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Dermal Pesticide Exposure Risk Study on Rice Spraying Activities for Gunung Pati Farmers

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Abstract: This study aims to assess the dermal exposure risk of Pesticide spraying activities among farmers in Gunungpati. The research uses a descriptive method with a semi-quantitative approach using the Dermal Risk Assessment Method (DREAM). Risk assessment was conducted on four activities: (1) pesticide measuring using bottle caps, (2) pesticide mixing with water in tanks, (3) pesticide spraying implementation, and (4) tank cleaning. The assessment evaluated exposure on nine body parts: head, upper arms, forearms, hands, front body, back, lower body, calves, and feet. Results showed the total actual dermal exposure at the job level was 40.3, categorized as moderate risk. The highest exposure was found during spraying activity (34.4 - moderate), followed by tank cleaning (2.9 - very low), Pesticide measuring (2.4 - very low), and mixing (0.45 - very low). The study recommends using complete personal protective equipment, including thick, long clothes, wide-brimmed hats, masks, eye protection, vinyl gloves, and boots to reduce dermal exposure risks. This research contributes to understanding occupational health risks in agricultural pesticide application and improving safety practices among farmers.

Keywords: dermal exposure, DREAM method, farmers, pesticide spraying, risk assessment

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INTRODUCTION

Agriculture is a sector that plays an important role in meeting basic human needs, namely food, fiber, and industrial raw materials. Agriculture has become the backbone of the economy, especially in agricultural countries like Indonesia. With supportive geographical and climatic conditions, Indonesia has the potential to develop the agricultural sector to produce superior products for both domestic and export needs. In Indonesia, Based on data from the Central Statistics Agency (Badan Pusat Statistik) in 2023, the number of Agricultural Business Households was recorded at 28.4 million households (Badan Pusat Statistik, 2023). Indonesia has carried out registration and licensing procedures for all types and groups of pesticides since 1970, coordinated by the Ministry of Agriculture by Government Regulation No. 7 of 1973 concerning the supervision of the circulation, storage, and use of pesticides. Types of pesticide permits include permanent permits granted for a period of 5 years, temporary permits, and trial permits for 1 year. Permits are granted to pesticides that are considered adequate, safe, meet other technical requirements, and are used by the instructions listed on the label (Untung, 2004).

Farmers often face various challenges in rice cultivation, one of which is the disturbance of pests and plant diseases that can threaten the harvest. To overcome this problem, the use of pesticides has become a standard solution among farmers. Pesticides are chemicals designed to kill, control, or repel plant pests. With its application, farmers can protect plants from significant damage and increase agricultural productivity (Ema Amalia, 2020). However, the use of pesticides is not free from risks and negative impacts, both for human health and the environment. Uncontrolled pesticide use that does not comply with safety standards can cause health risks, especially dermal exposure or direct contact of pesticides with the skin (Rodríguez-zamora et al., 2024). Excessive exposure to pesticides can adversely affect health in the long term (Ema Amalia, 2020).

Pesticide exposure can enter the body in 3 ways: inhalation, skin/dermal absorption, and ingestion (Ansell, 2024). Factors that can affect poisoning cases can be in the form of external factors, namely factors that come from outside the body, such as the number of pesticides used, type, frequency, working period, length of work, use of personal protective equipment, how to handle pesticides, spraying time and basic sanitation measures. Meanwhile, internal factors within the body include age, gender, genetics, nutritional status, level of knowledge, and health status. The common problem is that there are still many farmers who ignore the above things due to the lack of knowledge and awareness of farmers (Souisa et al., 2020). Surprisingly, many safety efforts only focus on preventing inhalation exposure, often ignoring the risks associated with dermal absorption. This is because the skin is the largest organ in the body and is vulnerable to pesticide exposure. Farmers must understand and address the potential dangers of direct skin/dermal contact with pesticides (Muzaqi & Tejamaya, 2019). Gunungpati District has an area of 5,399,085 Ha, and as many as 34% of the total population in Gunungpati are farmers; this is because Gunungpati District has a fairly large area of land in rice fields (Anggraeni et al., 2023). Based on the results of observations on farmers in Gunungpati District, problems were still found in pesticide spraying farmers do not use complete PPE when spraying. Therefore, it is necessary to study the dermal display of pesticides during pesticide spraying activities and appropriate control efforts.

The Dermal Risk Assessment (DREAM) method is a way to assess the risk of chemical exposure through the skin. This method is used to estimate the level of chemical exposure on outer clothing (as potential exposure) or directly on the skin (actual exposure). In addition, DREAM helps describe how the chemical spreads throughout the body and through which pathways exposure occurs—taking into account the activity and type of work. (Van-Wendel-De-Joode et al., 2003). This method evaluates exposure to 9 body parts: head, upper arms, lower arms, hands, front of the body, back, lower body, calves, and feet. The assessment is carried out for each type of work separately (Vermeulen et al., 2020). Research conducted by Muzakki in 2019 on Cold Fogging activities for Pest Control Technicians at PT. X Jakarta workers experienced dermal exposure to insecticide liquids used when spraying insecticides. The assessment method used was the Dermal Risk Assessment Method, which obtained a total actual dermal exposure at a job level of 38.14, which then entered the moderate category (Muzaqi & Tejamaya, 2019). The high potential risk of pesticide exposure in farmers in Gunungpati due to the lack of personal protective equipment has made researchers interested in researching the risk of dermal exposure to pesticides during spraying activities.

METHODS

This study is a descriptive study with a semi-quantitative approach. This study assesses the risk of dermal exposure in Pesticide spraying work in rice fields. The work has four activities, namely (1) Measuring pesticides using bottle caps, (2) mixing pesticides with water in the tank, (3) implementing pesticide spraying, and (4) Cleaning the tank. This study uses tools such as *the Dermal Risk Assessment Method* (DREAM). Dermal Risk Assessment Method or known as DREAM is one method of assessing chemical risks to the skin. This method is a development method that aims to serve as an initial assessment for dermal exposure from contamination in solid or liquid form, as framework for measurement strategies (what, who, where, worker groups like what,) and also as a basis for calculations for carrying out control (Van-Wendel-De-Joode et al., 2003).

The risk of exposure to dermal is calculated on nine parts of the human body, namely the head, upper arm, lower arm, hand, front of the body, back, lower body, lower calf, and foot. In all parts of the body, an assessment of the estimated potential dermal exposure (Skin-P) and the estimated actual dermal exposure (Skin-A) is carried out. For each route of exposure (emission/deposition/transfer), the risk level is calculated by involving *probability*, exposure intensity, *internal estimate,* and *estimate route factor* (Masís-Leandro et al., 2023). DREAM equation:

$$\text{Skin-P} = Ep + Dp + T_p \quad \text{(Equation 1)}$$
$$\text{Skin-A} = \text{Skin P} \times OHA/B_P \quad \text{(Equation 2)}$$
$$Ep = Pp \times Ip \times EI \times ERE \quad \text{(Equation 3)}$$
$$DP = PD \times ID \times EI \times ERD \quad \text{(Equation 4)}$$
$$TP = PT \times IT \times EI \times ERT \quad \text{(Equation 5)}$$

For an explanation of each parameter, see Table 1.

Table 1. Dermal Exposure Risk

Acronym	E_p= Potential Emission	DP = Potensial Deposition	TP = Potensial Transfer
	P= probability	I= intensity	
	Ei = internal estimate	ER = Estimate Route Factor	
Probability is the occurrence of a predicted exposure. The magnitude of the probability for:	Emissions and deposition	0 - Unlikely (<1% of job duration) 1 – Occasionally (1-10% of work duration) 3 – Frequently (10-50% of job duration) 10 - Almost constantly (50-100% of work duration)	
	Transfer (Defined as the frequency of contact with surfaces such as floors, tables, equipment, etc., Probability categories for transfer)	0 - Unlikely (<1% of job duration) 1 – Occasionally (1-10% of work duration) 3 – Frequently (10-50% of job duration) 10 - Almost constantly (50-100% of work duration)	
Intensity is the amount of chemicals on uncovered skin or clothing caused by exposure. The intensity values for each exposure pathway are:	Emissions and Deposition	1 – Little (<10% of body part exposed) 3 – Medium (10-50% body part exposed) 10 – Many(>50% body part exposed)	
	Transfer (Level of contamination from surfaces in contact with the body. Intensity category for transfer)	0 – not contaminated 1 – possibly contaminated 3 - 50% of the surface is contaminated	
E_I (Consideration of the physical and chemical properties of chemicals. Examples: the active ingredient content of the material, physical form, boiling point, viscosity, and *dustiness.*	Solids: $E_I = P_S \times C \times F \times D_U \times S_S$		
	Fluid: $E_I = P_S \times C \times E_V$		
	Steam: $E_I = P_S \times C$		
P_s = Physical state (Physical Form)	1 – Solid		
	1 – Fluid		
	0,3 – Steam		
C = Concentration	1 - >90% active ingredient		
	0.3 – 1-90% active ingredient		
	0.1 – If active ingredient < 1%		
F = Formulation	3 – powder or fine particles		
	1 – granula/ pellets/seeds/large particles		
	0.3 – if bound or pack		
D_U= Dustiness	3 – Yes		
	1 – No		
S_s= Stickiness – wax - moist (degree of stickiness)	1.75 Sticky		
	1 – No Sticky		
E_V = Evaporation or vaporization (Indicates boiling point)	3 – TD < 500 °C		
	1 – TD between 50-1500 °C		
	0.3 If TD > 1500 °C		
V = viscosity	1 – low (like water)		
	1.75 – medium (like oil)		
	3 – thick (like resin or paste)		
E_R = exposure route factor	3 – ERE (ER for emissions)		
	1 – ERD (ER for deposition)		
	1 – ERT (ER for transfer)		

For (Skin-A), the equation used is the multiplication of potential dermal exposure (Skin-P) with the dermal protection factor (OHA/BP). By multiplying using the formula as follows:

OHA = M× PFMHA× RF× GC × GD × UG × URF × BC (Equation 7)
OBP = M× PFMBP× RF (Equation 8)

For an explanation of each parameter, see Table 2.

Table 2. Dermal Protection Factors

M (type of material that covers hands or other body parts.
1 – no gloves/exposed body parts
0.1 – not woven but permeable
0.3 – woven clothing
0.03 – non-woven and non-permeable
PFM (protection factor)
1 – PFMHA
0.3 – PFMHB
RF (replacement frequency)
1 – daily
3 – weekly
0.3 – one time use
10 – monthly
GC (are non-woven gloves connected to the sleeves)
1 – Yes
3 – No
GD (duration of use of non-woven gloves)
10 – usage duration for 0-25% working duration
3 – usage duration for 25-99% of working duration
1 – duration of use for 100% of working duration
UG = Ultra glove. Is a double glove used?
1 – No
0.3 – Yes
URF (how often to change inner gloves when using double gloves)
1 – each time used
3 – daily
10– weekly/monthly
BC (Uses Protective Cream)
1 – no
0.3 – Yes

The total actual dermal exposure at the activity level (Skin-A task) is the sum of exposures on six body parts. From all the calculations above, DREAM's dermal exposure classification category can be taken as in the table below.

Table 3. Dermal Exposure Categories

No dermal exposure	0
Very low dermal exposure	0-10
Low dermal exposure	10-30
Medium dermal exposure (moderate exposure)	30-100
High dermal exposure	100-300
Very high dermal exposure	300-1000
Extreme dermal exposure (extremely high exposure)	>1000

To calculate time-weighted dermal exposure (Skinw-Atask), the total dermal exposure was multiplied by the estimated relative task duration. Duration estimate / RTD), where RTD is the multiplication of the duration and frequency of the task. SkinW – ATask = Total Skin – ATask X RTD, where RTD is the multiplication of frequency and duration divided by total working hours.

Table 4. Relative task duration estimate

Frequency x Duration
1 – 4-8 hours/day); >20->80 hours/week; >800 hours/year
0.3 - 1-4 hours/day); 4-20 hours/week; 160- 800 hours/year0.3 – woven clothing
0.1 – 11-40 minutes/day; 1-4 hours/week; 40- 160 hours/year
0.03 - >11 minutes/day; 0-1 hour/month; 0-4 hours/year

RESULT AND DISCUSSION

The use of pesticides by farmers is no longer based on indicative needs, but many farmers use pesticides excessively by spraying continuously, without paying attention to wind direction, and without paying attention to the presence or absence of pests. Pesticides commonly used contain hazardous chemicals. The chemicals found during the spraying process are regents, which are liquid pesticides and contain the active ingredient fipronil 50 g/l. Regent is one type of insecticide that works by blocking chloride ions that carry *Gamma-Aminobutyric Acid* (GABA) to the central nervous system of insects (Mahyuni, 2015). *Fipronil* in the regent content is harmful to health if swallowed. *Fipronil* can also cause skin irritation reactions and damage to internal organs in the central nervous system through repeated or prolonged exposure (Aldrich, 2021). In descriptive analysis, a value will be obtained that will refer to one total dermal exposure value. The values obtained in this study *Are there potential dermal exposure estimates (Skin-P), actual dermal exposure estimates (Skin-A), and total actual dermal exposure at task level (SkinW-A Task)* (Muzaqi & Tejamaya, 2019; Van-Wendel-De-Joode et al.,2003).

Potential dermal exposure estimate (Skin-P) value in Pesticide spraying work

Potential dermal exposure estimate (Skin-P) value in Pesticide Spraying Work is an estimated value of potential dermal exposure that exposes insect pest control in rice field x (Table 4). The semi-quantitative assessment process can be seen in the appendix.

Table 5. Potential Dermal Exposure Estimate (Skin-P) Values in Pesticide Spraying Work

	Skin-P Value				
No	**Exposed Body Parts**	**Pouring Pesticide into Bottle Cap**	**Mixing pesticides with water in a tank**	**Pesticide Spraying**	**Tank cleaning**
1	Head	1.2	1.2	1.2	1.2
2	Upper arm	1.2	1.2	1.2	1.2
3	Forearm	1.5	1.2	1.5	8.7
4	Hand	8.7	1.5	11.7	9.9
5	Upper Body	1.5	1.2	4.5	1.5
6	Back	0.3	0.3	0.3	0.3
7	Lower Body	1.2	1.2	3.6	1.2
8	Lower Calf	1.2	1.2	13.5	6.3
9	Foot	1.2	1.5	13.5	11.7
	Total	**18**	**10.5**	**51**	**42**
	Risk Category	Low Exposure	Low Exposure	Moderate Exposure	Moderate Exposure

Based on Table 5, from the four Pesticide spraying work activities (pouring, mixing, spraying, and cleaning), the highest potential dermal exposure estimate (Skin-P) value was obtained in the implementation of Pesticide Spraying work. The Skin-P value in the implementation of pesticide spraying activities on nine body parts is the head. 1.2; upper arm 1.2; lower arm 1.5; hand 8.7; upper body; 1.5; back 0.3; lower body 1.2; lower calf 1.2; and feet 1.2. Although in each part of the body, the dermal risk is included in the very low category, one activity is included in the medium category, namely the pesticide spraying activity. When pesticides are poured from the concentrate bottle into the tank, there is a potential for exposure to the hands. The greatest potential exposure is the deposition of chemical splashes that hit the hands. This will increase the high value of the possibility and amount of chemicals exposed. The length of contact with chemicals is related to the occurrence of contact. The duration of the implementation of pesticide spraying was quite long, namely 32 minutes, with high pesticide exposure.

Actual dermal exposure estimate (Skin-A) value in Pesticide spraying work

The Actual Dermal Exposure Estimate (Skin-A) value in Pesticide spraying work is the actual value of dermal exposure exposed to pest control techniques for Pesticide spraying work after corrections are made for hand and body protection factors and the characteristics of the chemical itself.

Table 6. Actual Dermal Exposure Estimate (Skin-A) Values in Pesticide Spraying Work

	Skin-A Value				
No	**Exposed Body Parts**	**Pouring Pesticide into Bottle Cap**	**Mixing pesticides with water in a tank**	**Pesticide Spraying**	**Tank cleaning**
1	Head	0.32	0.32	0.32	0.32
2	Upper arm	0.04	0.04	0.04	0.04
3	Forearm	0.45	0.36	0.45	2.61
4	Hand	78.30	13.50	105.30	89.10
5	Upper Body	0.14	0.11	0.41	0.14
6	Back	0.03	0.03	0.03	0.04
7	Lower Body	0.11	0.11	0.32	0.11
8	Lower Calf	0.36	0.36	4.05	1.89
9	Foot	0.36	0.45	4.05	3.51
	Total	**80.10**	**15.27**	**114.97**	**97.74**
	Risk Category	Moderate Exposure	Low Exposure	High Exposure	Moderate Exposure

Based on Table 6, the *actual dermal exposure estimate (Skin-A) value* in the pesticide spraying work is highest in the hand exposure of the pesticide spraying activity, which is 105.30; this shows the highest actual dermal exposure value in the hand area. In total, the Skin-A value is in the High category. This shows the highest actual dermal exposure value in the hand area. In pouring pesticides into bottle caps, pesticide exposure occurs in the hand area because the implementation of this activity uses hands so that the exposed chemicals will directly touch the hands. The absence of gloves also affects their high value. Farmers do not use gloves when carrying out Pesticide spraying activities, from pouring pesticides from the concentrate bottle into the tank to implementing the Pesticide spraying itself. The high dermal exposure in pesticide spraying activities is influenced by the spraying duration and the chemicals' nature. In the implementation of pesticide spraying, chemicals with particle diameters between 5-50 microns are deposed and exposed to the entire body area, which causes the high Skin-A value in this activity. Farmers will remain in the rice fields that have been exposed to pesticides during the pesticide spraying process. So, the duration of dermal exposure during the pesticide spraying process will be the same as the duration of the pesticide spraying process, which will last 32 minutes.

value at task level (SkinW-ATask)

At this stage, the exposure values of 9 body parts will be added up, including the head, upper arms, lower arms, hands, upper body, back, lower body, lower calves, and feet.

Table 7. Total actual dermal exposure at task level (SkinW-ATask)

No.	**Activities**	**Type of work**	**Total Skin Value $_{w}$-A $_{task}$**	**Category**
1.	Pouring Pesticide into Bottle Cap	Pesticide spraying	2.4	Very Low exposure
2.	Mixing pesticides with water in a tank	Pesticide spraying	0.45	Very Low exposure
3.	Pesticide Spraying	Pesticide spraying	34.4	Moderate exposure
4.	Tank cleaning	Pesticide spraying	2.9	Very Low exposure
Total			40.3	Moderate exposure

It was obtained that the *Total actual dermal exposure value* in Pesticide spraying work *(SkinW-ATask)* was 34.4 and fell into the moderate category. Overall, the risk of dermal exposure from Pesticide spraying work consisting of four activities was classified as moderate or medium risk. Several factors that cause the risk of dermal exposure are not using gloves during the pesticide spraying process. On the other hand, in the activity of mixing pesticides with water in the tank, the dermal exposure value was very low due to the small composition of chemicals used and the short duration of work. The chemicals used in one pesticide spray were 10 ml/8 l of water for approximately 32 minutes. The work carried out after the pesticide mixing process was pesticide spraying. This work was carried out in less than 1 hour, from the start of pouring pesticides into the bottle cap to the pesticide spraying process. Dermal exposure that occurs due to this work affects almost all parts of the body. Mainly, when the pesticide spraying activity is carried out, the risk of dermal exposure can be explained as follows: In Pesticide Spraying, there are also four activities that when we review them with other activities, these activities are included in activities 1, 2, 3 and 4. Activity 1 is the activity of pouring pesticides into the bottle cap. This is the first activity carried out by farmers during the pesticide spraying process.

This activity has the potential for chemical exposure to the lower arm and hand areas. After pouring the Pesticide into the bottle cap, the farmer mixes the chemical with water. During the pesticide mixing activity, exposure to the hand area is risky. This is due to direct contact with the Pesticide when pouring the Pesticide into the tank. In this activity, there is a risk of exposure to the lower arm and hand area due to splashes of the mixed chemicals (Khalishah et al., 2023). In activity 3, farmers spray Pesticide onto the rice, which takes 32 minutes (Sinambela, 2024). This causes a risk of dermal exposure to hands, especially when farmers hold the tank. Activity 4 is the activity of cleaning the tank; during the implementation of tank cleaning, there is exposure to pesticides in the hands and feet because the implementation of tank cleaning itself is directly discharged into the stream by farmers without the use of PPE. Farmers who do not use gloves will also affect the high value. Farmers who spray pesticides do not use gloves, long clothes, and boots, which can cause a high risk of exposure to the hands, lower arms, and legs (Desye et al., 2024). The duration or length of exposure to pesticides and continuous exposure is more dangerous than intermittent exposure at the same time. Therefore, sprayers who are exposed repeatedly and for a long time, it can cause chronic poisoning. Exposure to the hands and feet is more significant than exposure to the upper arm area because chemical particles are directed forward during the implementation. So that exposure is spread to all body parts that are not covered. Improving the agricultural sector requires various supporting facilities: agricultural tools, fertilizers, chemicals, and pesticides. Agricultural systems based on high-energy input materials, such as chemical pesticides, can cause environmental pollution, especially in the agricultural environment (Sinambela, 2024).

CONCLUSION

Based on results, observations, and analysis that have been done, it can concluded that there is a risk of significant dermal exposure in farmers using pesticides, shown by the results evaluation using the Dermal Risk Assessment method (DREAM), obtained results that risk occupational dermal exposure spraying Pesticide with the total value of actual dermal exposure at job level was 40.3 and entered to in moderate category. For each activity, the total actual dermal exposure at (1) Spraying Pesticide is of 34.4 and entered in category moderate, (2) activity cleaning tank by 2.9 and entered very low category, (3) activity pouring Pesticide to closed bottle by 2.4 and entered very low category, and (4) Mixing Pesticide with a deep water tank; the actual dermal exposure value is 0.45 and is included in the very low category. For lower level risk dermal exposure, it is necessary to use a top and bottom long and thick hat, mask, protective eyes, sheath vinyl hands, boots, and use glass measure.

DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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