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Behavior-Based Risk Assessment of Indirect Pesticide Exposure Among Older Adults Residing in Agricultural Families in Ubon Ratchathani Province, Thailand

Laksanee Boonkhao[1*], Sasithon Thomsri[1], Siriprapa Wongprasan[1], Udomporn Khanthong[1], Sitthichai Chaikhan[1], Pongsak Rattanachaikunsopon[2], Sanguansin Ratanalert[1]

[1] College of Medicine and Public Health, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand
[2] Department of Biological and Health Science, Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand

Corresponding Author Email: luksanee.b@ubu.ac.th

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ABSTRACT

The study aimed at evaluating household-behavior risk to indirect pesticide exposure in older adults and quantifying the associated risk levels utilizing the Occupational Health and Safety Assessment Series 18001 (OHSAS 18001) framework. This study employed a survey research design to assess indirect pesticide exposure prevention strategies among older adults residing in agricultural families. Data was collected using a questionnaire, focusing on household-level activities that influence exposure risk. Although the majority of the participants demonstrated robust adherence to recommended preventative measures (>95%), a number of risky behaviors continued to occur. These encompassed direct interactions with farmers before changing clothes (9.6%), drying contaminated garments within domestic spaces (8.4%), and exchanging personal belongings (7.6%). A total of 235 risk issues were detected, with 58.3% categorized as moderate risk, 14.5% as high risk, and 6.8% as extremely high risk. High-risk and extremely high-risk behaviors were primarily associated with contaminated clothing, the inadequate storage of agricultural implements, and the sharing of housing areas. The findings indicated a considerable knowledge-practice gap and underscored home behavioral pathways as the key factors in indirect pesticide exposure among older adults. Interventions must emphasize behavior-focused instructions and structural alterations to mitigate take-home contamination.

1. INTRODUCTION

The widespread application of pesticides is a vital element of global agricultural output, especially in nations with intensive crop production systems [1, 2]. Despite their economic advantages, pesticides provide significant risks to human health and environmental safety owing to their acute and chronic toxicities [3-5]. National surveillance data from several countries, including Thailand, have indicated a sustained increase in pesticide imports and poisoning incidents, underscoring ongoing exposure risks for both agricultural workers and their family members residing near farming operations [6, 7]. These hazards are especially concerning for older adults, a demographic group that is quickly increasing worldwide and is physiologically more susceptible due to age-related decreases in metabolic, neurological, and immunological functions [8-10]. Although research has primarily concentrated on occupational exposure among farmers, a growing body of evidence has indicated that indirect or secondary pesticide exposure within households represents a neglected yet substantial public health issue. Indirect exposure may arise through various channels, including contaminated clothing introduced into the household, inadequate storage of agricultural implements, pesticide residues on surfaces, air and dust contamination, and proximity to the farmers shortly after the application of pesticides [11, 12]. These exposure pathways provide significant risks for older adults who may spend extended periods indoors, possess restricted mobility, or lack awareness of the latent dangers inherent in their regular activities.

Although there are chemical-safety education programs in numerous farming areas, prior research has indicated that mere knowledge is inadequate to guarantee safe household activities [13, 14]. Significant discrepancies persist between awareness and actual behaviors, especially concerning clothing management, personal cleanliness following pesticide use, and the communal utilization of household products. Behavioral deficiencies can maintain chronic, low-level exposure conditions that lead to enduring health consequences, such as neurological impairment, endocrine disruption, and heightened vulnerability to environmental toxins [15, 16].

In semi-urban agricultural communities, where agricultural zones are located close to residential areas, the likelihood of indirect exposure is significantly heightened [17]. Older adults in these environments sometimes reside in multigenerational households alongside active farmers, resulting in inadvertent

exposure to pesticide residues transferred from the fields into living areas. Nonetheless, household-level risk evaluations targeting older adults remain limited, especially those that utilize systematic, internationally acknowledged risk-assessment frameworks.

The northeastern region of Thailand has the highest proportion of farmers, with Ubon Ratchathani Province, particularly the Hua Ruea Subdistrict, functioning as a significant semi-urban agricultural hub. The area comprises lowland plains conducive to agriculture and livestock farming, which are enhanced by natural water sources and drainage canals. According to the June 2025 report from Hua Ruea Subdistrict Health Promoting Hospital, Hua Ruea has a population of approximately 9,419 residents distributed across 16 villages. The majority of these residents rely on agriculture as their primary occupation. The extensive use of organophosphate pesticides in this region is raising considerable concerns over indirect household exposure, especially among those agricultural families living adjacent to the treated fields. Pesticide exposure may occur both directly and indirectly. Indirect exposure frequently occurs unintentionally. For example, using chemical-handling equipment at home or storing and discarding chemical containers in a home might result in spills or airborne chemicals that contaminate the environment and come into contact with household residents. Additionally, farmers' homes may become contaminated by chemicals from their bodies, skin, and clothing while they are working. As a result, chemicals may spread throughout the living area, exposing residents to the substances. Older adults residing in these households may exhibit heightened vulnerability to chronic, low-level exposure due to age-related physiological changes and frequent participation in domestic tasks that increase contact with contaminated clothing, equipment, and indoor dust. Notwithstanding these risks, scientific data about the magnitude and characteristics of indirect pesticide exposure in older adults remains insufficient. The Occupational Health and Safety Assessment Series 18001 (OHSAS 18001)-based risk matrix was focused on identifying and prioritizing household behaviors and environmental conditions associated with indirect pesticide exposure. The framework provides a systematic method for hazard identification and risk ranking in situations where quantitative exposure measurements are unavailable.

This study evaluated the risks associated with indirect pesticide exposure among older adults residing in agricultural households. The researchers adapted the approach to evaluate risk in older adults living in homes, taking into account the likelihood and severity of events, based on the risk assessment criteria of the Department of Industrial Works, Thailand, in compliance with OHSAS 18001 framework.

2. METHODOLOGY

This study utilized a survey research design to evaluate indirect pesticide exposure prevention strategies among older adults living in agricultural families. The data were gathered via a structured assessment questionnaire designed in alignment with the OHSAS 18001 framework, concentrating on household-level activities that affect exposure risk. The survey was administered at the residences of older adults residing in the Hua Ruea Subdistrict of Ubon Ratchathani Province, Thailand, from October 2025 to February 2026.

2.1 Population and sample

The target demographic consisted of older adults aged 60 and above, who were living in agricultural families that were frequently utilizing pesticides in the Hua Ruea Subdistrict of Ubon Ratchathani Province, Thailand. Local administrative records indicated that the studied region had 1,777 older adults across 16 villages, all of which were situated within an agricultural community marked by extensive pesticide use. In each chosen household, the eldest qualifying older adult was appointed as the respondent to ensure uniformity and to reduce intra-household variability.

$$n = \frac{NZ^2\alpha/2[p(1-p)]}{[e^2(N-1)] + [Z^2\alpha/2[p(1-p)]]}$$

$$= \frac{1777(1.96)^2[0.589(1-0.589)]}{[0.059^2(1777-1)] + [(1.96)^2[0.59(1-0.59)]]} = 232$$

The sample size was calculated utilizing the formula for calculating a population percentage, employing n = 232, N = 1777, Zα/2 = standard normal value at confidence level 95% (α = 0.05, Z = 1.96), an estimated proportion of high-level pesticide related behaviors (p = 0.589) derived from existing literature [18], and a margin of error established at 10% of p. Upon applying the finite population correction, the minimum requisite sample size was determined to be 232 participants. To address potential non-response and fieldwork discrepancies, an additional 5% was incorporated, resulting in a final target sample of roughly 250 participants.

Table 1. Number of participants in each village

Village	Number of Older Adults (Persons)	Number of Participants (Persons)
Village No. 1	149	21
Village No. 2	150	21
Village No. 3	111	16
Village No. 4	126	18
Village No. 5	177	25
Village No. 6	111	16
Village No. 7	148	21
Village No. 8	65	9
Village No. 9	80	11
Village No. 10	75	11
Village No. 11	153	22
Village No. 12	105	15
Village No. 13	85	12
Village No. 14	88	12
Village No. 15	81	11
Village No. 16	73	10
Total	**1,777**	**251**

The stratified random sampling within each village was done according to Table 1 by calculating the population proportion in 16 villages; thereafter, the simple random sampling was applied to collect the data. The participation criteria consisted of the following: (1) being an adult aged 60 years or older, (2) being the eldest of the older adults in the family, (3) being a resident for a minimum of six months, and (4) being capable of communicating and providing informed consent. Individuals exhibiting significant cognitive deficits, communication obstacles, or acute medical conditions that prevented participation were excluded.

2.2 Research tools

Three principal study instruments were utilized to gather data and evaluate indirect pesticide-exposure risks in older adults. All instruments were created in accordance with recognized occupational health and safety standards and conformed to the OHSAS 18001 risk-assessment framework.

1. The General Information Questionnaire: A systematic questionnaire was employed to gather the demographic and health-related data from participants. The tool of 8 items featured multiple-choice questions regarding sex, age, household size, and chronic illnesses, etc.

2. The Hazard Identification Checklist: The checklist functioned as the principal instrument for delineating behavioral routes that enable the transmission of pesticides into residential settings. Each participant was assessed using a 20-item household behavior checklist. Responses indicating compliance with the recommended preventive behavior were classified as safe practices and were not subjected to further risk assessment. Responses indicating non-compliance (unsafe practices) identified from the checklist were considered potential hazards. Each identified hazard was subsequently evaluated using a risk matrix based on the likelihood of occurrence and the severity of potential consequences (Table 2). Risk levels were determined according to the criteria presented in Table 3.

Table 2. The likelihood and severity matrix for hazard evaluation

Likelihood	Severity			
	Low (1)	Moderate (2)	High (3)	Extremely High (4)
Frequently (4)	4	8	12	16
Occasionally (3)	3	6	9	12
Unlikely (2)	2	4	6	8
Rarely (1)	1	2	3	4

Table 3. The risk level categorization for indirect pesticide exposure

Risk Scores	Risk Levels
1–2	Low
3–6	Moderate
8–9	High
12–16	Extremely high

3. The OHSAS 18001-based Risk Assessment Form: A universal risk assessment form was modified from the Department of Industrial Works (Thailand) to evaluate the risk severity and to prioritize hazardous behaviors, in accordance with the OHSAS 18001 requirements. The instrument evaluated two dimensions: (1) the likelihood of occurrence (four levels: rare to frequent) and (2) the severity of the consequences (four levels: low to extremely high). Risk scores were calculated by multiplying the likelihood and the severity (Table 2). Then the scores were classified into four categories: low (1–2), moderate (3–6), high (8–9), and extremely high (12–16) (Table 3). This facilitated the accurate measurement of the household pesticide exposure hazards and the identification of behaviors requiring prompt intervention.

2.3 Quality assessment of the research tool

The checklist and questionnaire's content validity was assessed by three specialists in occupational health, environmental health, and pesticide safety. Modifications were implemented based on the experts' suggestions. Furthermore, the Index of Item Objective Congruence (IOC) values varied from 0.67 to 1.00, signifying acceptable validity.

2.4 Data collection and analysis

Data collection was conducted via individual household visits, which were conducted in cooperation with village health volunteers (VHVs), who enabled community access and aided in finding qualifying families. Before the fieldwork commenced, all research assistants underwent uniform training to guarantee the consistent implementation of the survey instruments and compliance with the ethical protocols.

The hazard identification checklist was finalized by conducting participant interviews and by direct observations of households, which allowed the study team to verify the actual practices that were related to pesticide management, contamination routes, and household environmental conditions. Subsequent to the hazard identification process, the OHSAS 18001-compliant risk assessment form was utilized to assess both the likelihood and the severity of the identified hazards. The research team thoroughly evaluated each behavioral component identified as a potential risk by using the established criteria to generate risk scores.

2.5 Data analysis

The data were examined utilizing descriptive statistical methods. Normally distributed variables were presented with means and standard deviations, while non-normally distributed variables were summarized with medians, interquartile ranges, minimums, and maximums.

In the hazard identification checklist, each of the 20 behavioral components was designated as a binary variable (1 = Safe practice observed, 0 = Unsafe practice observed). Frequencies and percentages were computed to determine the prevalence of both safe and risky household behaviors contributing to indirect pesticide exposure among older adults. Risk assessments were conducted by the research team based on both participant interviews and direct household observations. To minimize subjectivity, all identified hazards were reviewed and discussed among the investigators, and final risk scores were assigned through consensus according to the predefined scoring criteria. In addition, the risk assessment instrument and scoring framework were reviewed by experts in occupational health, environmental health, and pesticide safety during the content validation process. Risk scoring was performed using a standardized assessment guide adapted from the Department of Industrial Works (Thailand) and the

OHSAS 18001 risk assessment framework. The guide specified operational definitions for each likelihood level (rare, unlikely, occasional, and frequent) and severity level (low, moderate, high, and extremely high).

The behavioral items were subsequently grouped into five indirect pesticide exposure pathways according to the primary contamination route represented by each behavior. This classification was used to facilitate visualization and interpretation of exposure pathways in the Sankey diagram.

2.6 Ethical aspects

The protection of the rights of the volunteers who participated in the project was taken into consideration. On September 11, 2025, the Human Research Ethics Committee of Ubon Ratchathani University gave its approval to this study, which was given the project number: UBU-REC-177/2568.

3. RESULTS

3.1 Demographic and health characteristics

A total of 250 older adults participated in the study. The majority were female (57.6%), with a median age of 67 years (range: 60–93). The median household size was four members. More than half of the participants (57.6%) reported having no chronic diseases. Among the 106 participants who reported at least one chronic disease, hypertension and diabetes were the most commonly reported (both at 51.9%). A substantial proportion (94.0%) had previously received training or information related to pesticide safety, primarily from the subdistrict health-promoting hospitals (85.1%). Most participants (88.4%) reported no acute symptoms that were potentially related to pesticide exposure within the preceding month. All details are presented in Table 4.

3.2 Household behaviors related to indirect pesticide exposure

The behavioral assessment revealed a high compliance with several recommended preventive practices. More than 95% of households reported the following: (1) separating the older adults' bedrooms from those areas used to store pesticide-contaminated equipment (98.4%), (2) requiring farmers to wash their hands before eating with older adults (98.4%), and (3) maintaining designated storage areas for agricultural tools (97.6%). Similar levels of compliance were observed for separating the drinking containers, properly washing all produce, and accessing safe sources of water (approximately 96%).

Despite these positive findings, several unsafe behaviors were identified. Of the older adults, 9.6% reported close contact with farmers returning from pesticide spraying before changing clothes. In addition, 8.4% of households dried pesticide-contaminated clothing within the residential compound, while 7.6% shared personal items, such as towels, soap, or bedding. These practices represent key pathways for secondary contamination and indicate gaps between the training that had been received and the daily household routines. All details are presented in Table 5.

Table 4. The demographics and health characteristics of the older adults (n = 250)

Demographics and Health Characteristics	Numbers	Percentages (%)
Genders		
Female	144	57.6
Male	106	42.4
Age: Median = 67, IQR = 10, min = 60, max = 93		
Number of household members: Median = 4, IQR = 3, min = 1, max = 8		
Chronic diseases		
No	144	57.6
Yes	106	42.4
Common chronic diseases (n = 106) (More than one response allowed)		
High blood pressure	55	51.9
Diabetes	55	51.9
High cholesterol	6	5.7
Thyroid disease	3	2.8
Kidney disease	3	2.8
Liver disease	1	0.9
Received knowledge or had training about pesticides		
Yes	235	94.0
No	15	6.0
Sources of information/training about chemicals (more than one could be answered)		
Subdistrict health promoting hospital	200	85.1
Subdistrict administrative organization/municipality	84	35.7
Public health office	49	20.9
Agricultural office	41	17.4
Symptoms within the past month		
No unusual symptoms	221	88.4
Stinging nose, burning eyes, dizziness, headache, itchy skin	25	10.0
Seizures, unconsciousness, shock, irregular heartbeat	3	1.2
Blurred/dark vision, chest pain/tightness, diarrhea, vomiting, hand tremors	1	0.4

Table 5. Preventive household behaviors related to indirect pesticide exposure among older adults

Lists	Safe Practice Observed (%)	Unsafe Practice Observed (%)
B1. Older adults' sleeping areas are separated from locations used to store pesticide-contaminated clothing and equipment.	98.4	1.6
B2. Farmers, who have completed pesticide application, ought to wash their hands with soap prior to dining with older adults.	98.4	1.6
B3. Agricultural equipment is stored in a designated area separate from spaces regularly used by older adults.	97.6	2.4
B4. Separate drinking water containers are provided for pesticide applicators and older adults.	97.6	2.4
B5. Clothing used during pesticide application is kept separate from clothing worn by older adults.	97.2	2.8
B6. Farmers' work clothing is stored away from food preparation and dining areas.	97.2	2.8
B7. Older adults use safe water sources and avoid entering areas recently treated with pesticides.	97.2	2.8
B8. Serving spoons are routinely used during shared household meals.	96.8	3.2
B9. Prior to intake, farm-fresh fruits and vegetables are regularly cleansed or washed by utilizing vinegar, baking powder, potassium permanganate, or salt.	96.4	3.6
B10. Farmers' work clothing is stored separately from areas regularly used by older adults.	95.6	4.4
B11. Household containers are not used for mixing or preparing pesticides.	95.2	4.8
B12. Household living areas, including kitchens and living rooms, are regularly cleaned to reduce pesticide residue accumulation.	94.4	5.6
B13. Following pesticide application, the availability of a designated shower and changing facility is ensured for household members.	94.0	6.0
B14. Separate cleaning materials are used for household cleaning and for removing pesticide residues from equipment.	93.2	6.8
B15. Wastewater from cleaning pesticide equipment is disposed of in a location away from residential living areas.	93.2	6.8
B16. Used pesticide containers are disposed of safely and are not burned near residential areas.	92.8	7.2
B17. Used pesticide containers are not reused for household purposes.	92.8	7.2
B18. Personal belongings (e.g., towels, soap, bedding) are not shared between pesticide-exposed household members and older adults.	92.4	7.6
B19. Pesticide-contaminated work clothes are dried outside residential living areas.	91.6	8.4
B20. Older adults avoid close contact with farmers until they have changed clothes after pesticide application.	90.4	9.6

Behavioral items were grouped according to their primary indirect pesticide exposure pathway. Classification was based on the most likely route by which pesticide residues could be transferred from agricultural activities to older adults within the household. All details are presented in Table 6. The Sankey diagram illustrates the distribution of hazards across primary pathway categories that are linked to 20 behavioral risk factors, where node size and flow thickness proportionally represent the hazard frequency. Analysis revealed five distinct source categories from 235 risk issues, in which Hygiene & Sanitation and Direct contact were equally predominant at n = 63 each (26.8% of the total risk issues, respectively). These were followed by Food & Water (n = 55, 23.4%) and Storage & Equipment (n = 45, 19.2%), with environmental factors showing the lowest contribution (n = 9, 3.8%) (Figure 1).

Table 6. Classification of household behavioral items according to indirect pesticide exposure pathways

Exposure Pathway	Behavioral Items
Household environment	B1, B10, B12, B19
Hygiene & sanitation	B2, B9, B13, B18
Direct contact	B5, B20
Food and water contamination	B4, B7, B8, B11
Storage & equipment management	B3, B6, B14, B15, B16, B17

3.3 Risk assessment of indirect pesticide exposure

Across the 250 participants, 235 risk issues from 62 households were identified by the 20-item household behavior checklist. Each unsafe response was treated as one hazard and subsequently evaluated using the risk assessment matrix. Three behaviors requiring structural household modifications demonstrated critically high-risk profiles, with 75-80% of observed hazards classified as high severity or extremely high severity: separate storage for agricultural tools (80%), separate drinking containers (75%), and proper wastewater disposal systems (75%). In contrast, frequently occurring behaviors showed predominantly moderate risk distributions, consisting of using designated shower facilities (84%), using serving spoons (81%), and washing fresh produce (82%). This dichotomy between high-severity infrastructure deficits and moderate-severity behavioral gaps suggested the need for dual intervention strategies that can address both structural modifications and educational reinforcement (Figure 2).

The Bubble chart displays the negative correlation between the frequency of occurrence and the average risk score across 20 indirect pesticide exposure behaviors among older adults (n = 62 households, 235 risk issues). Bubble size represents the frequency magnitude. The colors indicate the various risk categories: yellow (moderate, scores 3-6), orange (high, scores 8-9), and orange-red (extremely high, scores 12-16). The red broken line marks the high-risk threshold (score ≥ 8). High-risk behaviors with low frequency (B3, B4, B15) indicated infrastructure gaps that require urgent intervention, while low-risk behaviors with high frequency (B5, B12) reflected the existing practices that are effective. However, the red color begins at the score of 12 per OHSAS 18001 standards, and the

observed data ranged from 3.38 to 10.50 (Figure 3).

Across the 250 participants, a total of 235 risk issues were identified from the risk matrix approach. Most of the risks were classified at the moderate level (58.3%), followed by the low level (20.4%), the high level (14.5%), and the extremely high level (6.8%). All details are presented in Table 7.

The behaviors most commonly associated with high-risk scores included drying contaminated garments in the house and utilizing household containers to prepare the pesticides. Items classified as extremely high risk encompassed the following: (1) the absence of designated storage zones for agricultural equipment in proximity to older adults' residences, (2) a lack of distinct sleeping quarters for older adults that are separate from pesticide contaminated materials, and (3) the sharing of personal items, such as towels or soap, with household members, who have been exposed to pesticides.

Table 7. The distribution of the indirect pesticide exposure risk levels among older adults

Risk Levels	Numbers	Percentages (%)
Extremely high	16	6.8
High	34	14.5
Moderate	137	58.3
Low	48	20.4

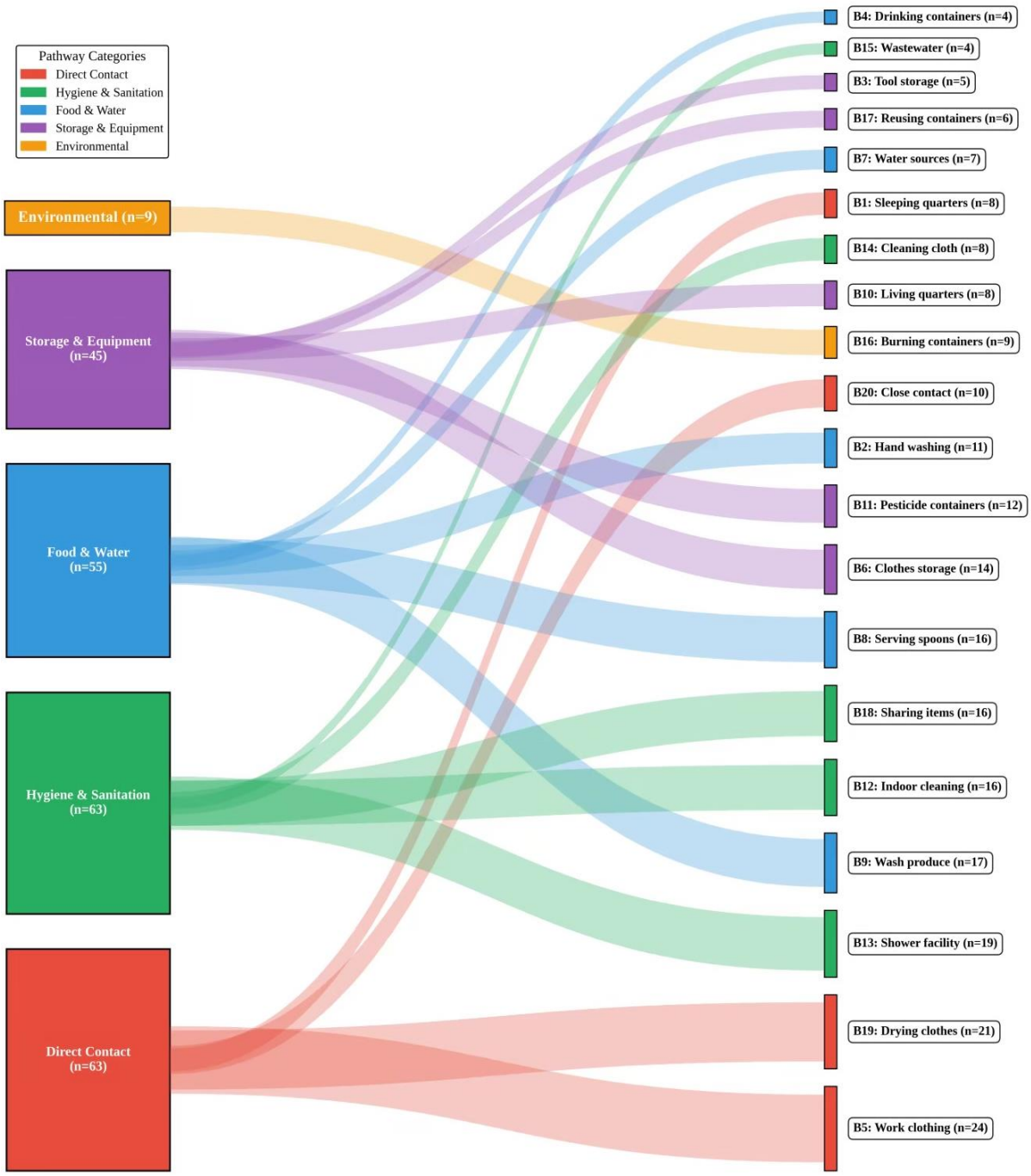

Figure 1. Hazard distribution by pathways and sources

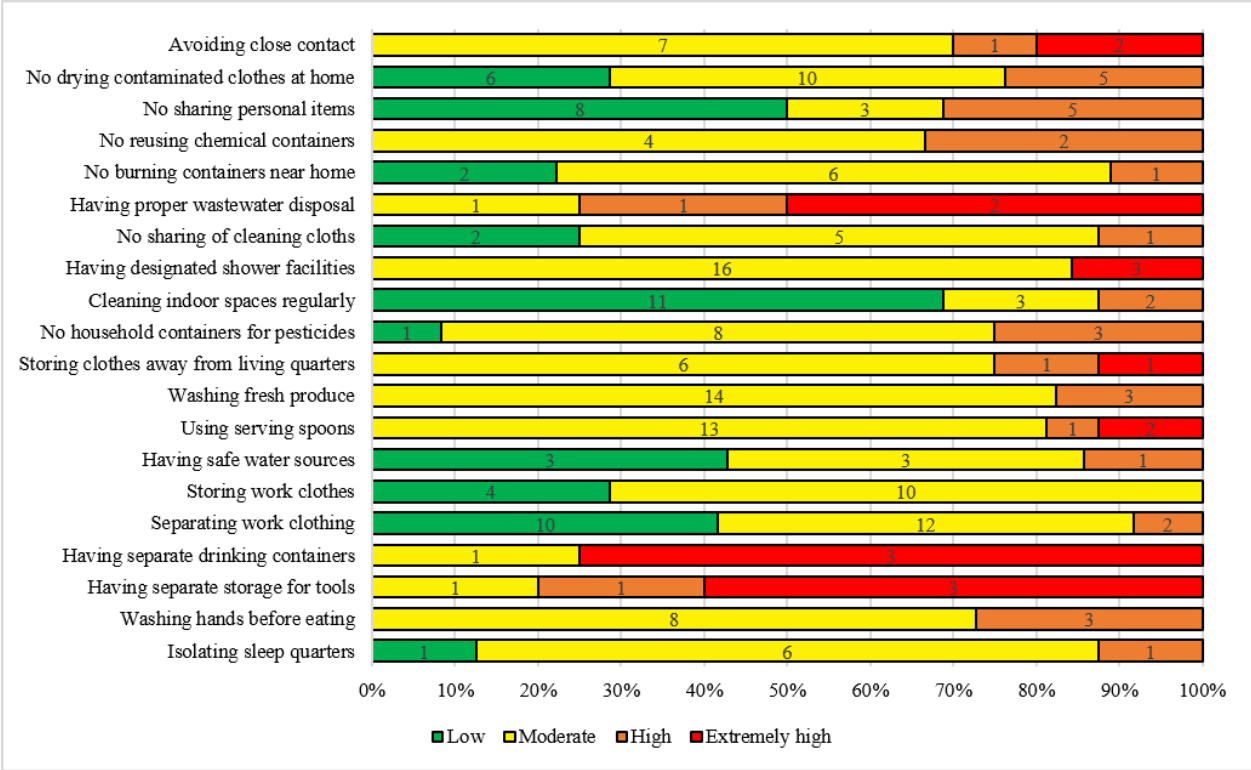

Figure 2. The stacked bar chart of risk assessment results by household behavior type

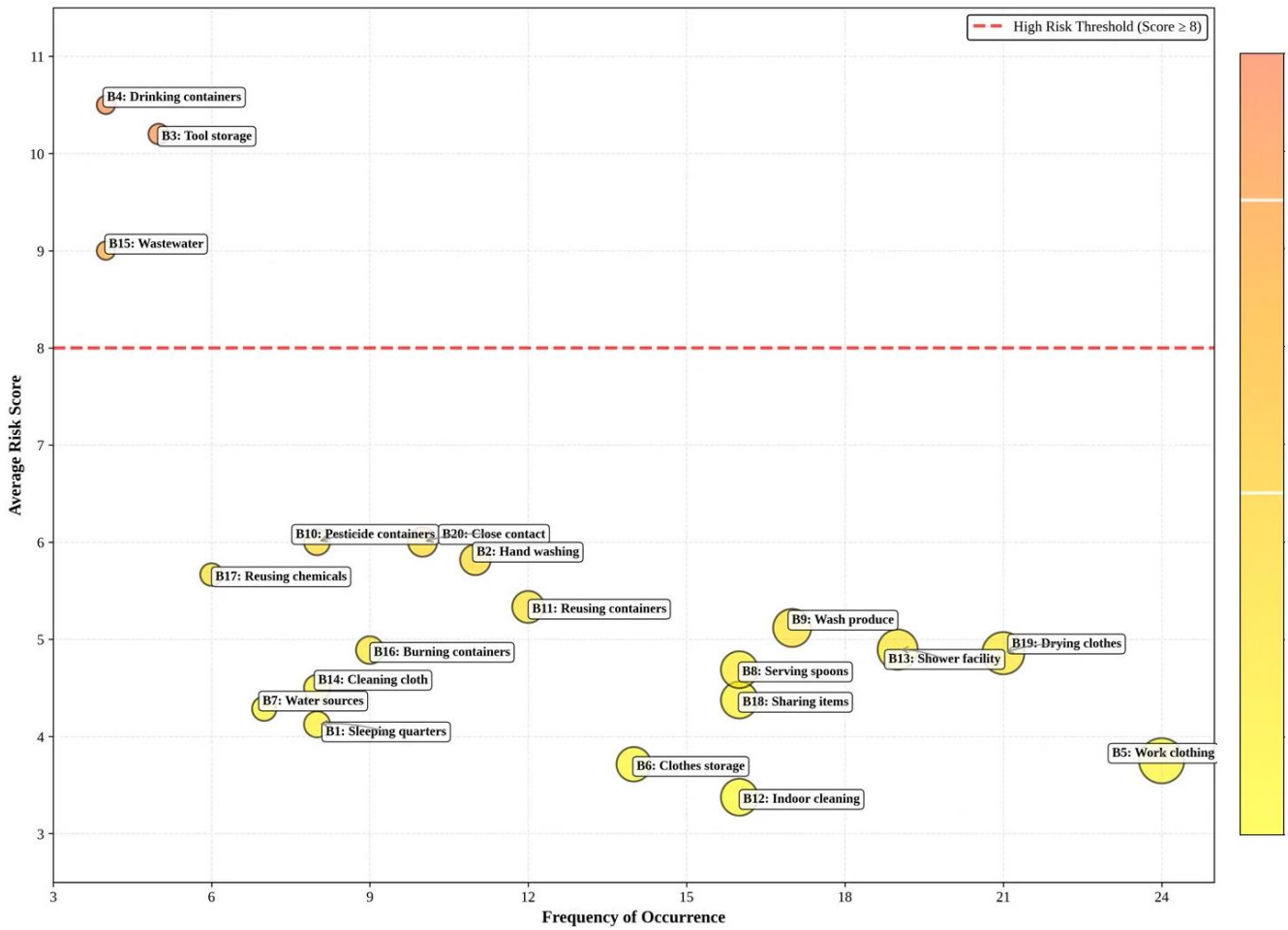

Figure 3. Distribution of risk-assessed hazards identified from 62 households with unsafe practices (235 hazards) among the 250 older adults included in the study

4. DISCUSSION

This study found that older adults living in agricultural families continue to face a risk of indirect pesticide exposure, despite a high incidence of having previously participated in chemical safety training. Despite the fact that compliance with numerous recommended preventive measures had exceeded 90%, several risk behaviors remained, especially those associated with contaminated clothing, proximity to post-spraying activities, and the sharing of household objects. The findings distinctly demonstrated a persistent knowledge-practice gap, a phenomenon that has been consistently documented in recent studies, indicating that information-based training alone is inadequate when seeking to achieve sustained behavioral changes in rural and semi-urban agricultural communities [14, 19, 20].

The Sankey diagram (Figure 1) illustrates that hygiene and sanitation, along with direct contact pathways, had been the primary contributors to home pesticide risk factors, each representing 26.8% of all detected risks. This was succeeded by food and water contamination and storage-related pathways. This pattern robustly corroborates the existing evidence that the take-home transfer of pesticides through contaminated clothing, skin contact, shared fabrics, and insufficiently segregated living spaces constitutes the primary mechanism by which pesticides infiltrate domestic environments [21, 22].

Risk categorization of the domestic activities (Figure 2) demonstrated a significant distinction between the structural restrictions and the behavioral deficiencies. Behaviors requiring physical or infrastructural modifications, such as the absence of designated storage areas for pesticide equipment, public drinking vessels, and inadequate wastewater disposal systems, have led to disproportionately raised and extraordinarily high-risk assessments. These findings corresponded with increasing regional and international evidence that environmental and housing limitations in rural areas can significantly restrict the practicality of safe pesticide handling guidelines, even among informed households [13, 18]. Conversely, the activities that occur more frequently, such as drying clothing indoors, sharing personal goods, and engaging in post-spraying interactions that are in proximity to the farmers, were predominantly situated within the moderate risk category. Yet, these had significantly contributed to overall exposure. This underscored that moderate risk behaviors, when performed daily, may contribute to chronic low-level exposure, which is particularly concerning for older adults with age-related physiological susceptibilities [9, 10].

The bubble chart analysis (Figure 3) further demonstrated an inverse correlation between the frequency of conduct and the severity of risk. Infrequent behaviors, such as inadequate equipment storage or utilizing domestic containers for pesticide formulation, correlated with elevated severity scores, which signified underlying, yet significant vulnerabilities that may be neglected in standard safety trainings. In contrast, there are high-frequency behaviors of moderate intensity, which include the procedures of doing the laundry and having interpersonal interactions immediately after farmers have sprayed. These behaviors indicate entrenched home patterns that are resistant to alteration. Comparable trends have been observed in agricultural communities in Africa, South Asia, and Southeast Asia, where households possessing sufficient pesticide knowledge still encounter difficulties in altering their culturally ingrained practices concerning clothing management, domestic hygiene, and familial interactions after the application of pesticides [16, 20].

Overall, over fifty percent of the detected risks were categorized as being moderate risk, while more than twenty percent were classified as high or extremely high, indicating that household-level exposure pathways represent the primary source of indirect pesticide risk for older adults. The findings aligned with the international literature, which identified contaminated clothes, communal living environments, and inadequately designated storage locations as significant reservoirs of pesticide residues that impact vulnerable communities [21, 22].

A limitation of this study is that the OHSAS 18001 based risk matrix evaluates behavioral and environmental risk factors rather than actual pesticide exposure doses. Therefore, the risk classifications should be interpreted as relative indicators for prioritizing preventive interventions and not as direct measures of toxicological risk. Future studies should combine behavioral assessment with environmental sampling, biomonitoring, or pesticide-exposure models to improve exposure characterization. Furthermore, the risk classification relied on expert judgment using a structured risk matrix rather than direct exposure measurements. Although standardized scoring criteria and consensus review procedures were applied, formal inter-rater reliability testing was not performed. Future studies should evaluate inter-rater agreement and incorporate quantitative exposure assessments to improve the robustness of risk estimation. Moreover, because this study employed a cross-sectional design and relied on behavioral assessments and risk scoring, the findings should not be interpreted as evidence of actual pesticide exposure levels or causal health effects. The identified hazards represent potential exposure pathways that warrant further investigation using environmental monitoring and biomarker-based exposure assessments.

5. CONCLUSIONS

This study demonstrated that older adults living in agricultural households remain vulnerable to indirect pesticide exposure despite widespread participation in pesticide-safety training programs. Although most households reported compliance with recommended preventive practices, several critical behaviors continued to present substantial risks.

Priority intervention should focus on the highest-risk household conditions identified in this study, particularly the lack of designated storage areas for agricultural equipment, inadequate separation between living spaces and pesticide-contaminated materials, and the sharing of personal items with pesticide-exposed family members. Additional high-priority behaviors included drying contaminated work clothes within residential areas, using household containers for pesticide preparation, and maintaining close contact with farmers immediately after pesticide application.

To reduce take-home pesticide contamination, households should establish separate storage facilities for agricultural equipment, designate changing and shower areas for pesticide applicators, separate contaminated clothing from household laundry, avoid indoor drying of work garments, and minimize contact with pesticide applicators until they have changed clothes and completed personal hygiene procedures. These targeted interventions should be prioritized in community health promotion and agricultural safety programs to better

protect older adults from indirect pesticide exposure.

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REFERENCES

[1] Ismael, Nion, C., Isasa, I. (2024). Spatial distribution of pesticide use based on crop rotation data in La Plata River basin: A case study from an agricultural region of Uruguay. Environmental Monitoring and Assessment, 196(7): 633. https://doi.org/10.1007/s10661-024-12759-z

[2] Zhou, W., Arcot, Y., Medina, R., Bernal, J., Cisneros-Zevallos, L., Akbulut, M. (2024). Integrated pest management: An update on the sustainability approach to crop protection. ACS Omega, 9(40): 41130-41147. https://doi.org/10.1021/acsomega.4c06628

[3] Garud, A., Pawar, S., Patil, M.S., Kale, S.R., Patil, S. (2024). A scientific review of pesticides: Classification, toxicity, health effects, sustainability, and environmental impact. Cureus, 16(8): e67945. https://doi.org/10.7759/cureus.67945

[4] Pengpan, R., Kopolrat, K.Y., Srichaijaroonpong, S., Taneepanichskul, N., Yasaka, P., Kammoolkon, R. (2024). Relationship between pesticide exposure factors and health symptoms among chili farmers in Northeast Thailand. Journal of Preventive Medicine and Public Health, 57(1): 73-82. https://doi.org/10.3961/jpmph.23.353

[5] Muñoz-Bautista, J.M., Bernal-Mercado, A.T., Martínez-Cruz, O., Burgos-Hernández, A., et al. (2025). Environmental and health impacts of pesticides and nanotechnology as an alternative in agriculture. Agronomy, 15(8): 1878. https://doi.org/10.3390/agronomy15081878

[6] Laohaudomchok, W., Nankongnab, N., Siriruttanapruk, S., Klaimala, P., et al. (2020). Pesticide use in Thailand: Current situation, health risks, and gaps in research and policy. Human and Ecological Risk Assessment, 27(5): 1147-1169. https://doi.org/10.1080/10807039.2020.1808777

[7] Figueiredo, D.M., Nijssen, R., Krop, E.J.M., Buijtenhuijs, D., et al. (2022). Pesticides in doormat and floor dust from homes close to treated fields: Spatio-temporal variance and determinants of occurrence and concentrations. Environmental Pollution, 301: 119024. https://doi.org/10.1016/j.envpol.2022.119024

[8] Somboon, S., Jirapongsuwan, A., Kalampakorn, S., Tipyamongkolkul, M. (2022). Acute pesticide poisoning among mixed-crop agricultural workers in Thailand. Trends in Sciences, 19(3): 2154. https://doi.org/10.48048/tis.2022.2154

[9] Chan, L., Chi, S., Loo, T., Panirselvam, R., et al. (2023). Surveillance of pesticide poisoning in an East and a West Malaysian hospital: Characteristics of pesticide poisoning and the early impact of a national Paraquat ban. BMC Psychiatry, 23(1): 472. https://doi.org/10.1186/s12888-023-04974-8

[10] Sapbamrer, R., Sittitoon, N., Thongtip, S., Chaipin, E., et al. (2024). Acute health symptoms related to perception and practice of pesticides use among farmers from all regions of Thailand. Frontiers in Public Health, 11: 1296082. https://doi.org/10.3389/fpubh.2023.1296082

[11] López-Gálvez, N., Wagoner, R., Quirós-Alcalá, L., Ornelas Van Horne, Y., Furlong, M., Avila, E., Beamer, P. (2019). Systematic literature review of the take-home route of pesticide exposure via biomonitoring and environmental monitoring. International Journal of Environmental Research and Public Health, 16(12): 2177. https://doi.org/10.3390/ijerph16122177

[12] Kuiper, G., Young, B., Wemott, S., Erlandson, G., et al. (2022). Factors associated with levels of organophosphate pesticides in household dust in agricultural communities. International Journal of Environmental Research and Public Health, 19: 862. https://doi.org/10.3390/ijerph19020862

[13] Akkouch, N., Halwani, J., Shaarani, I. (2025). Exploring pesticide knowledge, practices, and health perceptions among farmers in Akkar, Lebanon. International Journal of Environmental Research and Public Health, 22(2): 260. https://doi.org/10.3390/ijerph22020260

[14] Karki, R., Tharu, N., Kaphle, M. (2025). Knowledge and practices regarding safe pesticide use among farmers in the Bardiya District, Nepal: A cross-sectional study. Journal of Public Health Research, 14(2): 22799036251350211. https://doi.org/10.1177/22799036251350211

[15] Sonowal, S., Mridusmita, D., Himadree, P., Gunjan, J., Monika, J. (2022). Pesticide impact on human health. International Journal of Zoological Investigations, 8(2): 717-725. https://doi.org/10.33745/ijzi.2022.v08i02.087

[16] Coleman, B., Asad, I., Heng, Y., Menard, L., et al. (2025). Pesticides and neurodevelopment of children in low and middle-income countries: A systematic review. Plos One, 20(6): e0324375. https://doi.org/10.1371/journal.pone.0324375

[17] Dereumeaux, C., Fillol, C., Quenel, P., Denys, S. (2020). Pesticide exposures for residents living close to agricultural lands: A review. Environment International, 134: 105210. https://doi.org/10.1016/j.envint.2019.105210

[18] Thupala, N., Srisookkum, T., Udomkaewkar, S., Khunyod, R., Lamluk, P., Juwa, S. (2025). Factors related to pesticide use behavior among the elderly in Na Muen District, Nan Province. Journal of Disease Prevention and Control: DPC 2 Phitsanulok, 12(2): 51-65. https://he01.tci-thaijo.org/index.php/dpcphs/article/view/274501.

[19] Keleb, A., Ademas, A., Abebe, M., Berihun, G., Desye, B., Bezie, A. (2024). Knowledge of health risks, safety practices, acute pesticide poisoning, and associated factors among farmers in rural irrigation areas of northeastern Ethiopia. Frontiers in Public Health, 12: 1474487. https://doi.org/10.3389/fpubh.2024.1474487

[20] Oshingbade, O., Moda, H., Akinsete, S., Adejumo, M., Hassan, N. (2025). Determinants of safe pesticide handling and application among rural farmers. International Journal of Environmental Research and Public Health, 22(2): 211. https://doi.org/10.3390/ijerph22020211

[21] Pascale, A., Laborde, A. (2020). Impact of pesticide exposure in childhood. Reviews on Environmental

Health, 35(3): 221-227. https://doi.org/10.1515/reveh-2020-0011
[22] Msibi, S.S., Chen, C.Y., Chang, C.P., Chen, C.J., Chiang, S.Y., Wu, K.Y. (2021). Indoor air exposure to multiple agricultural pesticides potentially posing the highest risk to young children. Aerosol and Air Quality Research, 21(9): 210062. https://doi.org/10.4209/aaqr.210062