofuran for kids was only 0.65 liter/day.

#### Acceptable Frequency of Exposure:

Based on the equation above, the frequency of safe exposure to carbofuran for kids in waterway streams during 228 days yearly.

#### Acceptable Time of Duration:

The result above showed that Carbofuran exposure in the waterway streams for kids weighing 15 kg was only allowed for 19.6 years.

Therefore, it can be concluded that children in the agricultural area of Pegayut Village can only be exposed to a maximum of 0.003 mg/l Carbofuran every day with a frequency of 228 days/year for 19.6 years.

### DISCUSSION

The health risk assessment due to pesticides exposure was developed using environmental health risk analysis methods. It is a method for estimating the level of risk of a chemical in the future (30). Furthermore, it has been used as a solid basis for further decision-making to take necessary efforts in controlling pesticides contamination in primary water sources in Dalian, China (33). A previous study in Saudi Arabia on health risk assessment in Al-Kharj area from the pollution of groundwater due to intensive application in dried areas identified vulnerable sources and assessed the risks of pesticides exposure to public health and the environment (34).

Although the results of Aldicarb, Carbaryl, Carbofuran, Profoxur, pH, and temperature measurements in the waterway streams were within the standard limit maximum (35-36), it was not safe for community living in Pegayut Village. The active ingredient Carbamate in the river was caused by the misapplication of pesticides and washing of equipment after the application. Furthermore, organophosphates and carbamates are the active ingredients that local farmers commonly use. Based on a previous study on the risk assessment of 29 pesticides in China, carbamate is the most widely used and is detected every season in the Huangpu River basin and aquatic biota (37).

A similar study in Ecuador stated that several types of active pesticide ingredients, including carbamate, have been used in rice farming and are the leading cause of contamination in the Guayas river basin (38). Similarly, carbamate was also identified in the Tulungagung vegetable farm, and the average of farmers used more than two types (39). According to a study, the level of carbofuran detected in the Nile waterway stream was 1.6 µg/l (2), while carbaryl level in the River Madre de Rios, Costa Rica, has an average of 0.62 µg/l (40). The residue of carbofuran and carbaryl

was also detected in the Feni district of Bangladesh due to contaminated aquatic ecosystems and human health effects (41). Meanwhile, the presence of several active ingredients in the river is caused by excessive use of pesticides as well as misuse during and after application, which leads to contamination of river water, groundwater, and surface water in the agricultural areas (42-43).

The dose-response assessment is the second step to examine the relationship between risk agent doses and human adverse health effects (29-30). It aims to determine the risk agents' pathways of entering the human body (30). Moreover, the dose and response assessment was carried out to determine the reference dose value of each active ingredient of carbamate. Data on the reference dose of the active ingredient carbamate is available on the IRIS website (31). Meanwhile, regular monitoring of carbamate exposure is necessary to support the estimation of health effects for the next epidemiological assessment.

Exposure assessment was carried out to determine the pesticides exposure route and calculate intake value. Moreover, pesticides are accumulated in the human body through several routes such as inhalation, ingestion, and dermal, which cause long-term and chronic effects (44). This study showed that the potential dose of aldicarb for grown-ups and kids was above the reference dosage value and the carbofuran potential dose for kids. The exposure was assessed through an ingestion route from river water that was consumed by communities living around the Pegayut farming. The result showed that pesticide exposure in the Pegayut waterway streams came from agricultural activities and several paddy mill factories in the village. The concentration of the active ingredient carbamate discovered in river water was among the variables used to calculate the potential dose or intake value. The potential dose value was affected by several variables, namely measuring carbamate levels, body weight, exposure time, and exposure time (30). A previous study showed that the potential dose below the reference dose caused acute health problems, and when it was more than the reference dose, chronic health problems occurred (45).

Although the guideline for health risk analysis in Indonesia has existed for several years, optimal implementation is not expected, especially health risk programs due to pesticides exposure in agricultural areas. Therefore, this study aims to develop a health risk analysis program due to pesticides exposure in agricultural areas and risk control strategies. In Europe, a related study on human health risk assessment was an essential part of approving active ingredients as an authority for plants protection and biocide products



in line with pesticide legislation (46). Risk assessment predicts pesticide exposures among farmers and their families and decides preventive activities for human adverse effects and environmental contamination (24). It contributes to identifying and determining active ingredients together with current and future environmental health status, especially in children (47). Based on a study in China, children in the agricultural regions are exposed to carbamate, mainly carbofuran. Meanwhile, both prenatal and postnatal exposure to carbamate leads to neurodevelopmental effects (48). A study in Mexico also stated that exposure to organophosphorus and carbamates increased oxidative stress levels in occupationally exposed farmers (49). Therefore, early prevention efforts are required to predict the development of diseases from exposure to pesticides, especially in people living in agricultural areas.

The Risk Quotient (RQ) is the final step in the environmental health risk analysis used to determine whether the active ingredient carbamate is safe or unsafe in waterway streams for the next 30 years in Pegayut village. The result showed that misuse and misapplication of pesticides caused pollution of waterway streams used by local communities for daily needs and the RQ of carbofuran was more than 1. Therefore, risk management is needed to decrease carbofuran concentration in waterway streams and communicate to local decision-makers or risk managers. Risk characterization provides alternative management to local decision-makers or managers by minimizing carbamate exposure in waterway streams through water treatment before use. Health risk assessment due to exposure such as carbamate increases the knowledge of pesticides pollution in the environment, reduces exposure, and explores its implications for public health, including farmers, families, and communities living in the agricultural areas.

This showed that pesticides exposure is through waterway streams, and the rice consumed is not examined in this study. Therefore, it is essential to determine the concentration of active ingredients in rice to estimate the risk level in the future. This study also contributes to the early detection of diseases caused by pesticides exposure in people living in agricultural areas, especially children. However, the weakness of this study is that parameter measurements were carried out only on the active ingredient of carbamate in waterway streams, and its monitoring in water was only carried out in one season, while the organophosphate group has not been examined due to limited funds. Therefore, there is a need to examine other active ingredients,

mainly organophosphate groups in both water and rice, to obtain complete information on pesticides exposure in several environmental media such as air, food, sediment, or soil.

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## CONCLUSION

The conclusion of this study is to provide information on the presence of the active ingredient of carbamate in waterway streams river in paddy fields area. The active ingredients of carbamate in the waterway streams were below the maximum limit. Since the carbofuran RQ (Risk Quotient) obtained was over 1, risk management needs to be carried out. The results of this study are methods of health risk analysis for carbamate exposure, which provide information for local decision-makers in managing the risk of exposure in waterway streams near agricultural areas. It is necessary to regularly monitor other parameters of the waterway stream's quality as an environmental health program at the public health center. Therefore, further study on carbamate concentrations and other pesticides in rice, air, and sediment is required.

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