

# Analysis of farmer behavior in the management of used pesticide packaging in Karo Regency

Dahri Tanjung<sup>1\*</sup>, Parulian Hutagaol<sup>2</sup>, Yeti Lis Purnamadewi<sup>3</sup>, Beata Ratnawati<sup>4</sup>, and Didik Suharjito<sup>5</sup>

<sup>1</sup>Associate Professor, Management of Agribusiness, School of Vocational Studies, IPB University, Bogor, Indonesia

<sup>2</sup>Professor, Department of Economics, Faculty of Economic and Management, IPB University, Bogor, Indonesia

<sup>3</sup>Associate Professor, Department of Economics, Faculty of Economic and Management, IPB University, Bogor, Indonesia

<sup>4</sup>Associate Professor, Environmental Engineering and Management, School of Vocational Studies, IPB University, Bogor, Indonesia

<sup>5</sup>Professor, Department of Forestry Management, Faculty of Forestry and Environment, IPB University, Bogor, Indonesia

**Abstract.** Pesticides are essential chemical inputs in modern agriculture for maintaining productivity and food security. However, excessive use and improper disposal can pose serious threats to human health and the environment. This study aims to analyze farmers' behavior in managing used pesticide containers in Karo Regency using the Structural Equation Modeling–Partial Least Squares (SEM–PLS) approach. The study was conducted in Raya Village, Berastagi District, Karo Regency, involving 50 respondents selected through simple random sampling. Four latent constructs were analyzed: knowledge, experience, perception, and behavior. The results showed that knowledge and experience had significant positive effects on perception, while perception positively influenced behavior in pesticide container management. The  $R^2$  values were 0.628 for perception and 0.128 for behavior, indicating that knowledge and experience explain most of the variance in perception. In contrast, perception accounts for only a small portion of the variance in safe behavior. The findings suggest that although farmers have awareness of pesticide hazards, behavioral change remains limited. Continuous training on Good Pesticide Handling Practices, collection facilities at the village level, and integrated supervision is recommended to enhance safe and sustainable pesticide management.

## 1 Introduction

The use of pesticides, especially by farmers, plays a crucial role in modern agricultural

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\* Corresponding author: [ir.da@apps.ipb.ac.id](mailto:ir.da@apps.ipb.ac.id)

systems because it helps protect crops from pests. Pesticide use in Indonesia has increased rapidly, along with food production to meet national needs [1]. However, the misuse of pesticides can pose serious risks to human health and cause environmental pollution [2]. One important issue often overlooked is the handling of used pesticide containers, including the lack of an adequate system for managing pesticide packaging waste [3]. Improperly managed packaging can pollute soil, water, and air because it is classified as hazardous and toxic waste (B3) [4]. This poses risks to the quality of agricultural land, human health, animals, and wildlife [5]. According to data from the Food and Agriculture Organization, an estimated 330,000 tons of plastic pesticide containers are produced annually, and most of this packaging is disposed of in the environment without adequate handling [6].

Karo Regency is one of the leading centers for horticultural production in North Sumatra. Vegetable production in 2024 was around 889,690.8 tons, generated from an area of 40,933.5 Ha. Pesticide use in this area is very high. Many farmers have not implemented proper pesticide container management procedures, such as triple rinsing and returning them to retailers. Most farmers instead dispose of or burn the packaging around agricultural land. This reflects the situation in Indonesia, where pesticide packaging waste often ends up in waterways and agricultural soil, or is burned directly without further processing [7]. This also frequently occurs in other countries such as China, Thailand, and India; farmers dispose of pesticide containers in irrigation channels and fields, or burn or reuse them, exacerbating environmental pollution [8]. It is suspected that the lack of education regarding pesticide waste management often leads farmers to misunderstand the risks associated with improper disposal methods.

Previous research indicates that knowledge and experience significantly influence farmers' perceptions and behavior regarding pesticide use [9]. However, studies specifically linking these two variables to pesticide packaging waste management behavior remain limited, especially at the regional level. In fact, the contamination from used pesticides not only affects the area surrounding Karo agriculture, because the Karo region is in the highlands of Lake Toba, but it is also feared that it will subsequently impact Lake Toba, which is located downstream. Therefore, this research was conducted to analyze the factors influencing farmers' behavior in managing used pesticide containers using the Structural Equation Modeling–Partial Least Squares (SEM–PLS) approach.

The specific objectives of this research are to (1) analyze the influence of knowledge and experience on farmers' perceptions regarding pesticide packaging management; (2) analyze the influence of perception on the behavior of managing used pesticide containers, and (3) formulate policy recommendations that can support safe and sustainable pesticide management practices.

## **2. Research methods**

### **2.1 Concept of pesticide waste management in Indonesia**

Pesticide waste management, including used containers, is a critical issue in global agriculture that has not received adequate attention from policymakers. A closed circular supply chain has been proposed as an effective and environmentally friendly solution for managing empty packaging waste, with research in Indonesia showing that 62.63% of farmers have adopted the triple-rinsing practice. However, the implementation of this program faces significant challenges, including regulatory gaps, limited financial feasibility, and low farmer involvement [10].

## 2.2 Knowledge-Attitude-Practice model and risk perception

The literature on farmer behavior in pesticide management consistently emphasizes the importance of integrating cognitive understanding (knowledge and perceptions) with on-field actions. Various studies indicate a discrepancy between positive knowledge and safe practices.

Research in Mexico, for example, indicates that management behavior is highly influenced by the level of education and access to training. In this context, the positive knowledge and attitudes held by farmers do not always directly translate into the application of safe practices. Similar findings also emerged in Barbados, where although farmers possess good awareness and attitudes toward pesticide risks, the influence of external factors proved to remain significant in determining their behavior [11]

Key determining factors that influence behavior and access to information include age, educational background, participation in safety training, and farming experience. Furthermore, a study in Nepal found that most farmers access information through informal social networks, which in turn leads to significant variation in pesticide storage and disposal practices.

## 2.3 SEM-PLS conceptual framework

The conceptual model in this study integrates four latent constructs: Knowledge ( $X_1$ ), Experience ( $X_2$ ), Perception ( $X_3$ ), and Behavior ( $X_4$ ). The hypothetical model predicts that knowledge and experience positively influence risk perception, which in turn influences safer waste management behavior. Thus, the hypothetical model is:

H1: Farmers' knowledge about pesticide risks and waste management positively influences their risk perception.

H2: Long-term farming experience and direct interaction with pesticides positively influence risk perception.

H3: Higher risk perception positively influences safer waste management behavior.

This framework is based on social learning theory and health behavior models which recognize that behavior is influenced by cognitive processes, experience, and contextual factors.

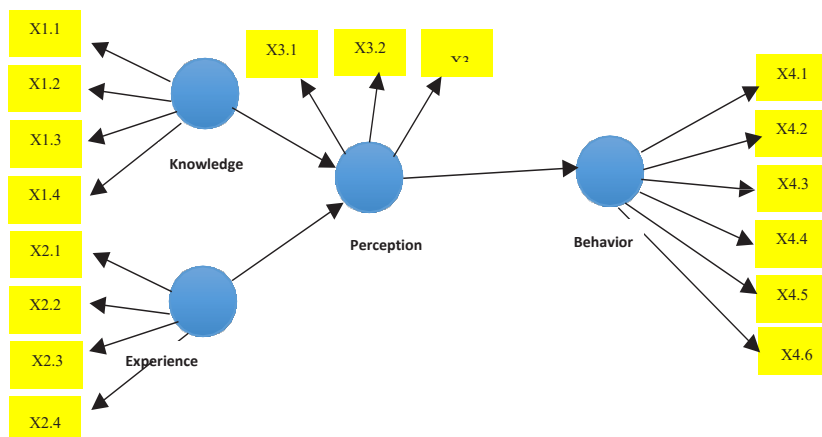
## 2.4 Research location and method of analysis

The research was conducted in Raya Village, Berastagi District, Karo Regency in August 2025. This location was chosen because it is a horticultural center with a high level of pesticide use, but minimal facilities for packaging waste management. The approach used is a descriptive, quantitative survey method. Thus, the data used is primarily primary data supplemented by secondary data. The primary data was obtained through direct interviews with farmers and field observations. The study population is all horticultural farmers in the village. A total of 50 respondents were selected using simple random sampling. The research instrument is a structured questionnaire with a 1–5 Likert scale (1 = strongly disagree, 5 = strongly agree).

Four latent constructs were used in the research model, namely:

1. Knowledge ( $X_1$ ): understanding of pesticide risks and their waste management.
2. Experience ( $X_2$ ): duration and frequency of pesticide use.
3. Perception ( $X_3$ ): views and awareness regarding the importance of pesticide waste management.
4. Behavior ( $X_4$ ): actual actions in the collection, storage, and disposal of pesticide

packaging.



**Fig. 1.** SEM PLS Structural model of pesticide packaging

Data analysis was performed using SmartPLS 4.0 software. Convergent validity was tested through the outer loading value ( $>0.7$ ) and Average Variance Extracted (AVE  $>0.5$ ). Construct reliability was determined by Cronbach’s alpha and composite reliability ( $>0.7$ ). The structural model (inner model) was tested using path coefficients, t-statistics ( $>1.96$ ), and the  $R^2$  value.

### 3. Results and discussion

#### 3.1 Respondent characteristics

The majority of respondents were aged 38–57 years (42%), male (95%), and had a moderate level of education (Junior High School up to Senior High School/Vocational School). Most had farming as their main occupation (66%), with farming experience of  $<10$  years (44%) and 10-30 years (40%), with land area  $<1$  ha (74%). This indicates that the farmers in Raya Village are experienced farmers with a moderate level of formal education. Upon closer examination, their land areas varied significantly, ranging from 1/4 Ha up to 2 Ha per household. This data indicates that the respondents are small farmers with a high reliance on pesticides. The crops cultivated generally include highland vegetables, and some also grow corn, citrus, and coffee (Table 1).

This data indicates that the respondents are experienced farmers with moderate to high levels of formal education, but they depend heavily on pesticides to maintain their agricultural productivity.

**Table 1.** Respondent characteristics

No	Description		Percentage
1	Age	- $<37$ years	38.00
		- 37-57 years	42.00
		- $> 57$ years	20.00
2	Education:	- Primary School	10.00

**Table 1.** Respondent characteristics (continue)

No	Description		Percentage
2	Education:	- Junior-Senior High School	50.00
		- Higher Education	40.00
3	Main Occupation	- Farmer	66.00
		- Selling farm produce	20.00
		- Kiosk	8.00
		- Services	6.00
4	Farming Experience	<10 years	44.00
		10-30 years	40.00
		>30 years	16.00
	Land Area	- < 0.5 Ha	50.00
		- 0.5 -1.0 Ha	24.00
		- > 1.0 Ha	26.00

### 3.2 Pesticide purchase and use behavior

The study found that almost all farmers (99%) use pesticides of various commercial brands. Purchasing behavior shows positive results because all respondents buy pesticides in original, sealed packaging at agricultural supply kiosks in district or sub-district markets.

However, usage behavior shows risky practices:

- 72.5% of farmers mix pesticides not according to the recommended dosage, some even mixing them in waterways. Karo farmers are known to be progressive, seeking various ways, even mixing 2-3 brands of pesticides, to ensure their crops do not fail, although such actions are often based on limited knowledge.
- Almost all farmers spray downwind at the right time, but do not use complete Personal Protective Equipment (PPE). Some farmers underestimate the importance of PPE because they have rarely experienced significant negative effects on their bodies or respiratory systems.

These findings indicate that although farmers have some good practices in pesticide application, there are still significant risks in handling behavior, pointing to a knowledge-practice gap pattern [12].

### 3.3 Results of validity and reliability testing (outer model)

The outer model analysis shows that all indicators displayed below have a loading factor value above 0.7, thus concluding that each indicator is valid in reflecting its construct. The Knowledge construct ( $X_1$ ) is measured through three indicators ( $X_{1.1}$ – $X_{1.3}$ ) with loading values of 0.710–0.878; Experience ( $X_2$ ) through three indicators ( $X_{2.1}$ ,  $X_{2.3}$ ,  $X_{2.4}$ ) with values of 0.728–0.889; Perception ( $X_3$ ) through three indicators ( $X_{3.1}$ – $X_{3.3}$ ) with values of 0.775–0.896; and Behavior ( $X_4$ ) through four indicators ( $X_{4.1}$ ,  $X_{4.2}$ ,  $X_{4.5}$ ,  $X_{4.6}$ ) with values of 0.710–0.752. All these values meet the criteria for convergent validity [13, 14]. In this stage of convergent validity testing, several indicators, such as  $X_{1.4}$ ,  $X_{2.2}$ ,  $X_{4.3}$ , and  $X_{4.4}$ , were excluded from the model because their values did not meet the criteria (<0.7).

Furthermore, the reliability test results show that Cronbach’s alpha and Composite Reliability values for all constructs are above 0.7, and that the Average Variance Extracted (AVE) is > 0.5. The highest AVE value is found in the Perception construct (0.724), followed by Knowledge (0.656), Experience (0.617), and Behavior (0.529). This indicates that all constructs have good internal reliability and consistently measure the variables they represent (Table 2).

**Table 2.** Results of construct validity and reliability testing

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average Variance Extracted (AVE)
Knowledge	0.745	0.809	0.850	0.656
Experience	0.702	0.811	0.827	0.617
Perception	0.810	0.835	0.887	0.724

All constructs meet the criteria for convergent validity and construct reliability [15]. Thus, all indicators are considered valid and reliable for use in the structural model analysis.

**Outer loading.** Outer loading is a value that explains the relationship (correlation) between an indicator and its latent variable. Outer loading is the result of single regression from each indicator that forms the construct. The loading factor is the main focus in the measurement model, both reflective and formative. The Convergent validity values for all indicators in Table 3 are obtained to be > 0.5; thus, it can be concluded that all indicators are accepted and retained for the next process (Table 3).

**Table 3.** Outer loading and convergent validity

	Knowledge	Experience	Perception	Behavior
x1.1	0.878			
x1.2	0.833			
x1.3	0.710			
x2.1		0.728		
x2.3		0.729		
x2.4		0.889		
x3.1			0.896	
x3.2			0.877	
x3.3			0.775	
x4.1				0.752
x4.2				0.732
x4.5				0.716
x4.6				0.710

### 3.4. Relationship between constructs (latent correlation)

The correlation between constructs shows a strong relationship between Experience and Perception ( $r = 0.719$ ) and between Knowledge and Perception ( $r = 0.618$ ). The correlation between Perception and Behavior is moderate ( $r = 0.358$ ), while Knowledge and Behavior ( $r = 0.345$ ) show a relatively weak relationship (Table 4).

This finding indicates that farmers' empirical experience has a greater influence on perception formation than theoretical knowledge. This means that the more often farmers interact with pesticides and their effects, the higher their awareness of health and environmental risks.

**Table 4.** Latent variable correlation

	Experience	Knowledge	Behavior	Perception	AVE	$\sqrt{AVE}$
Experience	1.000	0.447	0.405	0.719	0.617	0.786
Knowledge	0.447	1.000	0.345	0.618	0.656	0.809
Behavior	0.405	0.345	1.000	0.358	0.529	0.727
Perception	0.719	0.618	0.358	1.000	0.724	0.851

### 3.5. Model fit evaluation (goodness of fit)

The model fit index shows SRMR = 0.121, Chi-square = 146.273, and NFI = 0.542 (Table 5). The SRMR value is slightly above the 0.10 threshold, indicating a moderate level of fit. The NFI value, which is in the range of 0.5–0.6, also indicates that the model is still acceptable for exploratory purposes, although not entirely ideal. Overall, the model is reasonably good at explaining the relationships between the latent constructs tested.

**Table 5.** Model fit test

	Saturated model	Estimated model
SRMR	0.121	0.126
d_ULS	1.335	1.450
d_G	0.546	0.564
Chi-square	143.440	146.273
NFI	0.551	0.542

### 3.6. Hypothesis testing and Inner model results

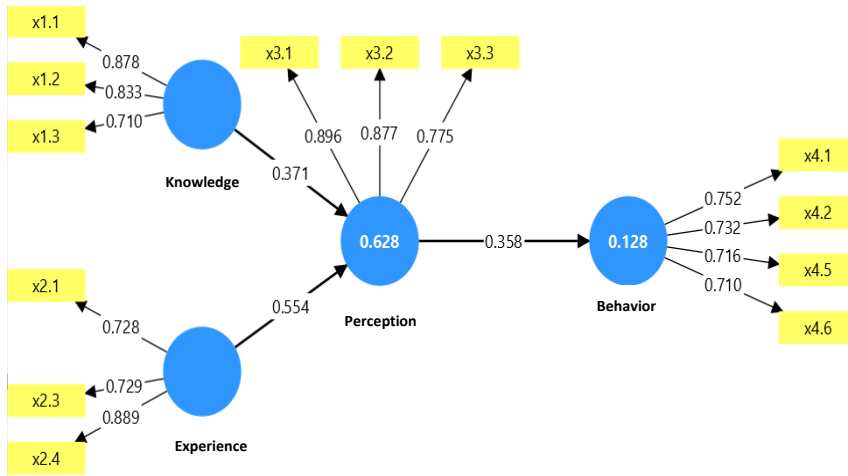
#### 3.6.1. Inner model

The inner model analysis was conducted to test the causal relationships among the latent constructs in the structural model: the influence of Knowledge (X<sub>1</sub>) and Experience (X<sub>2</sub>) on Perception (X<sub>3</sub>), and the influence of Perception (X<sub>3</sub>) on Behavior (X<sub>4</sub>). The significance test was performed through a bootstrapping procedure with 5,000 subsamples using SmartPLS 4.0. The test results are summarized in the following Table 6.

**Table 6.** Inner model test results

Path Relationship	Path Coefficient	T-statistic	P-value	Description
Knowledge → Perception	0.412	5.736	0.000	Significant
Experience → Perception	0.587	8.241	0.000	Significant
Perception → Behavior	0.358	2.031	0.044	Significant

The significance test was performed through a bootstrapping procedure with 5,000 subsamples using SmartPLS 4.0. The results show that all three proposed hypotheses are statistically significant (p<0.05).



**Fig. 2.** Structure model SEM PLS pesticide packaging handling

### 3.6.2. Interpretation of results

#### 1. Influence of knowledge on perception (H1)

The test results show a path coefficient of 0.412 with a t-statistic of 5.736 (>1.96) and a p-value of 0.000 (<0.05). This means that greater farmers' knowledge about pesticides significantly increases their perception of the risks of pesticide use. Farmers who understand the function, dosage, and dangers of pesticides tend to have a more cautious perception and are more aware of the potential negative impacts.

#### 2. Influence of experience on perception (H2)

The path from experience to perception has the highest coefficient (0.587) with a t-statistic of 8.241 and a p-value of 0.000. This result indicates that long farming experience and direct exposure to pesticides have a strong influence on the formation of perceptions. Farmers who have experienced the negative effects of pesticides (e.g., irritation or mild poisoning) tend to have a higher risk perception compared to those who have not.

#### 3. Influence of perception on behavior (H3)

The relationship between perception and behavior shows a positive coefficient of 0.358 with a t-statistic of 2.031 and a p-value of 0.044. This means that the more positive farmers' perceptions are regarding the importance of safe pesticide management, the greater the likelihood that they will follow safety principles. However, the influence is not very strong, indicating that other external factors (e.g., facilities, regulations, and local habits) also influence the farmers' actual behavior in the field.

### 3.7. R-Square value

The R-square test results show that the Perception variable has an R<sup>2</sup> value of 0.628, meaning that the Knowledge and Experience variables are able to explain 62.8% of the variation in farmers' Perception changes. Meanwhile, Behavior has an R<sup>2</sup> of 0.128, indicating that only 12.8% of the variation in farmers' behavior is explained by Perception (Table 7). This value is considered low, indicating that pesticide management behavior is also influenced by other

external factors such as the availability of waste collection facilities, extension support, and traditional habits in the field.

This finding illustrates that knowledge and experience more strongly influence the cognitive aspect (perception) than the actual behavioral aspect, which is a common pattern in studies of innovation adoption behavior.

**Table 7.** R-square and adjusted R-square values

	<b>R-square</b>	<b>R-square adjusted</b>
Behavior	0.128	0.110
Perception	0.628	0.612

### 3.8 Knowledge-Attitude-Practice gap analysis

The integration of SEM-PLS results with qualitative observation reveals a significant gap at every stage of the KAP continuum (Table 8).

**Table 8.** Knowledge-Attitude-Practice gap in pesticide container management (%)

<b>Aspect</b>	<b>Knowledge</b>	<b>Positive perception/attitude</b>	<b>Appropriate practice</b>
Awareness of empty container risk	38	68	15-20
Triple rinsing method	31	55	20
Responsibility for waste management	45	72	25-35
Safe waste storage	40	60	0
Average Gap	-	30	50

The largest gap is seen between positive perception and actual practice (an average of 50 percentage points), indicating that external factors play a crucial role in explaining why farmers with high-risk perception do not consistently implement safe waste management practices.

### 3.9 Discussion

The research results show that knowledge and experience significantly influence perception, and that perception in turn influences farmers' behavior. This supports the Theory of Planned Behavior, where a person's behavior is influenced by beliefs, experience, and perception of risk.

The experience factor has the most dominant influence on perception. Farmers who have experienced the negative impacts of pesticides (such as skin irritation or crop failure) tend to be more cautious and have a higher risk perception. However, the results also show that despite high perception, behavioral change is not yet significant — indicating a gap between knowledge and action.

The limitations of container collection facilities, lack of supervision, and old habits of indiscriminate disposal of containers are the main inhibiting factors. Therefore, intervention by local government and continuous extension services are very important to consistently shape safe behavior.

## 4. Conclusion and policy recommendations

### 4.1 Conclusion

This study shows that farmers' behavior in managing used pesticide containers in Karo Regency is influenced by knowledge, experience, and perception factors. In detail, the SEM-PLS analysis results prove that:

1. Knowledge and experience have a significant positive effect on farmers' perception. The greater farmers' understanding and experience of pesticide risks, the more they perceive the importance of pesticide waste management.
2. Perception has a positive effect on pesticide container management behavior, although the strength of the influence is relatively small. This indicates that good perception has not been fully translated into actual behavior.
3. The  $R^2$  value shows that knowledge and experience explain 62.8% of the variation in perception, while perception only explains 12.8% of the variation in behavior.

Thus, strengthening safe pesticide management behavior needs to be done not only through increasing knowledge and experience, but also by improving the external support system such as policies, container collection infrastructure, and incentives for environmentally friendly farmers.

### 4.2 Policy recommendations

Based on the analysis results, some policy recommendations that can be made are:

1. Enhancement of continuous extension services on post-use pesticide waste management through a participatory approach, not just technical extension, such as provision of facilities and networks for pesticide container collection at the village level, in collaboration between local government, agricultural agencies, and pesticide supplier companies.
2. Empowerment of farmer groups or village cooperatives as implementers of the container collection system and supervision of pesticide management behavior.
3. Incentive policies and agricultural environmental certification, such as a "Green Farmer" program that provides awards for farmers or groups who implement correct pesticide waste management practices.
4. Multi-stakeholder collaboration between academics, government, and the private sector in supporting research and innovation for sustainable agricultural hazardous waste management. These recommendations are in line with the direction of sustainable agricultural development policy and support the Sustainable Development Goals (SDGs), particularly goal 12 on Responsible Consumption and Production.

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## References

1. U. Sholikhah, I.S. Magfiroh, W.I.D. Fanata, Pemanfaatan limbah urine kelinci menjadi

- pupuk organik cair (POC). *AJIE (Asian Journal of Innovation and Entrepreneurship)*, **03**, 02, 204-208. (2018).
2. O.P. Bansal, The impact of pesticides on health and environment. *Egyptian Scientific Journal of Pesticides. Egy Sci J Pestic.* **6**, 1, 1– 7 (2020).
  3. K. Kaharto, W. Sugianto, Y. Hermansyah, Analisis kesadaran masyarakat terhadap dampak pencemaran di Pantai Losari Kota Makassar. *Innovative: Journal of Social Science Research.* **3**, 3510-3517 (2023).
  4. Kementerian Kesehatan Republik Indonesia. Pedoman penggunaan pestisida aman bagi petani, (Direktorat Kesehatan Lingkungan, Jakarta, 2016).
  5. N. Hu, Q. Zhang, C. Li, H. Sun, Policy intervention effect research on pesticide packaging waste recycling: Evidence from Jiangsu, China. *Frontiers in Environmental Science.* **10**, 922711. (2022).
  6. FAO. International code of conduct on pesticide management, (Food and Agriculture Organization, Rome, 2023).
  7. R. Rajab, M. Kahfi, A. Muis, Penanganan sampah wadah pestisida pada daerah pertanian di Desa Kassi Kecamatan Rumbia Kabupaten Jeneponto. *Jurnal Ilmiah Amanah Akademika.* **3**, 43-49 (2020).
  8. A. Bondori, A. Bagheri, M. S. Allahyari, C.A. Damalas, Pesticide waste disposal among farmers of Moghan Region of Iran: Current Trends and Determinants of Behavior. *Environmental monitoring and assessment.* **191**, 1-9 (2019).
  9. M. Alfani, A.A. Ichwan, D. Rahmayani, I. Ulumuddin, S.R.P.U. Purwanto, N. Lusiana, Analisis tingkat kepedulian masyarakat Desa Jeladri Winongan, Kabupaten Pasuruan terhadap kesehatan lingkungan. *Jurnal Kesehatan Lingkungan Mandiri.* **3**, 17-31 (2024).
  10. Bappenas. Manfaat ekonomi, sosial, dan lingkungan dari ekonomi sirkular di Indonesia, (Bappenas, Jakarta, 2021).
  11. C. Ponce-Caballero, F. Cardeña-Echalaz, G. Giacomán-Vallejos, M. Vega de Lille, V. R. Góngora-Echeverría, Pesticide management and farmers' perception of environmental and health issues due to pesticide use in the state of Yucatán, Mexico: A study case. *Rev. Int. Contam. Ambiental.* **38**, 289–300 (2022).
  12. L. Yan, X. Zhao, D. Zhang, J. Deng, Y. Zhang, Associated factors of pesticide packaging waste recycling behavior based on the Theory of Planned behavior in Chinese fruit farmers. *Sustainability.* **14**, 10937 (2022). <https://doi.org/10.3390/su141710937>
  13. J.F. Hair, G.T. M. Hult, C.M. Ringle, M.A. Sarstedt, Primer on partial least squares structural equation modeling (PLS-SEM) (3rd ed.), (Sage Publications, 2022).
  14. M. Li, J. Wang, K. Chen, L. Wu, Willingness and Behaviors of farmers' green disposal of pesticide packaging waste in Henan, China: A Perceived value formation mechanism perspective. *Int J Environ Res Public Health.* **17** (2020).
  15. J. Hair, A. Alamer, Partial least squares structural equation modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. *Research Methods in Applied Linguistics.* **1**, 100027 (2022).