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Enhancing sustainable practices for pesticide management and packaging disposal in rice cultivation: A case study of Bac Tan Uyen District, Binh Duong Province, Vietnam

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Vietnam's agricultural reliance, particularly on rice cultivation, raises concerns about pesticide usage and its packaging disposal, vital for sustainable and safe practices. This study focused on Bac Tan Uyen District in Binh Duong Province, Vietnam, assessing current practices, challenges, and opportunities for improvement in pesticide management. Through interviews with 100 rice farming households and rigorous data analysis, the study reveals the extensive use of 44 pesticides and 39 active ingredients (AIs) in the district. Notably, practices varied concerning pesticide choice, application, post-spraying actions, protective gear usage, and handling of pesticide packaging. The study highlights alarming trends like the utilization of hazardous AIs and improper disposal methods like burning or leaving empty pesticide containers in fields. However, positive aspects, such as high adherence to designated bins for empty containers (93%), were identified. The results emphasize the urgency of enhancing awareness and implementing sustainable practices for safe pesticide use and packaging disposal, crucial for environmental preservation and human health in rice cultivation.
Keywords: Pesticide use, pesticide packaging, rice cultivation, Binh Duong, Vietnam.

INTRODUCTION

Vietnam's economy relies heavily on its agricultural sector, which accounts for approximately 12% of the country's GDP (GSO, 2022). Rice remains the primary crop, occupying nearly 25% of the total agricultural land (GSO, 2022). Smallholder farmers in Vietnam, who are mainly rice cultivators, heavily rely on agriculture as their primary source of income (Kien, 2021). The main focus of strategies aimed at increasing agricultural production has been on intensifying rice farming through the adoption of high-yielding rice varieties and the increased use of agrochemicals (UNEP, 2005; Huan *et al*., 2008; Phong *et al*., 2010). Pesticides play a crucial role in modern agriculture, protecting crops from pests, diseases, and weeds (Damalas, 2009). However, their indiscriminate and excessive use can have negative impacts on human health, the environment, and the economy (Damalas, 2009). Rice cultivation relies heavily on the use of pesticides (Berg and Tam, 2012). In this context, the management of pesticide packaging is also a critical aspect of pesticide use, as it can significantly affect the safety and sustainability of rice production systems.

Pesticide packaging is an essential component of the pesticide supply chain, as it ensures the safe transport, storage, and disposal of pesticides. The packaging also plays a critical role in reducing the risks of contamination, exposure, and accidents associated with pesticide use. However, the disposal of pesticide packaging can pose significant environmental and health risks if not managed properly. In particular, improper disposal of pesticide packaging can lead to soil and water contamination, wildlife poisoning, and human health hazards (Jin *et al*., 2018). In developed countries, professional organizations are responsible for collecting packages, but in developing countries like Vietnam, the smallholder context presents a significant challenge to waste collection efforts.

Therefore, there is an urgent need for sustainable and safe pesticide use and packaging disposal management practices in rice cultivation. The effective management of pesticide use

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and packaging disposal can help reduce the negative impacts of pesticide use on the environment, protect human health, and promote sustainable rice production systems. This paper aims to access the current state of pesticide use and pesticide packaging disposal in rice cultivation in Bac Tan Uyen District, Binh Duong Province, Vietnam, identify the challenges and opportunities for improvement, and propose recommendations for sustainable and safe pesticide packaging disposal management practices.

MATERIALS AND METHODS

Study area: Bac Tan Uyen District lies to the east of Binh Duong Province in Vietnam, adjacent to the Dong Nai River and Be River in Vinh Cuu District, Dong Nai Province. The region benefits from year-round alluvial deposits from these rivers, fostering favorable conditions for agricultural growth. Presently, the agricultural sector stands as the primary economic driver in Bac Tan Uyen District, contributing significantly to its economic structure, with an agricultural production value reaching 2,765 billion VND in 2022, marking an average annual increase of 7.6%. Farming constitutes 78.58% of this value, while livestock raising accounts for the remaining 21.42%. Rice cultivation spans approximately 760 ha in the district, primarily concentrated in three communes: Lac An (279.80 ha), Tan My (130.82 ha), and Thuong Tan (349.38 ha).

***Rice farming household interviews*:** Data concerning pesticide utilization, agricultural management strategies, and work-related health risks associated with pesticide exposure in rice cultivation were gathered via structured interviews conducted within Bac Tan Uyen District. These interviews involved 100 rice farming households across three communes - Lac An, Thuong Tan, and Tan My - over the period between January and May 2023. Sample size formula is determined and followed by Yamane (1967):

$$n = \frac{N}{1 + N(e)^2}$$

With N as the household number in Lac An, Thuong Tan, and Tan My (which was 4,753 in 2022), and e representing the level of precision (set at 0.1), the required sample size, denoted as n, is 100. The People's Committees of the communes supplied the list of rice farming households. Using this list, the author conducted a random selection of 100 farmer households for interviews. All farmers clearly understood the content and purpose of the survey and participated voluntarily. The details acquired about pesticide usage encompassed the active components, application quantities, application methods, frequency per crop cycle, intervals between applications, and approximate application dates. Moreover, the interviews sought information on health concerns among workers, encompassing risks and impacts of pesticides on their well-being, both in the short and long term, and specifically, the prevalent negative health symptoms experienced by these farmers.

Data analysis: The interview data were compiled to record the AIs and their respective quantities applied per hectare per crop. Pesticide products containing multiple AIs were disaggregated into individual components based on information from producers. All application records were categorized into single-application instances of a particular AI per rice field within a season (with up to three crops per year). The calculation for the amount of pesticide AI utilized was determined using the following formula:

$$W_{AI} = \frac{\sum_{i=1}^{n} W_i \times P_{AI}}{S}$$

Where W_{AI} represents the quantity of AI used (g/ha); W_i signifies the quantity of pesticide used containing the AI of the farmer i (g); P_{AI} denotes the percentage of AI in the pesticide product (%); and S represents the total area over which the AI was applied (ha).

All data were statistically analyzed using one-way analysis of variance (ANOVA) and Tukey's post hoc ANOVA test for individual comparisons ($P < 0.05$, level of significance). SPSS 13.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

RESULTS AND DISCUSSION

Background information of rice farmers: Approximately 88% of farmers in the study are aged over 40, with the majority falling within the 50-59 age group (43%). Male farmers make up 96% of the sample. In terms of education, only 17% have completed high school, while 40% have received secondary education, 39% have primary education, and 4% have had no formal schooling. All farmers possess more than 20 years of experience in rice farming. The average farm size remains small, around 1 hectare, primarily due to the land tenure policy of the Vietnam Government (Escalada *et al.*, 2009). This is consistent with the findings of Berg and Tam (2012). Most farmers own their farms, and the average household size is 5 persons.

Pesticide patterns use: Out of the 100 farmers surveyed, a collective use of 44 distinct pesticides and 39 different AIs was identified in Bac Tan Uyen District (Table 1), which is lower compared to the number of AIs utilized in rice cultivation in the Mekong River Delta (54 AIs) (Dirikumo, 2023). All pesticides used in Bac Tan Uyen District are permitted in Vietnam according to the regulations of the Ministry of Agriculture and Rural Development (MARD, 2022). These pesticides are diverse and can be categorized into five groups of uses: herbicides, insecticides, fungicides, molluscicides, and rodenticides (Table 1). However, among the 39 active ingredients used, 10 are prohibited in numerous countries worldwide. Specifically, chlorfluazuron, coumatetralyl, glufosinate ammonium, propiconazole, and propineb are banned in 28 countries; brodifacoum and pymetrozine in 30 countries; butachlor and flocoumafen in 31 countries; and carbosulfan in 41 countries (Phong and Thong, 2020). Reducing pesticide use in Vietnam poses a significant challenge, given its deeply ingrained practices among rice farmers. However, the actual situation indicates that the Vietnamese Government has made noteworthy efforts to eliminate highly hazardous pesticides in the agricultural sector. According to the 2019 list published by the Ministry of Agriculture and Rural Development, there are a total of 503 mono-active ingredients categorized into pesticides (133 active ingredients), fungicides (157 active ingredients), and herbicides (85 active ingredients). The reality suggests that monitoring the combination of these mono-active ingredients into active groups is challenging. The list of highly hazardous pesticides permitted for use in 2019 in Vietnam indicates 1,804 active groups and 4,021 trade names, with 82 fewer active groups than in 2018 and 579 fewer trade names than in 2017.

Among the AIs used, there were two Ia (extremely hazardous) AIs: brodifacoum and flocoumafen, both utilized in rodenticides. Rodents inflict notable preharvest harm to low-land irrigated rice fields in Vietnam, contributing to approximately 10% of crop damage annually (Singleton, 2003). In the Red River Delta, individual farmers may encounter damage rates as substantial as 100%, with a considerable number experiencing recurrent rat-related crop damages (Tuan *et al*., 2003). Notably, flocoumafen, which is banned in 31 countries (Phong and Thong, 2020), is employed by up to 83% of farmers (Table 1). Flocoumafen stands out as a highly potent anticoagulant rodenticide, proving effective against various economically significant species, even those with warfarin-resistant strains. Its exceptional single-feed potency, coupled with intrinsic palatability, makes it particularly suitable for pulse baiting. Marketed as Storm under the Shell trademark, the wax-bound block represents the primary bait formulation chosen for commercial use. Recent advancements in formulation development enhance resistance to attacks by insects and fungi, and the addition of a bitter taste acts as a human deterrent without compromising the bait's appeal to rodents. Flocoumafen's exceptional efficacy is supported by numerous field trials (Johnson, 1988). In the United Kingdom, the utilization of flocoumafen is comparatively limited (Dawson *et al.*, 2001; Olney *et al.*, 1991; Thomas and Wild, 1996), and instances of its presence in predatory birds and mammals are infrequent (Shore *et al.*, 2003a and b; Walker *et al.*, 2007 and 2008a and b). The unexpectedly high usage of flocoumafen in Bac Tan Uyen District raises apprehensions regarding the potential risks to non-target organisms resulting from the use of anticoagulant rodenticides. This is especially concerning as this particular compound exhibits greater toxicity and persistence compared to other second-generation anticoagulant rodenticides approved in Vietnam (Fisher *et al.*, 2003; Parmar *et al.*, 1987). There were two AIs of Group Ib (highly hazardous) used in Bac Tan Uyen District: coumatetralyl in rodenticides and abamectin in insecticides (Table 1). Abamectin, recognized for its broad-spectrum insecticidal properties (Ananiev *et al.*, 2002), is frequently employed for managing the brown planthopper, *Nilaparvata lugens*. However, its application resulted in a reduction in both the parasitism rate and the emergence of progeny from the brown planthopper parasitoid (*Anagrus nilaparvatae*), as indicated by Sasmito *et al.* (2017). Abamectin is also commonly used in insecticides in rice fields in Indonesia (Luo *et al.*, 2013). While coumatetralyl, one of the first-generation anticoagulant rodenticides, is a multiple-dose anticoagulant belonging to the 4-hydroxycoumarin vitamin K antagonist category. Rodenticides containing coumatetralyl are extensively used in other provinces within the Mekong Delta region, such as Dong Thap and Hau Giang (Dirikumo, 2023).

Within rice cultivation in Bac Tan Uyen District, farmers employed 15 AIs classified under Group II (moderately hazardous), 8 from Group III (slightly hazardous), and 10 from Group U (unlikely to present acute hazard) (Table 1). Among these AIs, azoxystrobin, difenoconazole, hexaconazole, propiconazole in fungicides, carbosulfan, chlorfluazuron in insecticides, and fenclorim, pretilachlor in herbicides were utilized by all surveyed farmers. These specific AIs are also commonly used by most farmers in the Mekong Delta for rice cultivation (Dirikumo, 2023). This comprehensive dataset sheds light on the diverse range of pesticide AIs employed by farmers to manage various agricultural challenges, encompassing disease and pest control, as well as weed management.

The utilization of hazardous pesticide AIs in rice cultivation raises pressing concerns regarding its profound implications for both the environment and human health. Environmentally, the indiscriminate use of these pesticides may lead to biodiversity loss, soil contamination, and water pollution (Dirikumo, 2023; Phong and Thong, 2020; Shore *et al.*, 2003b) jeopardizing ecosystems' delicate balance and long-term agricultural sustainability. Human health is similarly at risk, with potential exposure through pesticide residues in rice, endangering consumers and posing occupational hazards for farmworkers (Phong and Thong, 2020; Dasgupta *et al.*, 2007). Moreover, the development of resistance in pests and the long-term degradation of the environment underscore the urgent need for sustainable alternatives and integrated pest management practices in rice cultivation. Transitioning towards environmentally friendly approaches is paramount to mitigating the far-reaching consequences of hazardous pesticides on both ecosystems and public health.

Table 1. The pesticides used by rice farmers in Bac Tan Uyen District, Binh Duong Province.

Pesticides	Active ingredient	% farmers using	WHO classification*
Herbicides (14)			
Ankill A 40WP	Quinclorac	2	III
	Bensulfuron Methyl	2	U
Bigson-fit 300EC	Pretilachlor	5	U
	Fenclorim	5	U
Butanil 55EC	Butachlor	8	III
	Propanil	8	II
Cantanil 550EC	Butachlor	33	III
	Propanil	33	II
CoChay 200SL	Diquat Dibromide	3	II
Dietmam 360EC	Pretilachlor	6	U
	Fenclorim	6	U
Facet 25SC	Quinclorac	1	III
Khai Hoang Q7 (Newfosinate 150SL)	Glufosinate Ammonium	10	III
Nominee 10SC	Bispyribac Sodium	19	III
Platin 55EC	Butachlor	12	III
	Propanil	12	II
Push 330OD	Cyhalofop butyl	1	U
	Ethoxysulfuron	1	III
Pyanchor 5EC	Pyribenzoxim	5	n.a.
Satunil 60EC	Thiobencarb	3	II
	Propanil	3	II
Sofit 300EC	Pretilachlor	94	U
	Fenclorim	94	U
Insecticides (11)			
Angun 5WG	Emamectin Benzoate	23	II
Brightin 4.0EC	Abamectin	3	Ib
Chess 50WG	Pymetrozine	20	III
Karate 2.5EC	Lambda Cyhalothrin	5	II
Marshal 200SC	Carbosulfan	3	II
Reasgant 5WG	Abamectin	18	Ib
Sulfaron 250EC	Carbosulfan	100	II
	Chlorfluazuron	100	U
Takumi 20WG	Flubendiamide	37	III
Tasieu 1.9EC	Emamectin Benzoate	15	II
Terin 50EC	Permethrin	1	II
Virtako 40WG	Chlorantraniliprole	41	U
	Thiamethoxam	41	II
Fungicides (14)			
Amistar Top 325SC	Azoxystrobin	100	U
	Difenoconazole	100	II
Anvil 5SC	Hexaconazole	78	III
Bump 650WP	Tricyclazole	15	II
	Isoprothiolane	15	II
CureGold 375SC	Azoxystrobin	65	U
	Difenoconazole	65	II
	Hexaconazole	65	III
Filia 525SE	Propiconazole	22	II
	Tricyclazole	22	II
Flint Pro 648WG	Propineb	1	U
	Trifloxystrobin	1	U
Kasumin 2SL	Kasugamycin	36	U
Mekongvil 5SC	Hexaconazole	2	III
Nativo 750WG	Tebuconazole	17	II
	Trifloxystrobin	17	U
Physan 20SL	Quaternary Ammonium Salt	65	n.a.
TilFuGi 300EC	Difenoconazole	1	II
	Propiconazole	1	II
Tilt Super 300EC	Difenoconazole	89	II
	Propiconazole	89	II
Totan 200 WP	Bronopol	92	II
TT-biomycin 40.5WP	Bronopol	1	II
Molluscicides (2)			
Helix	Metaldehyde	15	II
Toxbait 120AB	Metaldehyde	77	II
Rodenticides (3)			
Klerat	Brodifacoum	4	Ia
Racumin	Coumatetralyl	11	Ib
Storm	Flocoumafen	83	Ia

**WHO classification: Ia - Extremely hazardous; Ib - Highly hazardous; II - Moderately hazardous; III - Slightly hazardous; U - Unlikely to present acute hazard (WHO, 2020). n.a., not available*

Reasons for selection, dosage, and application methods of pesticides: Rice farmers in Bac Tan Uyen District opt for specific pesticides based on several primary factors. The foremost determinant is the perceived effectiveness of the pesticides, scoring an average rating of 4.74 out of 5 (Figure 1). The effectiveness of pesticides also remains the paramount factor in the pesticide selection process for vegetable-growing households in Thua Thien Hue Province (Chau *et al.*, 2019). Another pivotal factor is consultation with pesticide agents, garnering a rating of 4.58 out of 5 (Figure 1), indicating substantial reliance on professional guidance. Additionally, farmers heavily consider their own prior experiences, with an average rating of 4.21 out of 5 (Figure 1), shaping their preferences. Price of pesticides is another influential aspect, scoring 4.02 out of 5 (Figure 1), indicating a balance between effectiveness and cost. Meanwhile, price is considered the second most important factor after the effectiveness of pesticides in the research conducted by Chau *et al.* (2019). Surprisingly, conversely, the origin and manufacturer hold moderate importance, scoring 2.74 out of 5 (Figure 1). Concerns regarding the toxicity of pesticides to the environment and human health are notably lower, echoing the findings of Chau *et al.* (2019), with a rating of 2.24 out of 5 (Figure 1).

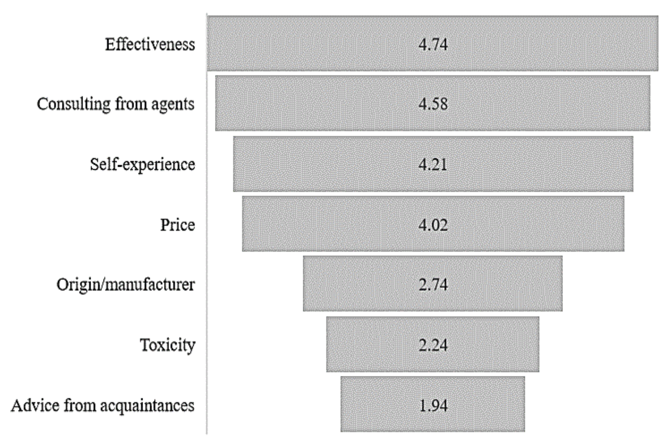

Figure 1. Reasons for choosing pesticides (from 1 - extremely unimportant to 5 - extremely important)

Farmers primarily rely on instructions found on product packaging (86%) and advice from pesticide agents (86%) for their pesticide application techniques. Adhering to the recommended dosages on packaging helps farmers prevent overdosing, which can result in pesticide residues on crops and in the environment. The study findings also revealed that 42% of farmers applied pesticides based on their own past experiences. Chau *et al.* (2019) similarly highlighted that farmers rely on pesticide usage based on packaging instructions, personal experiences, and advice from pesticide agents. Additionally, 11% of farming households in Bac Tan Uyen District rely on dosages recommended through media sources like TV, radio, and the internet. Surprisingly, advice from agricultural extension officers holds the lowest percentage (2%), indicating their limited influence in guiding farmers on pesticide use in rice cultivation within Bac Tan Uyen.

Utilizing interview data regarding cultivated areas, pesticide application frequency, and dosage, coupled with AI concentration data, this investigation computed the total weight of AIs employed by farmers across the entire crop, detailed in Table 2. The results show that each AI was used in several pesticides, with relatively large fluctuations. Notably, four AIs (cyhalofop butyl, ethoxysulfuron, permethrin, and propineb) were utilized only once. Thiobencarb emerged as the greatest volume used AI, reaching 1,015 g/ha in application. This compound is a component of the herbicide Satunil 60EC but was adopted by only 3% of the surveyed farmers.

Notably, the findings revealed that all surveyed farmers opted to combine various pesticides during a single spraying session to tackle multiple pests simultaneously (74%), streamline the spraying process to save time and effort (68%), and enhance the overall effectiveness of the pesticides used (39%). These practices reflect the farmers' pursuit of optimizing pest control measures while efficiently managing their agricultural resources. However, indiscriminate mixing of pesticides can pose risks to human health and the environment, potentially increasing pesticide residues in the surroundings.

The study outlined the post-spraying practices adopted by farmers concerning residual pesticides (Table 3). A significant majority (71%) indicated their tendency to spray until the pesticide sprayers were completely exhausted, highlighting a utilization strategy maximizing product usage. Additionally, a notable proportion (23%) resorted to spraying other crops, potentially increasing pesticide drift and residual contamination. Concerningly, a small yet concerning percentage (6%) opted to dispose of remaining pesticides by pouring them into the ground, canals, or ditches, which poses environmental risks due to leaching and contamination. Regarding pesticide rinsing water, a predominant practice (61%) involved direct pouring onto the fields, likely contributing to soil and water contamination. Notably, 24% disposed of this wastewater by pouring it into tree stumps within the garden, while 15% directed it into nearby canals, ditches, or rivers. Furthermore, storage practices for pesticides varied: a majority (55%) adhered to separate storage spaces, mitigating risks of accidental exposure, while smaller percentages stored pesticides in the porch (19%), garden (15%), or even the kitchen (11%), potentially increasing the likelihood of accidental poisoning and environmental contamination. These diverse practices underscore the need for targeted education and improved management practices to minimize environmental and health risks associated with pesticide handling and disposal.

Table 2. Actual weight of AIs used by farmers

No.	Active ingredient	Weight (g/ha)		LD_{50}
		Mean	SD	(mg/kg)
1	Abamectin	23	2	8.7
2	Azoxystrobin	138	8	>5,000
3	Bensulfuron Methyl	30	5	>5,000
4	Bispyribac Sodium	20	4	2,635
5	Brodifacoum	0.076	0.012	0.3
6	Bronopol	53	3	254
7	Butachlor	572	21	3,300
8	Carbosulfan	88	8	250
9	Chlorantraniliprole	22	6	>5,000
10	Chlorfluazuron	24	3	8,500
11	Coumatetralyl	1.125	0.366	16
12	Cyhalofop butyl	105	-	>5,000
13	Difenoconazole	80	5	1,453
14	Diquat Dibromide	863	10	231
15	Emamectin Benzoate	20	3	53-237
16	Ethoxysulfuron	11	-	3,270
17	Fenclorim	146	8	>5,000
18	Flocoumafen	0.015	0.003	0.25
19	Flubendiamide	31	8	>2,000
20	Glufosinate Ammonium	437	72	>1,500
21	Hexaconazole	64	6	2,180
22	Isoprothiolane	117	12	≥300
23	Kasugamycin	28	4	>10,000
24	Lambda Cyhalothrin	20	5	c56
25	Metaldehyde	548	107	227
26	Permethrin	200	-	c220
27	Pretilachlor	316	57	6,100
28	Propanil	466	166	c1,400
29	Propiconazole	44	7	1,520
30	Propineb	613	-	8500
31	Pymetrozine	139	12	D>2,000
32	Pyribenzoxim	28	3	>5,000
33	Quaternary Ammonium Salt	133	27	110
34	Quinclorac	170	20	2,680
35	Tebuconazole	6	1	1,700
36	Thiamethoxam	22	6	871
37	Thiobencarb	1,015	255	1,300
38	Tricyclazole	201	29	305
39	Trifloxystrobin	29	1	>5,000

Table 3. Farmers' pesticide practices in Bac Tan Uyen District.

Issues	Practices	Share (%)
Residual pesticides after spraying	Spray until finished	71
	Spray other crops	23
	Pour into the ground, canals, ditches	6
Pesticide rinsing water	Pour directly into the field	61
	Pour into tree stumps in the garden	24
	Pour into the canals, ditches, rivers	15
Storing pesticides	Separate storage	55
	Porch	19
	Garden	15
	Kitchen	11

Pesticides exposure: In efforts to reduce the impact of pesticide exposure, a majority reported using fundamental protective gear such as masks (71%) and hats (39%). However, the utilization of gloves (9%), glasses (2%), and shoes (1%) was notably less common among respondents. Consistent findings were observed in Dasgupta *et al.* (2007). It's notable that 23% of surveyed farmers did not employ any personal protective equipment during pesticide application (Fig. 2). The majority of farmers hold the belief that modern pesticides pose no threat to human health or the environment. Remarkably, all interviewed farmers seemed unaware of the potential health risks associated with pesticide exposure, both for themselves and consumers. This aligns with the findings reported in Hoi *et al.* (2009).

Figure 2. A farmer did not use personal protective equipment when spraying pesticides.

Farmers generally believe that their exposure to pesticides has minimal impact on their health, citing the absence of acute symptoms (87%) despite frequent exposure. Among the reported symptoms, neurological issues such as headaches (8%) and dizziness (2%), along with ocular irritation (3%), were the most commonly mentioned. Dermal problems like skin irritation and respiratory issues such as shortness of breath were not reported in Bac Tan Uyen District. These findings indicate significantly lower symptom rates following pesticide exposure among farmers in Bac Tan Uyen compared to those reported in studies by Dasgupta *et al.* (2007) and Du and Phuong (2003).

Pesticides packaging: The findings revealed varied practices among farmers regarding the handling of pesticide packaging post-use. A significant majority (93%) demonstrated adherence to placing empty pesticide containers into designated bins, indicating an awareness of proper disposal practices. In addition, local management agencies have constructed numerous bins and warehouses designated for the storage of used pesticide packaging (Figure 3). Pesticide packaging storage bins should exhibit the following characteristics: 1) Positioned in appropriate and easily identifiable locations along roadsides, intra-field traffic axes, and large field edges; situated away from flooding, in proximity to the pesticide preparation point; ensuring no adverse impact on domestic water sources, residential areas, traffic, and the rural landscape; 2) Constructed from durable materials resistant to corrosion, preventing leakage and chemical reactions with the waste contained inside; waterproof to prevent waste absorption to the exterior; secured against movement by wind or water; 3) Designed in a tubular or rectangular shape with a capacity of approximately 0.5-1 m^3, featuring a tight lid, bin wall's wide at least 5 cm; and 4) Displaying on the exterior the words "bin for storing pesticide packages after use" and a danger warning symbol compliant with Vietnamese Standard TCVN 6707:2009. However, concerning practices were observed: a notable proportion engaged in burning (22%) or leaving empty pesticide containers in the fields (22%), potentially contributing to environmental pollution and health hazards. Concerns arise from burning residual pesticides in containers, potentially releasing toxic compounds like polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) either through vaporization or formation from pesticide byproducts (Ramadan *et al.*, 2022). These persistent organic pollutants are resistant to degradation, remaining in the environment for decades and accumulating in the fatty tissues of organisms, leading to various detrimental impacts on behavior, reproduction, and development (El-Shahawi *et al.*, 2010). The extreme persistence of PCDDs/PCDFs contributes to their toxicity and carcinogenic potential in living organisms, originating from anthropogenic activities like waste combustion without adequate safety measures (Mukerjee, 1998). Additionally, a considerable percentage (19%) sold the used packaging to scrap dealers, leading to potential environmental contamination and health risks if not appropriately managed. A smaller percentage (5%) resorted to burying the containers, while an even smaller fraction (3%) disposed of them by throwing into nearby canals, ditches, or rivers, exacerbating water pollution risks. The environmental impact of these discarded pesticide packages is evident: residues contaminate the water and soil ecosystem, posing risks to the health of both humans and animals (Jin *et al.*, 2018). Moreover, given that most of these packages are composed of non-biodegradable plastic, their presence is likely to persist, adversely affecting water and soil quality. In this context, the utilization of biodegradable plastics has emerged as a feasible remedy (Liu *et al.*, 2014). Yet, its practicality diminishes when applied to pesticide packaging, considering the specific characteristics of the plastics needed. Consequently, plans need to be established for the systematic collection of this dispersed plastic waste to ensure proper disposal. Furthermore, a minimal percentage (3%) opted to reuse the empty containers, a practice that might result in cross-contamination or accidental pesticide exposure. In 2008, FAO/WHO issued guidelines that delineate various management strategies and established practices for the collection, recycling, and disposal of pesticide containers. The guidelines also highlight successful programs in developed nations like Germany, Canada, Australia, and France (FAO/WHO, 2008). Literature affirms that in the absence of such programs, pesticide containers are prone to causing pollution in both land and water. Similar observations are documented for countries such as Oman (Al Zadjali *et al.*, 2013), South Africa (Dalvie *et al.*, 2006), Ethiopia (Mengiste *et al.*, 2016), and Tanzania (Nonga *et al.*, 2011).

Figure 3. Designed warehouse and bins for used pesticide packaging and containers.

These findings underscore the need for comprehensive education and awareness campaigns regarding proper pesticide packaging disposal to mitigate adverse environmental and health impacts associated with improper disposal practices. Initiatives should be developed to educate farmers, pesticide retailers, and communities about the environmental consequences of improper pesticide container disposal. Specialized training programs for farmers must emphasize proper handling, cleaning, and recycling methods, stressing the potential risks of inadequate disposal and promoting eco-friendly practices. Community workshops and events should be organized to engage local residents in discussions on sustainable waste management, encouraging their active participation. Establishing dedicated collection centers in agricultural areas, collaborating with retailers, advocating for stringent government regulations, and incorporating environmental labels on pesticide products are essential strategies. Additionally, ongoing research into alternative, eco-friendly packaging materials is crucial. Regular monitoring and evaluation of these initiatives will ensure their effectiveness, fostering a culture of responsible waste management and reducing the environmental impact of pesticide packaging.

Conclusion: The study has illuminated the complexities surrounding pesticide use and packaging disposal in Bac Tan Uyen District, Binh Duong Province, Vietnam. It has identified critical areas of concern, notably the widespread use of various pesticides encompassing 44 pesticide products and 39 AIs. Furthermore, the findings have highlighted prevalent farming practices, showcasing both positive approaches, such as the high adherence (93%) to guidelines for disposing of empty pesticide containers and packaging in designated bins, and concerning behaviors, notably the burning and improper disposal of pesticide containers.

Despite some positive practices and an overall awareness of certain safety measures, gaps in knowledge and risky behaviors were apparent. Farmers' reliance on effectiveness and professional advice for pesticide selection underscored a need for greater education on the potential risks these chemicals pose to both health and the environment. Additionally, the study highlighted the need for improved protective measures during pesticide handling and emphasized the importance of targeted education to ensure safe disposal practices.

Future researchs should focus on exploring innovative collection and recycling systems, along with assessing socio-economic factors influencing farmers' adoption of sustainable practices, is crucial. Additionally, leveraging technology, such as mobile applications, for improved disposal processes warrants investigation. Collaborative efforts involving government bodies and local communities are essential for creating effective, culturally sensitive strategies for sustainable pesticide packaging management in rice cultivation.

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