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HEALTH RISK ASSESSMENT OF PESTICIDE EXPOSURE IN FARMERS AROUND RICE FARMING AREA IN OGAN ILIR REGENCY, SOUTH SUMATRA, INDONESIA

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ABSTRACT

Introduction: Pesticides are chemical compounds that are toxic to the environment and humans. Approximately 89.8% of farmers in South Sumatra use chemical pesticides. **Aims:** This study aims to analyze the health risks due to pesticide exposure among farmers residing in rice farming areas. **Methods:** This study used an analytical observational design with a cross-sectional approach and was conducted in Pemulutan Subdistrict, Ogan Ilir Regency, from October 2020 to January 2021. The sample size consisted of 61 randomly selected respondents. Blood test samples were taken and examined at the Palembang Health Laboratory Center. The cholinesterase was examined using the DGKC colorimetric (KINETIC) method. Independent t-test and multiple linear regression test were used to analyze the data. **Results:** The results of the analysis showed that the average cholinesterase level in the blood serum of the farmers was 7628.40 U/L. This study also found that 83.6% of the farmers did not use complete and standard personal protective equipment. The variables that were significantly associated with cholinesterase levels in the blood of the farmers were age group and length of farming. Length of farming was identified as a predictor variable. **Conclusion:** Pesticides used by farmers in rice farming areas vary widely, ranging from slightly to extremely hazardous. Although the cholinesterase levels in farmers are in the normal range, they can increase over a long period of time. The length of farming is a predictor of cholesterol levels in farmers.

Keywords: health risk assessment, pesticide exposure, farmers, rice farming area

INTRODUCTION

In recent years, the use of pesticides in agriculture and plantation areas has increased, particularly in developing counties such as Indonesia. Pesticides are toxic or highly toxic substances, especially if used inappropriately (Damalas and Koutroubas, 2016; Carvalho, 2017; Gupta, 2019). Organophosphates, pyrethroids, and carbamates are commonly used pesticides in Indonesian agriculture and have adverse effects on human health (Joko et al., 2020). In Indonesia, the number of pesticide formulations used and registered for agricultural and plantation activities has reached 3,207 (Directorate of Fertilizers and Pesticides, 2016; Maksuk, 2019b). Currently, organophosphates and carbamates are commonly used pesticides in developing countries (Hinson et al., 2016; Gupta et al., 2017; Mwabulambo et al., 2018). Organophosphate and carbamate pesticides are commonly used pesticides in Indonesia, including in the rice farming area of South Sumatra (Maksuk et al., 2021).

The overuse of pesticides can have negative effects on both human health and the environment (Kim et al., 2017; Yadav and Devi, 2017; Sharifzadeh et al., 2019;

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Upadhayay et al., 2020; Negatu et al., 2021). Previous studies have shown that active ingredients from pesticides can be found in rivers, surface water, and groundwater (Kapsi et al., 2019; Arisekar et al., 2021; Bhuiyan et al., 2021; Maksuk et al., 2021). Spraying pesticides on plants can pose a risk of inhalation for workers and harm the environment (Maksuk et al., 2018; Silva-Barni et al., 2019; Zhou et al., 2019). In addition, pesticides are harmful to both the environment and public health (Kumar et al., 2018; Salazar-Flores et al., 2020; Maksuk et al., 2021).

Pesticide poisoning is one of the negative health outcomes from pesticide exposure. For farmers and agricultural workers, pesticide poisoning has been identified as a significant occupational health issue (Cotton et al., 2018). This condition is exacerbated by using pesticides excessively and not following protocols (Vikkey et al., 2017). Both farmers and non-farmers are affected by the widespread use of pesticides, especially those who live near agricultural areas (Dereumeaux et al., 2020). Farmers are primarily exposed to pesticides during the application process through a variety of modes, including skin contact, oral intake, and inhalation (Damalas and Koutroubas, 2016; Maksuk et al., 2018; Barrón Cuenca et al., 2020).

In addition, the use of pesticides on plants and direct contact with them can cause neurotoxicity and carcinogenic effects in humans (Yadav et al., 2019). This carcinogenic effect is caused by prolonged exposure to pesticides (Koutros et al., 2016; Sabarwal et al., 2018; Pluth et al., 2019). Several studies reported that pesticide exposure is associated with physical symptoms, including itchy skin, headaches, convulsions, muscle weakness, and tremors (As' ady et al., 2019; Maksuk, 2019a; Mulyana et al., 2020; Oktaviani and Pawenang, 2020).

A previous study suggested that pesticides such as organophosphates and carbamates can interfere with acetylcholine hydrolysis, which is necessary for synaptic and neurotransmitter responses in the autonomic and central nervous systems (Rao and Jyothsna, 2016). These pesticides are antiacetylcholinesterase compounds that can disrupt the endocrine system (Kapeleka et al., 2019). Prolonged exposure to these pesticides has been found to result in lowered acetylcholinesterase (AChE) activity and neurotoxicity (Kapeleka et al., 2019; Neupane et al., 2017; Nganchamung et al., 2017).

Acetylcholinesterase (AChE) testing is performed to identify pesticide exposure in the blood, assess the possibility of human exposure to pesticides that inhibit cholinesterase activity (Cotton et al., 2018), and determine pesticide poisoning levels (Rosanti et al., 2021). AChE inhibition is a biomarker for pesticide exposure and toxicity in the human body and indicates the severity of pesticide poisoning (Rathish et al., 2018).

Several studies on AChE levels have been conducted in Indonesia on traditional commercial crops such as coffee, commercial tea plantations, and the floral industry, targeting exposed farmers. The evidence shows that exposure to pesticides is associated with physical symptoms, including itchy skin, headaches, convulsions, muscle weakness, and tremors (As' ady et al., 2019; Maksuk, 2019a; Mulyana et al., 2020; Oktaviani & Pawenang, 2020). Pesticide exposure is also associated with impaired ACHE activity and an increased incidence of hypertension in farmers (Zulfania et al., 2017).

Therefore, to detect the presence of active pesticide ingredients in the bodies of farmers or people who live in agricultural areas, it is necessary to carry out biological monitoring. One common method of biological monitoring is testing cholinesterase levels as a biomarker. In numerous studies, biological effect markers have been used for pesticide genotoxicity because they are effective early warning signs of disease caused by pesticide exposure (Benitez and Ramírez-Vargas, 2021).

Erythrocytes, plasma, serum, and red blood cells can all be used to measure cholinesterase levels (Cotton et al., 2018). Exposure to organophosphate pesticides can be determined by measuring cholinesterase levels in farmers (Neupane et al., 2017). Blood cholinesterase activity can be indicate ingestion of organophosphate pesticides in farmers (Kando et al., 2017). A study conducted in Thailand found that farmers who used pesticides inappropriately had substantially higher incidence of aberrant serum cholinesterase levels than those who used pesticides appropriately, which put their serum cholinesterase levels at risk (Santaweesuk et al., 2020).

Data on pesticide poisoning and diseases due to exposure to pesticides, especially among farmers, have not been documented. Available data are still limited among researchers, academics, and students. In Indonesia, biological monitoring of farmers is still rare, despite the known hazards of AChE inhibitors to several organs. As a result, this study aims to analyze the health risks associated with pesticide exposure in farmers residing in close proximity to rice farming areas.

METHODS

Design and Setting

This study used an analytical observational design with a cross-sectional approach and was carried out in Pemulutan Subdistrict, Ogan Ilir Regency, from October 2020 to January 2021. The population consisted of farmers and their families who were directly involved in agricultural activities and lived in the surrounding agricultural areas.

Participants and Procedure

The participants were farmers who resided in rice farming areas and were actively engaged in farming. The sample size was determined using a simple random sampling technique involving 61 participants. Data were collected through observations and interviews using a questionnaire. The inclusion criteria were farmers who were involved in agricultural activities, with a minimum work period of one year, and were willing to fill out an informed consent form as a participant. Blood pressure was measured using a mercury tensimeter by a nurse at a community health center. Blood samples were taken using materials, such as alcohol swabs, syringes, medical gloves, tissues, masks, label stickers, and markers. The tools used include a cooler box, a tensimeter, a vacuum container, an ice pack, a tourniquet, and a syringe. The blood samples of farmers were taken and examined at the Palembang Health Laboratory Center.

Furthermore, the blood samples of the farmers were sent to the Palembang Health Laboratory Center to test for cholinesterase levels using the DGKC colorimetric (KINETIC) method. The conventional reference values for males are 4612.462 to 11456.18 U/L and for females are 3928.69 to 10796.4 U/L.

Statistical Analysis

The Kolmogorof-Smirnov test was used to assess the normality of the data prior to performing any statistical tests. The data on age group, distance from home, length of farming, and length of staying were categorized based on their average values because the data were normally distributed. Furthermore, the data were analyzed using univariate and bivariate analyses, including the independent t-test and multiple linear regression. Finally, the results are presented in a table.

Ethical Consideration

This study was funded by the Health Polytechnic of Palembang in collaboration with the National Innovation Research Agency. Ethical approval was obtained from the Health Polytechnic of Palembang with an certificate number 499/KEPK/adm2/X/2020.

RESULTS

Identification of Pesticide Types Used by Farmers

The first step in assessing health risks is identifying the type of active pesticide ingredients used by farmers. According to Table 1, the results of interviews and direct observations in the houses of the farmers in Pemulutan Subdistrict showed that the use of active pesticide ingredients varied widely depending on the type of pests that attacked rice plants. The pesticides were categorized into slightly, moderately, and extremely hazardous.

Table 1. Identification of Pesticide Types Used by Farmers in Pemulutan Subdistrict, Ogan Ilir Regency

Pesticide Trade Name	**Active Ingredients**	**Classification** (WHO, 2019)
Fokker	Phoxim 500 g/L	II Moderately Hazardous
See Top	Isopropilaminegyphosate 525 g/L (glyphosate 389 g/L).	III Slightly Hazardous
Lindomin	2,4-D dimethylamine 865 gr/L	III Slightly Hazardous
Tuntas	Isopropilamineglyphosate 300g/L (glyphosate 222 g/L).	II Moderately Hazardous
Basmilang	Isopropilamineglyphosate 486g/L (glyphosate g/L)	III Slightly Hazardous
Ratgone	Brodifacoum 0.005%	III Slightly Hazardous
Regent	Fipronil 50 g/L	I Extremely Hazardous
DMA 6	s2,4-D dimethylamine 825 g/L (2,4-D 686 g/L)	II Moderately Hazardous
Yasithrin	Cypermethrin 30 g/L	II Moderately Hazardous
Fastac	Alphamethrin 15 g/L	II Moderately Hazardous

Cholinesterase Level in the Blood of Farmers

According Table 2, the average cholinesterase level in the blood of the farmers was 7628.4 U/L.

Table 2. Cholinesterase Level in the Blood of the Farmers

Variable	**Mean**	**Standard Deviation**	**Median (P25yo-P75yo)**
AChE Level (U/L)	7628.40	1576.01	7857.38 (6987.67-8517.16)

Characteristics of Participants

The respondent characteristics of rice farmers in Pemulutan District are explained in the following table:

Table 3. Characteristics of Rice Farmers in Pemulutan Subdistrict, Ogan Ilir Regency (n = 61)

Variables	n	Percentage (%)
Sex		
- Male	32	52.5
- Female	29	47.5
Education level		
- Primary School	32	52.5
- Junior High School	9	14.8
- Senior High School	19	31.1
- Bachelor's Degree	1	1.6
Age group		
- ≥49 years	33	54.1
- <49 years	28	45.9
Length of farming		
- ≥21 years	34	55.7
- <21 years	27	44.3
Length of staying		
- ≥40 years	35	57.3
- <40 years	26	42.7
Home distance to		
paddy field	30	49.1
- ≤300 meter	31	50.9
- >300 meter		
Type of activity		
- Sprayers	23	42.6
- Pesticide mixers	12	22.2
- Seed spreaders	5	0.1
- Harvesters	14	25.9
- Others	7	9.6

Based on Table 3, most of the farmers are men with primary school education, over 49 years old, and have been farming for more than 21 years.

Farmer Behavior in Using Pesticides

According to Table 4, 83.3% of the farmers did not use standard personal protective equipment (PPE). In addition, 50.8% of the farmers did not clean their bodies after using pesticides and instead used river water near the paddy fields, which caused decontamination.

Table 4. Farmer Behavior in Using Pesticides

Variables	n	Percentage (%)
The use of PPE		
- No	51	83.6
- Yes	10	14.4
Decontamination after pesticide application		
- No	31	50.8
- Yes	30	49.2

Correlation between the Characteristics of Farmers and Acetylcholinesterase (AChE) Levels

Table 5 shows a significant correlation between cholinesterase levels in the blood of the farmers and two variables, namely age group (p = 0.004) and length of farming (p = 0.005). This indicates that the average cholinesterase level in the blood of farmers differed depending on age group and length of farming. Specifically, cholinesterase levels were found to be hinger in farmers aged under 49 years than those aged above 49 years. In addition, cholinesterase levels in farmers with more than 21 years of experience were found to be higher than those with less than 21 years of experience.

Table 5. Correlation between Acetylcholinesterase (AChE) Levels and the Characteristics of the Farmers (n = 61)

Variables	n	Mean of AChE (U/L)	p-value
Age group			**0.04**
- ≥49 years	33	7257	
- <49 years	28	8065	
Sex			
- Female	32	7688.7	0.762
- Male	29	7561.9	

Variables	**n**	**Mean of AChE (U/L)**	**p-value**
Education level			
- Low	41	7604.3	0.852
- High	20	7677.5	
Home distance to paddy field			
- ≤300 meter	30	7391.9	0.873
- >300 meter	31	7926.3	
Length of farming	34	7972.1	**0.005**
- ≥21 years	27	7195.7	
- <21 years			
Length of staying			
- ≥40 years	35	7391.9	0.173
- <40 years	26	7926.3	
Type of activity			
- Sprayer	23	7906.9	0.286
- Non-sprayers	38	7462.9	
The usage of PPE			
- No	51	7591.7	0.566
- Yes	10	7815.4	
Decontamination after pesticide application			
- No	31	7832.5	0.223
- Yes	30	7417.5	

However, no significant correlation was found between cholinesterase levels in the blood of farmers and gender, education level, length of staying, length of farming, type of activity, the usage of PPE, and decontamination after pesticide application. The average cholinesterase level in the blood of farmers was in the normal range. However, the mean cholinesterase level was found to be higher in female farmers, sprayers, and those who did not decontaminate after pesticide application. The correlation between cholinesterase levels and characteristics of the farmers is presented in Table 5.

Health Effects on Farmers

Health effects experienced by farmers based on physical symptoms were assessed and blood pressure was measured. Statistical analyses were performed to analyze the correlation between cholinesterase levels with physical symptoms and hypertension incidence. The results showed that the prevalence of hypertension and physical symptoms were not related to cholinesterase levels in the blood of farmers. In addition, the average cholinesterase level was in the normal range.

However, it important to note that farmers in Pemulutan Subdistrict reported physical symptoms and hypertension incidence. The correlation between cholinesterase levels with physical symptoms and hypertension incidence is presented in Table 6.

Table 6. Correlation between Cholinesterase Levels with Physical Symtoms and Hypertension Incidence in the Farmers (n = 61)

Variables	**n**	**Mean of AChE (U/L)**	**p-value**
Itchy skin			
- Yes	32	7758	0.510
- No	29	7485.4	
Skin redness			
- Yes	23	7320.5	0.298
- No	38	7814.8	
Shortness of breath	18	7178	0.279
- Yes	43	7816.9	
- No			
Chest pain			
- Yes	16	7684.9	0.865
- No	45	7608.3	
Cough			
- Yes	17	7705.7	0.806
- No	44	7598.6	
Cramp			
- Yes	28	7493.2	0.535
- No	33	7743.1	
Muscle weakness	21	7417.5	0.421

Variables	n	Mean of AChE (U/L)	p-value
- Yes	40	7739.1	
- No			
Dizziness			
- Yes	18	7360.9	0.357
- No	43	7740.4	
Eye irritation			
- Yes	20	7647.5	0.944
- No	41	7619.1	
Hypertension			
- Yes	43	7543.7	0.521
- No	18	7830.7	

Based on the results of the multiple linear regression analysis, it was found that length of farming was a predictor of the presence of pesticides in the blood of the farmers. The R-squared value was only 0.091 or 9.1%, indicating that length of farming determined only 9.1% of the cholinesterase levels in the blood of the farmers, while the rest of the percentage was determined by other variables.

Table 7. The Results of the Multiple Linear Regression Analysis

Variables	Unstandardized Coefficients		Standardized Coefficients	p-value
	B	Std. Error	Beta	
(Constant)	7214.4	869.7		0.0005
Type of activity	-554.2	407.1	-0.172	0.179
Length of farming	843.4	397.3	0.268	0.038
R-square = 0.091				

DISCUSSION

Identification of Pesticide Types Used by Farmers

This study found that the pesticides used by the farmers contained active ingredients such as glyphosate and carbamate. In addition, farmers in Pemulutan Subdistrict used multiple types of active ingredient pesticides. A study conducted in Ethiopia found that approximately 30% of the pesticides used by farmers in the country were classified as neonicotinoids, pyrethroids, and organophosphates (Mrema et al., 2017).

Other studies have reported that organophosphate pesticides were also widely used by chili farmers in Thailand (Nganchamung et al., 2017). In addition, previous studies reported that the use of pesticides not only eradicated pests in rice plants, but also polluted river water used by people in the river basin (Maksuk et al., 2021).

Cholinesterase Level in the Blood of Farmers

This study found that the average cholinesterase level in the blood of the farmers was in the normal range. Cholinesterase is an enzyme found in cellular fluids that hydrolyzes acetylcholine to choline and acetic acid. It also acts as a crossroads for nervous system vibrations (US EPA, 2017). Cholinesterase inhibition, especially butyl cholinesterase, is a reliable biomarker for detecting organophosphate and carbamate exposure (Sine et al., 2019). Moreover, it is used to identify pesticide poisoning by analyzing the blood serum or plasma of farmers and other pesticide users (Benitez and Ramírez-Vargas, 2021).

Another studies found that 77% of patients with organophosphate poisoning had mild symptoms based on their serum cholinesterase levels, while approximately 23% had moderate to severe symptoms. The severity of the poisoning was related to the serum cholinesterase levels and the duration of organophosphate exposure (Rao and

Jyothsna, 2016). A study conducted on rice farmers in Thailand found that 68.6% of them had aberrant serum cholinesterase levels. This was caused by inappropriate and non-standard use of pesticides (Santaweesuk et al., 2020).

Furthermore, a study on migrant laborers in Thailand revealed a risk to the health of farmers due to abnormal cholinesterase activity, which was found to be 58.5% (Thetkathuek et al., 2017). Similarly, a study on farmers in Nepal showed that the average plasma cholinesterase level before and after spraying was 1.41 and 1.29 IU/L, respectively, respectively, indicating an 8.51% decrease. In addition, farmers were more likely to exhibit clinical poisoning symptoms after spraying (Neupane et al., 2017).

A study in Morocco found that the average level of butylcholinesterase activity in farmers was 7304.80 U/L, while the average in non-farmers was 9746, 42 U/L (Sine et al., 2019). The presence of pesticides in the bodies of farmers can be attributed to several variables, including age, sex, length of farming, type of activity, excessive use, use of PPE, and decontamination after pesticide application. Excessive and inappropriate use of pesticides can increase cholinesterase levels and the incidence of poisoning in farmers who spray pesticides.

Correlation between the Characteristics of Farmers and Acetylcholinesterase (AChE) Levels

This study found that the majority of farmers were females, aged above 49 years, had a primary school education, and had been farming for more than 21 years. In addition, the majority of farmers reported using incomplete PPE and did not decontaminate after pesticides application. The variables that were found to be related to cholinesterase levels in the bodies of farmers were age (above 49 years) and length of farming (more than 21 years). Cholinesterase levels were found to be higher in female farmers than in male farmers.

Similarly, a study on rice farmers in Thailand found that the majority of the farmers were females, aged between 40 and 59 years, and had a primary school education (Santaweesuk et al., 2020). Another study in Malaysia also found that the majority of farmers were females, above 42 years old, and had a secondary school education. In addition, the study found that exposure to pesticides in farmers was significantly related to cholinesterase levels (Rudzi et al., 2022). In a study on migrant farmers in Thailand, it was found that the majority of them were females with an average age of 30 years. The study also found that the farmers experienced a decrease in cholinesterase levels (Thetkathuek et al., 2017).

Another study on farmers in Southern Thailand found that male farmers had a significantly higher risk than female farmers. However, female farmers had a higher prevalence of abnormal serum AChE levels (15.2%) than male farmers (10.2%) (Guytingco et al., 2018). Moreover, a study on farmers found that poisoning symptoms were related to age, length of farming, type of spraying equipment, and use of PPE (Oktaviani and Pawenang, 2020).

However, a study on farmers in Kadibolo Village found no relationship between age and sex of farmers with cholinesterase levels (Prasanti and Harningsih, 2022). In a study on farmers who spray pesticides, it was found that cholinesterase enzyme activity was related to length of farming, duration of spraying, frequency of spraying, and use of PPE (Tutu et al., 2020). The aforementioned studies suggest that cholinesterase levels in the blood of farmers are influenced by several variables, including age, sex, length of farming, type of activity, use of PPE, spraying methods, and frequency of spraying pesticides. Although some of these variables are not significantly related, the examination of cholinesterase levels in the bodies of farmers revealed the presence of active pesticide ingredients.

Health Effects on Farmers

The results of this study revealed that the majority of farmers experienced physical symptoms, such as itchy skin, red eyes, dizziness, headaches, eye irritation, and even hypertension. A study in Sungai Penuh Village found that physical symptoms experienced by farmers were related to pesticide poisoning, including fatigue, weakness, burning skin, excessive sweating, discoloration of the skin, blurred vision, eyeballs shrinking and dilating, nausea, vomiting, diarrhea, stomach cramps or stomach pain, difficulty breathing, chest pain, and the like (Marisa and Pratuna, 2018).

The incidence of hypertension in rice farmers is influenced by several factors, including age, sex, length of farming, type of activity, behavior in using PPE, and decontamination after pesticide application. Accoring to a study in Dolago Padang Village, Central Sulawesi, the occurrence of hypertension is associated with the duration of working, the types of pesticides used, and the time spent spraying pesticides (Salikunna et al., 2022).

Another study in Malaysia found that dizziness was the most common symptom that farmers reported, followed by nausea, coughing, chest pain, difficulty breathing, sore throat, vomiting, phlegm, and wheezing (Rudzi et al., 2022). A study on farmers in Southern Thailand found that farmers frequently experienced symptoms, such as coughing, fatigue, dizziness, and dry and irritated skin. Those with abnormal serum AChE levels reported dizziness as their main symptom (Guytingco et al., 2018).

According to a study conducted in Malaysia, most farmers who experienced physical symptoms did not use PPE while spraying pesticides. The masks they used were typically made of worn cloth, and some farmers did not wear any protection at all (Rudzi et al., 2022). A previous study in Dolago Padang Village, Central Sulawesi showed a correlation between exposure to pesticides and the prevalence of hypertension among rice farmers. This correlation was found to be related to the duration of working, the types of pesticides used, and the time spent spraying pesticides (Salikunna et al., 2022).

In addition, another study found that 60% of farmers in Juhar Regency had hypertension, which was associated with non-standard spraying and incomplete PPE (Yuandra et al., 2020). In West Java, the majority of farmers sprayed pesticides themselves in addition to using pesticides. Moreover, a study showed that farmers who used pesticides were more likely to suffer from hypertension (47.9%) than those who did not use pesticides (27.3%) (Prihartono et al., 2022).

The main finding of this study was that cholinesterase levels were found in the blood of farmers who were directly involved in using pesticides to control pests in rice farming areas. The length of farming was found to be a predictor for cholinesterase levels at 9.1%, with the remaining percentage being determined by other variables. Other variables that contribute to the presence of active pesticide ingredients in the bodies of farmers included incomplete PPE, failure to decontaminate the body after pesticide application, and spraying activities.

Limitations

This study has several limitations. First, the sample size was smaller than calculated due to farmers' reluctant to draw blood. Second, this study lacks information on the time of previous spraying and the interval between the spraying and blood sample taken. Finally, recall bias is likely to be a limitation when workers are asked to recall previously experienced symptoms.

CONCLUSION

The majority of farmers in Ogan Ilir Subdistrict used active pesticide ingredients, namely carbamate and organophosphate, which ranged from slightly to extremely hazardous. Although the cholinesterase levels found in farmers were in the normal range, the presence of active pesticide ingredients in the bodies of farmers could trigger physical symptoms and increase the risk of hypertension.

It is recommended that community health centers regularly monitor water quality and conduct health checks on farmers, especially due to their routine and periodic exposure to pesticides. Regular counseling is also necessary through collaboration between the community health centers and agricultural extension workers to protect the health of farmers.

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