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Prevalence and factors associated with acute pesticide poisoning among pesticide handlers at a Macadamia Estate, Northern Malawi: a cross-sectional study

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Abstract

Background

Acute pesticide poisoning (APP) remains a global public health concern. Although developing countries use only a fraction of the pesticides produced worldwide, they bear a disproportionately high burden of pesticide poisoning. Pesticide use improves agricultural productivity by reducing crop losses, but it also poses substantial risks to human health. This study determined the prevalence, symptom distribution, and exposure-related risk factors for APP among pesticide handlers at a macadamia estate in Northern Malawi.

Methods

In this cross-sectional study, 144 eligible participants were selected using stratified random sampling. Data were collected through face-to-face interviews using a structured, pretested questionnaire after written informed consent had been obtained. The questionnaire captured: demographic characteristics, signs and symptoms of APP, and exposure-related risk factors. APP was defined using the World Health Organization APP case definition matrix. Associations between exposure-related risk factors and occupational APP were assessed using multivariable binary logistic regression.

Results

APP prevalence was 63.9% (95% CI: 56.1%–71.7%), and skin irritation was the most frequently reported symptom (58.5%). Exposure-related risk factors significantly associated with APP were secondary education (AOR = 11.56, 95% CI: 3.35–39.92, $p < 0.001$), drinking water while handling pesticides (AOR = 39.58, 95% CI: 3.07–509.80, $p = 0.005$), direct contact with pesticides (AOR = 5.84, 95% CI: 1.68–20.26, $p = 0.005$), and entering treated fields immediately after pesticide application (AOR = 5.13, 95% CI: 1.49–17.70, $p = 0.01$).

Conclusions

Nearly two-thirds of pesticide handlers at the estate met the case definition for APP, indicating a substantial occupational health burden. APP was significantly associated with secondary education, drinking water while handling pesticides, direct contact with pesticides, and entering treated fields immediately after pesticide application. To reduce occupational pesticide exposure, targeted behavioral safety interventions should strengthen safe pesticide-handling practices.

Background

Pesticides are chemical substances formulated to control pests, and including herbicides, insecticides, fungicides, and bactericides (1, 2). Their use can improve agricultural productivity by reducing crop losses, but exposure during handling pose risks to human health (1, 2). Pesticide exposure can occur during and immediately after application, mixing, cleaning, and transportation (3, 4), mainly through dermal contact, inhalation, or ingestion, and may result in acute or chronic toxicity among pesticide handlers.

The World Health Organization (WHO) defines acute pesticide poisoning (APP) as any health effect or illness that occurs within 48 hours of confirmed or suspected exposure to the pesticide (1, 5, 6). Acute toxicity may present with local or systemic effects, including skin irritation, skin corrosion, headache, chest pain, cough, vomiting, diarrhea, dizziness, among others (1). WHO developed a standardized case definition matrix for APP, in which a worker reporting two or more subjective signs and symptoms within 48 hours of pesticide exposure in the previous year is classified as an APP case.

Globally, an estimated 3.54 million tons of pesticides are used in agriculture, contributing to approximately 20,000 deaths among farmers each year. About 30% of pesticide use occurs in developing countries, where more than 5 million cases of pesticide poisoning have been reported (7, 8). Over the last decade, pesticide use increased by 20% globally and by 153% in low-income countries, including Malawi (9). This pattern places agricultural workers in developing countries at increased risk of acute toxicity (2). However, despite extensive pesticide use in these settings, evidence on APP remains limited: studies from developing countries account for only 1–2% of published literature on APP and health (1, 10).

In Malawi, concerns regarding health effects of pesticide exposure are well documented (2, 11). Previous evidence suggests that only about 25% of workers use personal protective equipment (PPE) when handling pesticides, while approximately 75% report APP-related signs and symptoms (12). Despite these concerns, empirical evidence on the prevalence and determinants of APP among agricultural workers in Malawi

remains limited (5). This study therefore aimed to determine the prevalence and symptom distribution of APP; and to assess associations between exposure-related risk factors and APP among pesticide handlers at a macadamia estate in Northern Malawi.

Methods

Study design

This cross-sectional study was conducted among pesticide handlers in November 2025. **Study area**

The study was conducted at a macadamia estate in northern Malawi. The estate covers about 1730 hectares; macadamia is grown on 1,018 hectares, while other crops are grown on 712 hectares. The estate employs pesticide handlers who are involved in pesticide spraying, transportation, mixing, and storage, making it an appropriate setting for assessing occupational exposure and APP-related outcomes.

Study population

The study population comprised active pesticide handlers working at the estate. Eligible participants were workers who had handled pesticides and had worked for more than one year in their respective sections, including spraying, transportation, mixing, and storage. The time threshold was guided by the duration indicated in the standardized case definition matrix for APP.

Sampling and sample size

The study included 144 pesticide handlers. The sample size was calculated using a single population proportion formula with finite population correction, based on an assumed APP prevalence of 30.4% and allowing for a 15% non-response rate, and a 95% confidence level (13). Stratified random sampling was used to obtain proportional representation from the pesticide application, mixing, transportation, and stores sections. The sampling frame was obtained from the Human Resources Department and included all eligible pesticide handlers in these sections. The required number of participants was allocated proportionately to each stratum, after which simple random sampling was used to select participants. Each eligible worker was assigned a unique number corresponding to the sampling frame, and the final participants were selected using a random number generator.

Data collection

Data were collected through face-to-face interviews using a structured, pretested questionnaire (14, 15). The questionnaire captured participants' demographic characteristics, pesticide-handling practices, exposure-related factors, and self-reported signs and symptoms of APP. APP was defined according to the WHO standard case classification matrix as the occurrence of two or more subjective symptoms within 48 hours of pesticide exposure during the preceding year (1, 16)

Data analysis

The outcome variable was APP, coded as "1" for participants who reported two or more symptoms and "0" for those who reported one or no symptoms. Sociodemographic variables were dummy-coded, with the lowest category assigned as the reference category. Exposure risk factors were categorized as "1" for the existence of the exposure risk factor and "0" for its absence, with absence used as the reference category. The independent variables included PPE use, pesticide contact, label reading, pesticides handling practices, smoking, eating or drinking during pesticide handling, post-exposure hygiene practices, reuse of pesticide containers, and early re-entry into treated fields. Data were analyzed using Stata (Version 17, StataCorp LLC, College Station, TX). Descriptive statistics summarized participants' demographic and occupational characteristics. Associations between APP and predictor variables were first assessed using Fisher's exact test. Variables with a *p-value* of 0.20 or less were entered into a backward elimination logistic regression model to identify factors independently associated with APP (17). Adjusted odds ratios (AORs) with 95% confidence intervals were used to assess the strength of associations, and statistical significance was determined at *a p-value* less than 0.05.

Results

Demographic characteristics of the participants

Table 1 summarizes the demographic characteristics of the study participants. A total of 144 pesticide handlers enrolled in the study completed the survey, giving a response rate of 100%. Participants were aged 19–75 years, with a mean age of 34.2 ± 12.2 years; the largest age group was 26–33 years (31.3%). Most participants were male (92.4%), married (84.0%), and worked in the spraying section (93.1%).

Primary education was the most commonly reported level of schooling (63.9%), and most pesticide handlers had worked at the estate for 1–3 years (68.1%).

Table 1
Demographic characteristics of the study participants (n = 144)

Demographic characteristics	Number; n (%)
Gender	133 (92.4)
Male	11 (7.6)
Female	
Occupation	3 (2.1)
Mixing	134 (93.0)
Spraying	4 (2.8)
Transportation	3 (2.1)
Stores	
Marital status	19 (13.2)
Single	121(84.0)
Married	3 (2.1)
Divorced	1(0.7)
Widowed	
Age group (years)	42 (29.2)
18–25	45 (31.2)
26–33	17(11.8)
34–40	33 (22.9)
41–60	7 (4.9)
>60	
Education	92 (63.9)
Primary	51(35.4)
Secondary	1(0.7)
University	
Job experience (years)	98 (68.0)
1–3	25 (17.4)
4–6	7(4.9)
7–10	14 (9.7)
>10	

Prevalence of acute pesticide poisoning

Participants reported multiple signs and symptoms of pesticide exposure, number of symptoms per worker ranged from 1 to 27 with a median of 5 symptoms. Skin irritation was the most frequently reported symptom (58.5%), followed by burning eyes (52.8%) and cough (45.3%). Several other symptoms were reported by at least 20% of participants, including excessive tearing, runny nose, excessive sweating, headache, red eyes, burning nose, diarrhea, chest pain, and skin rash (Fig. 1). Less frequently reported symptoms (< 20%) included exhaustion, stomach cramps, excessive salivation, dizziness, nausea, muscle weakness, blurred vision, shortness of breath, numbness, tremor, twitching of the eyelids, staggering gait, insomnia, sore throat, vomiting, muscle cramps and seizures, with prevalence ranging from 0.9% to 19.8%.

Among the 144 pesticide handlers, 36.1% did not meet the APP case definition. Accordingly, 63.9% of participants met the APP case definition, giving an APP prevalence of 63.9% (95% CI: 56.1%–71.7%).

Factors associated with occupational acute pesticide poisoning

A higher proportion of female workers reported APP than male workers, although the association was not statistically significant (90.9% vs 61.7%, $p = 0.098$). APP was also more frequently reported among workers in the spraying section (62.2%, $p = 0.144$) and among married workers (63.6%, $p = 0.674$), but these associations were not statistically significant. By age group, the highest proportion of APP was reported among workers aged 18–25 years (71.4%). Educational level was significantly associated with APP, with APP reported among 53.3% of workers with primary education compared with 82.4% of those with secondary education ($P = 0.001$). By work experience, 58.2% of workers with less than four years of experience and 80.0% of those with 4–6 years of experience reported APP.

Self-reported use of personal protective equipment was generally high: more than 90% of pesticide handlers reported wearing coveralls, boots, gloves, chemical-resistant aprons, and face shields, although head protection use was low (19.4%). Reading pesticide labels was not significantly associated with APP ($p = 0.603$), although 61.1% of APP cases were reported among workers who read labels to understand safe handling procedures. Several pesticide-handling practices were significantly associated with APP. Almost all workers who cleaned nozzles with their mouth reported APP (93.3%, $p = 0.032$). APP was also significantly reported among workers who took a shower after handling pesticides (46.5%, $p = 0.001$), changed clothes after handling pesticides (61.4%, $p = 0.111$), and took contaminated clothes home (83.9%, $p = 0.011$), as shown in Table 2.

Table 2

Association between selected practices and occupational acute pesticide poisoning among pesticide handlers (n = 144)

Exposure risk factors	App status		p-value
	APP n (%)	No APP n (%)	
Wearing gloves	56(56)	44(44)	0.003
Wear	36(81.8)	8(18.2)	
Do not wear			
Wearing safety goggles	81(60.9)	52(39.1)	0.008
Wear	11(100)	0(0)	
Do not wear			
Wearing head protection	10(35.7)	18(64.3)	0.001
Wear	82(70.7)	34(29.3)	
Do not wear			
Getting into contact with pesticides	71(71.2)	21(22.8)	0.001
Get into contact	21(40.4)	31(59.6)	
Do not get into contact			
Smoking while handling pesticides	14(100)	0(0)	0.002
Smoke	78(60)	52(40)	
Do not smoke			
Drinking water when handling pesticides	37(97.4)	1(2.6)	0.001
Drinks	55(51.9)	51(48.1)	
Do not drink			
Eating food when handling pesticides	21(95.5)	1(4.5)	0.001
Eat or chew	71(58.2)	51(41.8)	
Do not eat or chew			
Washing hands after handling pesticides	81(60.9)	52(39.1)	0.008
Wash	11(100)	0(0)	
Do not wash			
Mixing pesticides with bare hands	28(90.3)	3(9.7)	0.001
Mix with bare hands	64(48.1)	49(51.9)	
Do not mix with bare hands			
Applying pesticides when its windy	53(67.1)	26(32.9)	0.390
Apply when windy	39(60)	26(40)	
Do not apply			
Reusing pesticide empty containers	11(91.7)	1(8.3)	0.056
Reuse	81(61.4)	51(38.6)	
Do not reuse			
Wearing chemical resistant apron	67(62)	41(38)	0.548
Wear	25(69.4)	11(30.6)	
Do not wear			
Observes re-entry period in treated fields	41(85.4)	7(14.6)	0.001

Exposure risk factors	App status		p-value
	APP n (%)	No APP n (%)	
Observe	51(53.1)	45(46.9)	
Do not observe			

After adjustment for other variables in the logistic regression model, secondary education was independently associated with APP when compared with primary education (Table 3). Workers with secondary education had higher odds of reporting APP (AOR = 11.56; 95% CI: 3.35–39.92; $p < 0.001$). Drinking water while handling pesticides was strongly associated with APP (AOR = 39.58; 95% CI: 3.07–509.80; $p = 0.005$). Direct contact with pesticides was also associated with increased odds of APP (AOR = 5.84; 95% CI: 1.68–20.26; $p = 0.005$). Similarly, entering treated fields immediately after pesticide application was associated with higher odds of APP (AOR = 5.13; 95% CI: 1.49–17.70; $p = 0.010$). Being female, work experience, cleaning nozzle with mouth, wearing gloves when handling pesticides, eating while handling pesticides, taking a shower after handling pesticides and taking contaminated clothes home were not statistically significant with reporting APP.

Table 3
Logistic regression analysis of factors associated with occupational acute pesticide poisoning (n = 144)

Exposure risk factors	AOR	95% CI	p-value
Gender	1.00		
Male			
Female	10.48	0.76–144.542	0.079
Education Level	1.00		
Primary			
Secondary	11.56	3.346–39.915	< 0.001***
Job experience	1.00		
1–3 years			
4–6 years	3.24	0.702–14.956	0.132
7–10 years	9.87	0.622–156.623	0.105
>10 years	1.28	0.187–8.771	0.8
Cleaning nozzle with mouth	1.00	0.359–58.92	0.241
Do not clean	4.60		
Clean			
Wearing gloves when handling pesticides	1.00	0.055–1.071	0.062
Do not wear	0.24		
Wear			
Getting into direct contact with pesticides	1.00	1.682–20.258	0.005
Do not get into contact	5.84		
Gets into contact			
Drinking water while handling pesticides	1.00	3.072–509.802	0.005
Do not drink	39.58		
Drink			
Eating while handling pesticides	1.00	0.255–319.512	0.226
Do not eat	9.03		
Eat			
Taking a shower after handling pesticides	1.00	0.097–1.128	0.077
Do not shower	0.33		
Shower			
Taking contaminated clothes home	1.00	0.09–1.995	0.278
Do not take	0.43		
Take			
Accessing treated fields immediately	1.00	1.485–17.704	0.01
Do not access	5.13		
Access			
*** Indicate a significant level of p < 0.001			

Discussion

This study found a high prevalence of acute pesticide poisoning (APP) among pesticide handlers, with 63.9% meeting the WHO case definition. This finding is consistent with global evidence showing that APP remains common among agricultural workers exposed to pesticides (1, 10). The high burden observed in this study suggests substantial occupational exposure and points to gaps in preventive measures during pesticide handling. A comparable prevalence of 60.3% was reported among farmers and farm workers in western Iran, while a higher prevalence of 73% has been reported elsewhere (18, 19). Other studies report even higher burdens in occupational settings, with 50–96% of APP cases attributed to occupational exposure in Tanzania and APP prevalence exceeding 90% among agricultural workers in Turkey and India (1, 19, 20). Similarly, pesticide poisoning among farmers was reported at 88% in Cambodia, while in India, 83% of APP cases were attributed to organophosphates (21, 22). The findings also align with evidence from Northeast Thailand, where APP was reported among 84.4% of chili farmers, of whom 66.7% had cholinesterase levels below normal. In Kuwait, 82% of respondents reported having experienced APP (23). Collectively, these findings suggest that pesticide handlers in several agricultural settings remain at considerable risk of pesticide-related illness. This finding underscores the need for routine APP surveillance and stronger workplace controls to reduce pesticide exposure during handling, particularly in estate-based agricultural settings where workers may face repeated exposure.

Skin irritation was the most frequently reported symptom, suggesting that dermal contact was an important route of exposure in this population. Skin irritation has been associated with exposure to pesticides such as glyphosate, karate, and cypermethrin (24). The ocular symptoms reported by workers may reflect splashes or spray drift during mixing and application. Participants also reported multiple symptoms, which may indicate repeated or poorly controlled exposure. Severe symptoms such as seizures (0.9%) and unconsciousness (0%) were rarely reported, suggesting that although APP was common, severe systemic manifestations were uncommon in this study population. Similar symptom patterns have been reported in other agricultural settings, including pesticide-related symptoms among workers exposed to carcinogenic pesticides in Morocco and skin irritation among pesticide-handling farmers in Nepal and exposed workers in Malawi (11, 25, 26). Evidence from Nepal has also linked pesticide exposure with abnormal neurobehavioural performance among farmers, including headache and impaired concentration (26, 27). These findings underline the need for stronger controls to reduce direct contact with pesticides among handlers.

Workers who had attended secondary school were more likely to report APP than those with primary education (AOR = 11.56; $p < 0.001$). One possible explanation is that workers with higher educational attainment may have greater health literacy, enabling them to recognize, interpret, and recall pesticide-related symptoms more accurately, leading to better reporting of previous exposure experiences. This explanation is consistent with evidence from Ethiopia, where workers with higher educational attainment were 20% more likely to report pesticide poisoning (28). However, findings in the literature are not consistent. Studies from Turkey and India have reported higher risks and odds of pesticide poisoning among illiterate workers and those without formal education, including a 2.5-fold higher risk reported among illiterate workers in Turkey (1, 19). In the present study, the association with secondary education may therefore reflect differences in symptom recognition and reporting rather than biological susceptibility. This finding suggests that APP prevention efforts should not rely on education level alone, but should include practical, repeated training that helps all pesticide handlers recognize symptoms early and apply safe handling practices consistently.

Drinking water while handling pesticides was strongly associated with APP (AOR = 39.58; $p = 0.005$). This practice may increase exposure through ingestion, particularly when workers drink without washing their hands or when pesticide residues on hands, clothing, or containers contaminate drinking water. Similar findings have been reported in India and North Carolina, where drinking water during pesticide handling was associated with APP (19, 29). Evidence from Brazil and Ethiopia also suggests that drinking water during pesticide handling can increase pesticide exposure and APP risk (13, 30). Pesticide residues on workers' hands or clothing may contaminate drinking water and create an oral route of exposure (31). Poor hygiene practices, including inadequate handwashing before drinking, have been linked to increased pesticide exposure among farmers (31). The frequent reporting of this behavior may partly explain the high prevalence of APP observed in this study (27). Providing designated drinking-water points with handwashing facilities at the estate could help reduce oral exposure during pesticide handling.

Entering treated fields immediately after pesticide application was associated with higher odds of APP (AOR = 5.13; $p = 0.010$), probably through dermal contact with residues on treated crops and through inhalation of pesticide vapors or drift (32, 33). Pesticide residues may remain on treated crops and be transferred to workers during subsequent farm activities if fields are accessed before the recommended re-entry interval (34). The association observed in this study is supported by evidence showing that workers who enter treated fields shortly after pesticide application may face substantially greater APP risk, partly because pesticide residues can remain on foliage and be transferred to clothing and skin when safe re-entry intervals are not followed (35–37). This reinforces the importance of enforcing re-entry periods and limiting direct contact with treated crops. These findings highlight the need to strictly enforce re-entry intervals, implement clear field-entry procedures after pesticide application, and provide suitable protective clothing when early entry into the treated field cannot be avoided (38).

Direct contact with pesticides was also independently associated with APP (AOR = 5.84; $p = 0.005$). Such contact may occur through leaking spraying equipment, spills, spray drift, or splashes during mixing and application. A Turkish study found that workers who came into direct

contact with spray solution during preparation or spraying had twice the risk of pesticide poisoning (1). During handling, pesticides may come into contact with the skin, eyes, or nose, particularly where protective clothing is inadequate or equipment is defective. Close contact with sprayed foliage also increases exposure among applicators (39). In China, direct pesticide contact was associated with pesticide poisoning among exposed workers (40). In Ethiopia, more than 80% of APP cases occurred among workers with direct contact with pesticides (28). Defective backpack sprayers have also been identified as an important source of exposure through leakage during loading, mixing, and application in the Philippines (33). Evidence from Thailand also suggests that leaking chemical containers and pesticide-soaked clothing during application substantially increase poisoning risk, with reported adjusted odds of 8.98 and 2.93, respectively (22). These findings highlight the importance of maintaining spraying equipment, reinforcing correct PPE use, and washing off any pesticide that contacts the skin or eyes immediately with clean water.

This study used the WHO APP definition to support standardized case identification and comparability with other studies. However, because APP was based on self-reported symptoms, recall bias or differences in symptom recognition among participants may have affected the findings. The cross-sectional design also limits causal interpretation of the associations observed.

Conclusion

This study found a high prevalence of APP among pesticide handlers at the macadamia estate, indicating a substantial occupational health burden in this workforce. APP was significantly associated with secondary education, drinking water while handling pesticides, direct contact with pesticides, and entering treated fields immediately after pesticide application. These findings point to the need for practical workplace interventions that reduce direct pesticide exposure, improve access to safe drinking water and handwashing facilities during work, and strengthen compliance with re-entry intervals after pesticide application. Regular refresher training and routine monitoring of pesticide-handling practices may help reduce pesticide-related illness among estate workers.

Declarations

Ethics approval and consent to participate

The Malawi University of Business and Applied Sciences Research Ethics Committee (MUBASREC) granted ethical approval (certificate number RI-2025-0045). We obtained written informed consent from all participants before data collection to ensure participation was voluntary and anonymity was assured. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests

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Author Contribution

AB conceptualized, investigated, analyzed and interpreted data as well as wrote the draft manuscript. KK and LK conceptualized, supervised, edited, revised and were major contributors in writing the manuscript. All authors read and approved the final manuscript

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Data Availability

The dataset used in the current study is available from the corresponding author upon reasonable request.

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Figures

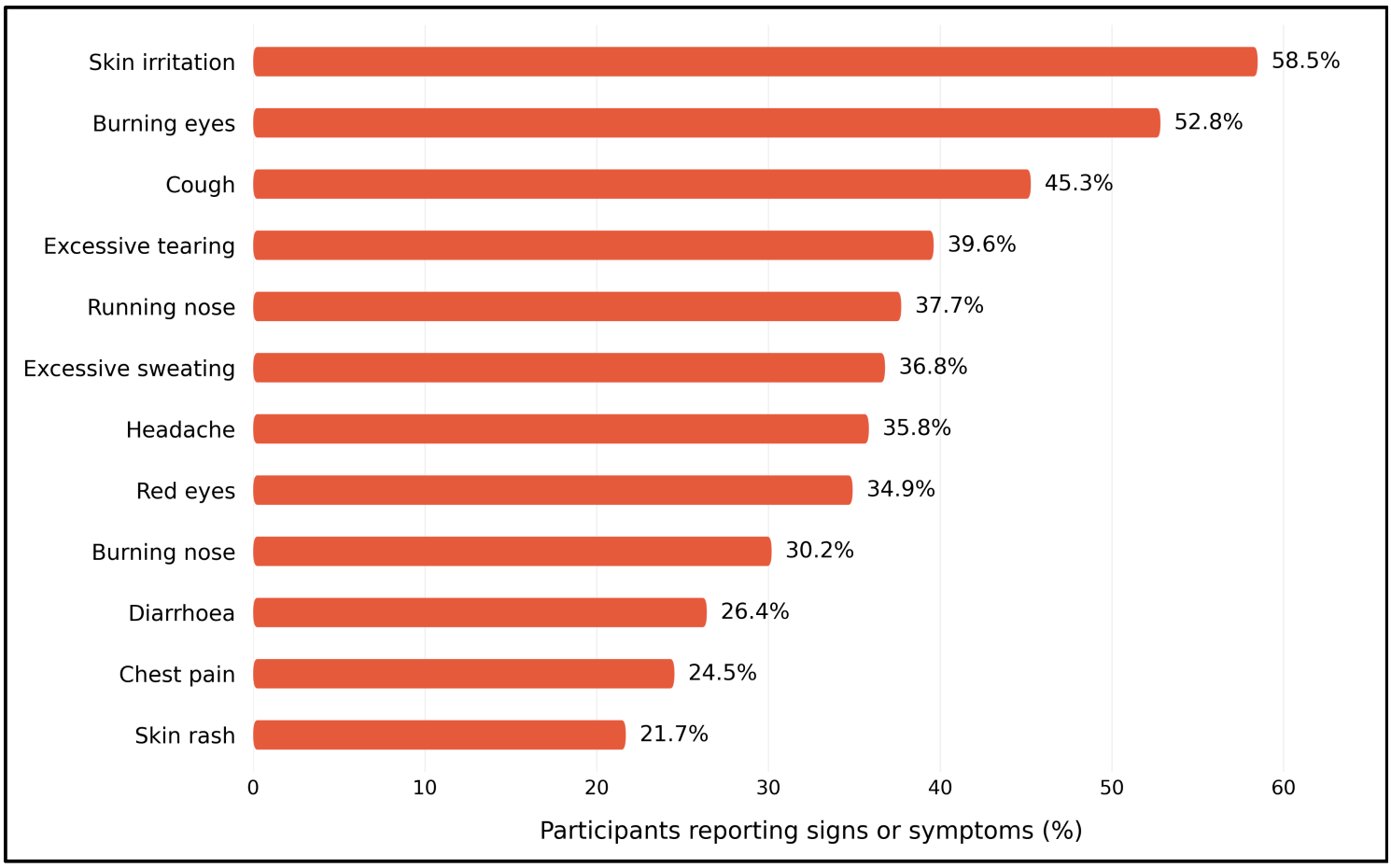


Figure 1

Most frequently reported signs and symptoms of acute pesticide poisoning among pesticide handlers (n=106)