ISSN 2985-5667 (Online) | 2985-6353 (Print) | Vol. 4, No. 3, August (2026), pp. 197-208

Published by: IARN Institute

International Journal on Health and Medical Sciences

Journal homepage: https://journals.iarn.or.id/index.php/HealMed/index

Risk analysis of unsafe actions and unsafe conditions associated with occupational accidents among patchouli oil distillery workers

Hesti[1], Hasbi Ibrahim[2], Fatmawaty Mallapiang[3], Habibi[4], La Ode Ismail Ahmad[5]

[1,2,3,4]Public Health Study Program, Faculty of Medicine and Health Sciences, Universitas Islam Negeri Alauddin Makassar, Indonesia

[5]Islamic Religious Education Study Program, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Alauddin Makassar, Indonesia

Article Info

Article history:

Received Jul 30, 2026
Revised Aug 7, 2026
Accepted Aug 18, 2026

Keywords:

HIRADC;
Occupational Accidents;
Patchouli Oil Distillation;
Unsafe Actions;
Unsafe Conditions.

ABSTRACT

Traditional patchouli oil distillation exposes workers to heat, pressure, unsafe equipment, and limited safety measures. However, studies have rarely combined worker level statistical evidence on accident related factors with task specific risk prioritization in this industry. This study examined associations between unsafe actions, unsafe conditions, and occupational accidents and identified priority risks and controls. A cross-sectional study included all 130 workers in Benua and Lalembu Districts, South Konawe Regency, Indonesia. Data were collected using questionnaires, interviews, and direct observation. Associations were assessed using chi-square tests and odds ratios with 95% confidence intervals. Hazard Identification, Risk Assessment, and Determining Control was used to connect hazard identification and likelihood severity assessment with the selection of practical controls. Overall, 73.8% reported a history of occupational accidents. Burns were most common (42.3%), and opening (58.5%) and closing (57.7%) vessels were the most accident prone activities. Unsafe actions (OR=4.10; 95% CI: 1.69–9.96; p=0.001) and unsafe conditions (OR=2.68; 95% CI: 1.13–6.35; p=0.022) were significantly associated with accidents. HIRADC generated a tas -specific hazard register, risk-priority ranking, and control plan. High priority risks included vessel explosions, hot surfaces, leakage, inadequate maintenance, and absent safety instruments and operating procedures. Integrating statistical association analysis with HIRADC provides a context-specific risk control framework for this understudied industry. The findings support engineering controls, inspections, standard operating procedures, training, supervision, and appropriate personal protective equipment, providing distillery owners and occupational health authorities with practical priorities for preventing severe accidents.

Corresponding Author:

Hesti,
Faculty of Medicine and Health Sciences,
Universitas Islam Negeri Alauddin Makassar,
Jl. H.M. Yasin Limpo No. 36, Sulawesi Selatan, 92113, Indonesia
Email: hestianinsih@gmail.com

1. INTRODUCTION

Occupational accidents remain a major public health and labour concern because they may cause injury, disability, death, productivity loss, and substantial socioeconomic consequences. Approximately 2.93 million workers die annually from work-related accidents and diseases, while 395 million sustain non-fatal occupational injuries (International Labour Organization, 2023). Occupational safety protection is particularly important in informal enterprises, where prevention systems are generally less developed. In February 2024, informal employment accounted for 59.17% of Indonesia's employed population and was more prevalent in rural areas (Badan Pusat Statistik, 2024). Informal workers frequently have limited access to safety training, social protection, hazard-control technology, and workplace inspections, leaving them exposed to occupational hazards without adequate protection (Occupational safety and health in the informal economy, 2015).

Patchouli oil distillation is an important informal economic activity in several rural areas of Indonesia, including Benua and Lalembu Districts in South Konawe Regency, Southeast Sulawesi. Patchouli farming and processing provide income for local households and contribute to the rural economy (Wulandari et al., 2018). Conventional distillation involves transporting dried leaves, preparing firewood, manually loading and sealing the vessel, maintaining combustion, separating oil from condensed water, opening the heated vessel, and removing the residue. These activities involve manual handling, open combustion, hot metal surfaces, and pressurized steam, exposing workers to burns, cuts, falls, musculoskeletal injuries, respiratory irritation, fires, and explosions. A previous local study documented an accident in which a worker fell through a deteriorated internal vessel support and came into contact with hot water while removing patchouli residue (Ekoodoh & Aswar, 2020).

These occupational hazards may result from unsafe actions, unsafe conditions, or their interaction. Unsafe actions include failing to use personal protective equipment, handling firewood carelessly, adopting awkward postures, and opening a vessel while it remains hot or pressurized. Unsafe conditions include defective equipment, open furnaces, slippery floors, inadequate ventilation, deteriorated vessel components, and the absence of temperature and pressure indicators. However, worker behaviour is also shaped by equipment design, supervision, workload, work organization, and the physical environment. Therefore, accidents should not be attributed solely to individual behaviour, and both unsafe actions and unsafe conditions need to be (Baldissone et al., 2019).

A preliminary survey of 20 patchouli oil distillery workers in Benua and Lalembu found that half had experienced an occupational accident during the previous three months. Reported events included burns, slips, falls, entrapment, puncture wounds, and fires. Observations also showed that several distillation units operated without adequate work procedures, temperature and pressure indicators, machine guarding, safe flooring, or consistent use of personal protective equipment. These findings indicate the need to identify not only worker level factors associated with accidents but also hazardous work stages and their control priorities.

Risk factor analysis and HIRADC provide complementary evidence. Statistical analysis can quantify the associations of unsafe actions and unsafe conditions with occupational accidents but cannot identify which task-specific hazards require immediate control. In contrast, HIRADC identifies hazards at each work stage, assesses their likelihood and consequences, classifies risk levels, and determines appropriate controls. This approach is consistent with risk-management standards that require risk identification, analysis, evaluation, and treatment (International Organization for Standardization, 2018). It also supports the hierarchy of controls, which prioritizes elimination, substitution, and engineering controls over administrative measures and personal protective equipment (National Institute for Occupational Safety and Health, 2024).

Previous studies have generally examined unsafe actions and unsafe conditions or described workplace hazards without integrating worker-level associations with task specific risk prioritization. This limits the translation of findings into operational controls, particularly because accidents result from interactions among worker behaviour, equipment, work organization, and the physical environment (Baldissone et al., 2019). Evidence on traditional patchouli oil distillation is also limited to individual accident events without systematic risk ranking (Ekoodoh & Aswar, 2020). This study addresses these gaps by combining epidemiological analysis with HIRADC to generate association estimates, hazard priorities, and practical control recommendations.

Available evidence on traditional patchouli oil distillation has primarily described individual hazards or accident events without integrating worker level epidemiological analysis with task specific risk prioritization. Combining these approaches is therefore important for translating statistical findings into feasible prevention measures in workplaces with limited formal safety systems. This study aimed to analyse the associations of unsafe actions and unsafe conditions with occupational accidents among patchouli oil distillery workers in Benua and Lalembu Districts. It also used HIRADC to identify task specific hazards, classify risk levels, and establish priority control measures.

2. RESEARCH METHOD

Study Design and Setting

This study employed an analytical cross-sectional design (Siregar et al., 2022) combined with a task-based occupational risk assessment. The cross-sectional component was used to examine the associations of worker characteristics, unsafe actions, and unsafe conditions with occupational accidents. The occupational risk assessment component was used to identify hazards, estimate risk levels, and determine priority control measures for each stage of patchouli oil distillation.

The study was conducted from September to October 2025 at informal patchouli oil distillation workplaces in Benua and Lalembu Districts, South Konawe Regency, Southeast Sulawesi, Indonesia. The observed work process included transporting dried patchouli leaves, preparing firewood, loading leaves into the distillation vessel, closing the vessel, inserting firewood into the furnace, operating the furnace and distillation vessel, separating patchouli oil from condensed water, opening the vessel, removing patchouli residue, and managing the remaining residue.

Population and Sample

The study population consisted of all 130 patchouli oil distillery workers identified in Benua and Lalembu Districts. Total sampling was applied therefore, all 130 workers were included as study participants. Workers were recruited from active informal patchouli oil distillation workplaces in the study area. The unit of analysis for the cross-sectional component was the individual worker. For the HIRADC component, the unit of analysis was each activity or task performed during the patchouli oil distillation process.

Data Collection and Research Instruments

Primary data were collected through structured questionnaires, interviews, and direct workplace observations. The questionnaires assessed worker characteristics, accident history, unsafe actions, and unsafe conditions. Interviews with workers and distillery owners provided further information on previous accidents, occupational safety knowledge, work processes, and equipment operation. Observations covered all distillation stages, from transporting raw materials to managing patchouli residue, to identify unsafe behaviours, hazardous conditions, potential consequences, and existing controls. Secondary data from local government records and distillery owners described the study setting, workforce, work units, and documented accidents. Before data collection, the questionnaire was pilot tested among 30 individuals, and item validity was evaluated using Pearson item–total correlations.

Hazard Identification and Risk Assessment

Occupational hazards were assessed using Hazard Identification, Risk Assessment, and Determining Control. The assessment began by mapping the sequence of patchouli oil distillation activities. Risk level was calculated by multiplying the likelihood score by the severity score: $Risk\ score = Likelihood\ x\ Severity$. The combination of likelihood and severity produced a score ranging from 1 to 25. Risk scores were classified as low risk (1–4), medium risk (5–10), or high risk (12–25).

To maintain the consistency of the HIRADC observations, the researcher used the same structured observation checklist, operational definitions, and assessment procedures across all distillation sites. Observations followed the predetermined stages of the distillation process, from the transportation and loading of patchouli leaves to vessel operation, oil separation, vessel opening, and residue removal. Each identified hazard was assessed using the same five level likelihood and severity criteria derived from AS/NZS 4360:2004 (AS/NZS 4360, 2004), and the risk rating was calculated consistently by multiplying the likelihood and severity scores. Observational findings were cross-checked against questionnaire responses, interviews with workers and distillery owners, and reported accident histories. When information was unclear, the relevant work activity and equipment condition were reexamined before the final risk rating was assigned. This procedural standardization and data-source triangulation were used to reduce inconsistency and subjective variation in the HIRADC assessment.

Potential hazards were then identified for each activity and classified according to whether they arose primarily from unsafe actions or unsafe conditions. Scores for unsafe actions and unsafe conditions were obtained by summing the questionnaire responses and converting them into percentages of the maximum possible score. Because the items were rated on a four point Likert scale, the standardized scores theoretically ranged from 25% to 100%. Following the class interval method, this range was divided equally into two predefined categories (Stang, 2018). The resulting interval width was 37.5 percentage points, establishing a cut-off of 62.5%. Scores of ≥62.5% were classified as higher risk, whereas scores of <62.5% were classified as lower risk.

Determination of Risk Control Measures

Risk control recommendations were developed according to the hierarchy of controls. The proposed measures were arranged from the most effective to the least effective: elimination, substitution, engineering controls, administrative controls, and personal protective equipment. Elimination and substitution focused on removing hazardous work practices or replacing unsafe tools and equipment. Engineering controls included modifications to the furnace and distillation vessel, installation of temperature and pressure indicators, pressure relief devices, physical guards, improved ventilation, safer working platforms, and non slip flooring.

Administrative controls included the development of simple standard operating procedures, routine equipment inspections, safety signs, work rest arrangements, training, supervision, and emergency procedures. Personal protective equipment included heat resistant gloves, safety footwear, long sleeved work clothing, eye or face protection, and respiratory protection appropriate to the identified exposure. Higher level controls were prioritised because they reduce hazards with less dependence on continuous individual compliance (National Institute for Occupational Safety and Health, 2024).

Statistical Analysis

Categorical data were summarized using frequencies and percentages. The prevalence of occupational accidents was calculated by dividing the number of workers who reported at least one accident by the total number of study participants. Associations between occupational accidents and age, education, daily working hours, length of employment, unsafe actions, and unsafe conditions were examined using the Pearson Chi-square test. Fisher's exact test was applied when the expected cell frequency assumption for the Chi-square test was not fulfilled. The magnitude of each association was presented as an odds ratio with a 95% confidence interval. Statistical significance was established at $p < 0.05$. All analyses used complete data from the 130 workers.

Ethical Considerations

Ethical clearance was granted by the Health Research Ethics Committee, Faculty of Medicine and Health Sciences, Universitas Islam Negeri Alauddin Makassar, on October 7, 2025, under approval number B.249/KEPK/FKIK/X/2025.

3. RESULTS AND DISCUSSIONS

A total of 130 patchouli oil distillery workers participated in the study. Most workers were aged ≥30 years (64.6%), had a low educational level (58.5%), worked for more than eight hours per day (96.2%), and had worked in patchouli oil distillation for less than three years (69.2%). Hazardous unsafe actions and unsafe conditions were identified in 78.5% and 76.2% of workers, respectively. Based on the questionnaire-based risk assessment, 73.8% of workers were categorized as being at risk due to unsafe actions and 75.4% due to unsafe conditions.

Table 1. Characteristics, accident history, and occupational safety factors among patchouli oil distillery workers

Variable	Category	n	%
Age	≥30 years	84	64.6
	<30 years	46	35.4
Education	Low	76	58.5
	High	54	41.5
Daily working hours	>8 hours	125	96.2
	≤8 hours	5	3.8
Length of employment	<3 years	90	69.2
	≥3 years	40	30.8
Occupational accident history	Yes	96	73.8
	No	34	26.2
Unsafe action: hazard identification	Hazardous	102	78.5
	Non-hazardous	28	21.5
Unsafe condition: hazard identification	Hazardous	99	76.2
	Non-hazardous	31	23.8
Unsafe action: risk assessment	At risk	96	73.8
	Not at risk	34	26.2
Unsafe condition: risk assessment	At risk	98	75.4
	Not at risk	32	24.6

Of the 130 workers in Table 1, 96 (73.8%) reported having experienced at least one occupational accident during their employment in patchouli oil distillation. Burns were the most frequently reported accident, affecting 55 workers (42.3%). Other reported events included being caught between or struck by objects in 47 workers (36.2%), falls in 28 workers (21.5%), slips in 26 workers (20.0%), fires in 18 workers (13.8%), explosions in six workers (4.6%), and puncture wounds in four workers (3.1%). Workers could report more than one accident type; therefore, the percentages were not mutually exclusive. Accidents were most frequently reported during the opening of the distillation vessel, involving 76 workers (58.5%), followed by closing the vessel in 75 workers (57.7%) and removing patchouli residue in 63 workers (48.5%). Accidents were also reported during the 10–14-hour distillation process in 60 workers (46.2%) and while inserting firewood into the furnace in 58 workers (44.6%).

The high occurrence of accidents during vessel opening (58.5%) and closing (57.7%) can be explained by the convergence of thermal, pressure-related, mechanical, and ergonomic hazards. Vessel opening is performed after prolonged heating, when the vessel walls, lid, condensate, and patchouli residue may remain hot and residual steam pressure may still be present. In the absence of reliable pressure gauges, temperature indicators, pressure relief devices, and standardized cooling or depressurization criteria, workers may rely on personal judgement to determine whether the vessel is safe to open. Premature opening may therefore result in the sudden release of steam, hot water, or heated residue. Workers may also need to apply considerable force or use improvised tools when releasing hot or jammed lids and clamps, increasing the likelihood of burns, slips, struck-by injuries, and hand entrapment.

Vessel closing presents a different but related hazard pattern. Workers manually lift, position, align, and secure heavy vessel lids and fastening components, often while maintaining awkward postures. These activities create pinch and crush points for the hands and fingers. Worn gaskets, clamps, hinges, bolts, or vessel surfaces may also prevent proper sealing, potentially causing steam leakage, unstable pressure, or vessel failure during the subsequent heating process. Both activities require workers to remain in close proximity to hot metal surfaces and are repeated during every distillation cycle. Wet or slippery floors, inadequate maintenance, limited supervision, inconsistent use of heat resistant gloves and face protection, and the absence of safe handling tools further increase the risk.

The high proportion of workers with an accident history indicates that occupational hazards were embedded throughout the production process rather than being limited to a single activity. Burns were particularly prominent because workers routinely interacted with open flames, hot metal surfaces, embers, boiling water, and pressurized steam. Evidence from occupational burn studies similarly shows that open flames, hot liquids, and inadequate protective measures are important causes of workplace burn injuries (Hoveidamanesh et al., 2024; Mian et al., 2011). Heat exposure may also impair physical and cognitive performance, potentially increasing the probability of traumatic injury in addition to causing dehydration and heat-related illness (Spector et al., 2019).

The concentration of accidents during vessel opening, vessel closing, and residue removal is consistent with the hazards observed in the study area. These activities involved direct contact with hot equipment, manual handling of a heavy vessel cover, sudden release of steam, slippery surfaces, awkward working postures, and entry into vessels with potentially deteriorated internal supports. A previous study in the same local patchouli processing context documented an accident in which a worker fell through a deteriorated vessel support and came into contact with hot water (Ekoodoh & Aswar, 2020; Gambacorta et al., 2021). These findings suggest that accident prevention should prioritize critical work stages rather than relying solely on general safety education.

Worker Characteristics Associated with Occupational Accidents

Age, education, and daily working hours were not significantly associated with occupational accident history (Table 2). Length of employment was significantly associated with occupational accidents (p=0.018). However, the direction of the association requires careful interpretation. Workers with less than three years of employment had lower odds of reporting an accident than those who had worked for at least three years (OR=0.300; 95% CI: 0.107–0.847).

Table 2. Associations of worker characteristics, unsafe actions, and unsafe conditions with occupational accident history

Variable	Category	Accident, n	No accident, n	OR (95% CI)	p-value
Age	≥30 years	61	23	1.200 (0.523–2.751)	0.667
	<30 years	35	11		
Education	Low	57	19	1.154 (0.524–2.542)	0.722
	High	39	15		
Daily working hours	>8 hours	92	33	0.697 (0.075–6.463)	0.229*
	≤8 hours	4	1		
Length of employment	<3 years	61	29	0.300 (0.107–0.847)	0.018
	≥3 years	35	5		
Unsafe action: hazard identification	Hazardous	82	20	4.100 (1.688–9.959)	0.001
	Non-hazardous	14	14		
Unsafe action: risk assessment	At risk	76	20	2.660 (1.146–6.174)	0.020
	Not at risk	20	14		
Unsafe condition: hazard identification	Hazardous	78	21	2.683 (1.134–6.345)	0.022
	Non-hazardous	18	13		
Unsafe condition: risk assessment	At risk	77	21	2.509 (1.067–5.897)	0.032
	Not at risk	19	13		

Age was not associated with accident history, indicating that exposure to the hazardous distillation process occurred across age groups. Evidence concerning age and occupational injury is not uniform. A systematic review found that older workers did not consistently experience a greater overall number of injuries, although the pattern and severity of injuries may differ by age and occupation (Bravo et al., 2020). In the current study, the dominance of uncontrolled heat, open combustion, manual handling, and unsafe equipment may have had a greater influence on accident occurrence than chronological age.

Education was also not significantly associated with occupational accidents. This result does not necessarily mean that education and safety literacy are unimportant. A worker's formal educational attainment may not accurately represent their understanding of task specific hazards. Previous evidence has shown that workers with low literacy skills can have a higher occupational injury risk (Celik et al., 2026; Pejtersen & Holt, 2022). However, in informal patchouli oil distillation, both workers with lower and higher formal education may receive the same limited safety training and work under similarly hazardous conditions. Task-specific training and practical safety literacy may therefore be more relevant than general educational attainment.

Daily working hours were not significantly associated with accident history. Nevertheless, almost all workers were exposed to working hours exceeding eight hours, leaving only a very small comparison group. This highly unbalanced distribution reduced the ability of the statistical test to detect a meaningful difference and produced a wide confidence interval. A systematic review found that working for more than 12 hours per day was associated with a higher risk of safety incidents, whereas the evidence for working more than eight hours per day was weaker (Matre et al., 2021). Because the distillation process lasted approximately 10–14 hours, fatigue, reduced alertness, and prolonged exposure to heat and other hazards remain operationally important even though the association was not statistically significant in this study.

Workers with less than three years of employment had lower odds of reporting an occupational accident than workers with longer employment. This finding differs from studies showing that injury rates generally decrease as job experience increases (Bena et al., 2013). The difference may be explained by the measurement of the outcome in this study. Accident history was defined as ever having experienced an accident during employment, without a standardized recall period. Workers with longer employment consequently had a longer period during which an accident could occur and be reported. Therefore, the observed association may reflect cumulative exposure opportunity rather than a direct protective effect of shorter employment. This finding should not be interpreted as evidence that newly employed workers are inherently safer.

Unsafe Actions and Occupational Accidents

Unsafe actions showed the strongest association with occupational accident history. Among workers categorized as having hazardous unsafe actions, 82 of 102 (80.4%) reported an accident, compared with 14 of 28 (50.0%) in the non hazardous category. Workers with hazardous unsafe actions had 4.1 times the odds of reporting an accident (OR=4.100; 95% CI: 1.688–9.959; p=0.001).

The questionnaire based risk assessment produced a similar pattern. Occupational accidents were reported by 76 of 96 workers (79.2%) in the unsafe-action risk category and by 20 of 34 workers (58.8%) in the comparison category. Workers categorized as being at risk due to unsafe actions had 2.66 times the odds of reporting an occupational accident (OR=2.660; 95% CI: 1.146–6.174; p=0.020).

The observed unsafe actions included failure to use appropriate personal protective equipment, lifting heavy materials without assistance, handling firewood without hand and foot protection, working in non ergonomic positions, pushing firewood too forcefully into the furnace, approaching hot pipes, opening or closing a vessel without adequate coordination, and entering a vessel while it was still hot. These behaviours increased workers' direct exposure to mechanical, thermal, ergonomic, and fire related hazards. The findings are consistent with previous Indonesian studies. Unsafe actions were associated with occupational accidents among cement production workers (Basri & Pirmah, 2023), ferry crews (Jamil et al., 2023), and industrial workers in Padang (Anshari et al., 2025). A study of furniture workers also found a significant association between unsafe actions and occupational accidents (Irkas et al., 2020).

The significant association between unsafe actions and occupational accidents in this study supports previous Indonesian evidence showing that workers' knowledge, skills, attitudes, and physical condition are associated with occupational accident risk (Sandewa & Adhiwijaya, 2014). These findings highlight the importance of safety training, appropriate work practices, and continuous supervision in reducing preventable accidents. Unsafe actions should not, however, be interpreted solely as individual worker failures. Workers' behaviour is shaped by equipment design, workload, training, supervision, availability of protective equipment, and established workplace practices. Accident-prevention research has emphasized the importance of examining unsafe acts together with unsafe conditions and organizational factors rather than using behavioural findings to assign blame to workers (Baldissone et al., 2019). In the study area, unsafe actions often occurred in workplaces where safe alternatives, mechanical aids, written procedures, and suitable protective equipment were unavailable.

Unsafe Conditions and Occupational Accidents

Unsafe conditions were also significantly associated with occupational accident history. Accidents were reported by 78 of 99 workers (78.8%) exposed to hazardous conditions and by 18 of 31 workers (58.1%) in the non-hazardous category. Hazardous unsafe conditions were associated with 2.68 times greater odds of reporting an accident (OR=2.683; 95% CI: 1.134–6.345; p=0.022).

Based on the questionnaire based risk assessment, 77 of 98 workers (78.6%) categorized as exposed to risky unsafe conditions reported an accident, compared with 19 of 32 workers (59.4%) in the comparison group. Risky unsafe conditions were associated with 2.51 times greater odds of occupational accidents (OR=2.509; 95% CI: 1.067–5.897; p=0.032).

The unsafe conditions included the absence of material handling equipment, leaking or cracked vessels, missing or non functioning temperature and pressure indicators, inadequate equipment maintenance, open furnaces, hot pipes without guarding, slippery floors, poor housekeeping, inadequate lighting, lack of safe access routes, and the absence of standard operating procedures. Several distillation units also lacked adequate fire control equipment, equipment inspection schedules, safety training, and consistent supervision.

These results support findings from cement production and ferry work, where unsafe physical and organizational conditions were associated with occupational accidents (Basri & Pirmah, 2023; Jamil et al., 2023). The relationship between unsafe actions and unsafe conditions was also evident in the present study. For example, a worker may be classified as acting unsafely when opening a pressurized vessel, but the underlying risk is amplified when the vessel lacks a pressure gauge, functioning safety valve, inspection schedule, and safe opening procedure (Dyreborg et al., 2022; Spellmen, 2023). Effective prevention must therefore address the work system rather than relying only on instructions for workers to be more careful.

HIRADC Findings and Priority Hazards

The HIRADC assessment identified 19 hazards related to unsafe actions and 15 hazards related to unsafe conditions. Among the unsafe action hazards, one was classified as low risk, 13 as medium risk, and five as high risk. Among the unsafe condition hazards, one was classified as low risk, six as medium risk, and eight as high risk.

Table 3. Distribution of HIRADC risk levels

Hazard category	Low risk, n	Medium risk, n	High risk, n	Total
Unsafe actions	1	13	5	19
Unsafe conditions	1	6	8	15
Total	2	19	13	34

In the table 3. High risk unsafe actions included opening or closing a vessel with an inadequate seal or valve, working near an unprotected residue disposal edge, entering a hot vessel with a deteriorated internal support, and burning patchouli residue near the distillation shelter or without fire control equipment. The two highest scores, both 20, concerned fires caused by unsafe residue burning practices. High risk unsafe conditions were primarily related to vessel integrity and operation. These included cracked or leaking vessels, the absence of temperature and pressure indicators, equipment without adequate safety features, poor maintenance, chainsaw use without inspection, fire or explosion hazards, and the absence of operating procedures, training, and supervision.

Table 4. Priority high risk hazards and proposed control measures

Activity or hazard	Potential consequence	Initial risk score	Proposed priority controls
Opening or closing a vessel with an inadequate seal or valve	Vessel explosion and fatal injury	15	Replace unsafe valves with safety valves; inspect seals and valves; establish an opening and closing procedure
Entering a hot vessel or standing on a deteriorated internal support	Severe burns, fall, or fatality	15	Prohibit entry while hot; allow complete cooling; use long-handled tools to remove residue
Removing residue near an unprotected edge	Fall into the disposal area and burns	12	Install a physical barrier and residue chute; mark a safe standing area
Burning residue close to the distillation shelter	Fire and property damage	20	Relocate the burning area; construct a contained burning pit; provide fire-control equipment
Burning residue without fire-control equipment	Uncontrolled fire	20	Provide extinguishers, water, and sand; establish supervised burning procedures
Cracked, corroded, or leaking vessel	Explosion, burns, and fatal injury	15	Remove unsafe vessels from service; repair or replace damaged components; perform scheduled inspections
Missing temperature or pressure indicators	Uncontrolled overheating or overpressure	15	Install a thermometer and pressure gauge; monitor operating limits
Equipment without adequate safety features or maintenance	Mechanical failure and worker injury	12	Replace unserviceable equipment; introduce preventive maintenance and equipment inspection forms
Chainsaw used without pre-use inspection	Chain failure and severe injury	12	Conduct pre-use inspection; install guards; provide face, hearing, hand, and foot protection
Absence of SOPs, training, or adequate supervision	Human error and repeated unsafe practices	12	Develop simple SOPs; conduct periodic training; introduce daily checklists and supervisory records

The high risk findings (Table 4) demonstrate that the most serious hazards could not be adequately controlled through personal protective equipment alone. Vessel explosions and the sudden release of hot steam require engineering controls, including functional pressure gauges, temperature indicators, safety valves, reliable seals, and preventive maintenance. Research on boiler risk assessment has similarly identified damaged safety valves and inadequate pressure monitoring as critical high-risk conditions requiring inspection, repair, sensor installation, and safety valve certification (Rahma & Hasanudin, 2023). The highest risk scores were found in patchouli residue burning. This practice was conducted close to combustible shelters and, in some workplaces, without extinguishers or other fire control equipment. Relocating residue burning away from the workplace, constructing a contained burning area, and providing basic firefighting resources should therefore be prioritized. For vessel cleaning, eliminating entry into a hot vessel is preferable to relying on heat resistant clothing. Long handled residue-removal tools and adequate cooling time would reduce the need for direct worker exposure.

The proposed control measures followed the hierarchy of controls. Elimination and engineering measures should receive priority because they reduce exposure at its source. Administrative measures, including SOPs, training, equipment inspection, work rest arrangements, and supervision, remain necessary but depend on consistent implementation. Personal protective equipment should be treated as the final layer of protection. The hierarchy of controls similarly positions elimination, substitution, and engineering controls above administrative measures and personal protective equipment because higher-level controls are less dependent on continuous worker compliance (National Institute for Occupational Safety and Health, 2024). Based on the

HIRADC calculations, the proposed controls could reduce the estimated residual risk scores to the low risk range. However, these reductions were projected from the risk matrix and were not measured after actual implementation. A follow-up intervention study is required to determine whether installing engineering controls, introducing standard procedures, and providing training reduce observed accidents and exposure levels.

This study has several limitations. Its cross sectional design precludes causal inference, while self reported lifetime accident history may be affected by recall bias and unequal exposure periods. Given the high accident prevalence, odds ratios may overestimate prevalence ratios. The bivariate analysis did not control for confounding, and workplace temperature, steam pressure, noise, smoke, and physical workload were not objectively measured. In addition, residual HIRADC scores reflected expected rather than empirically observed risk reductions.

Nevertheless, the findings provide practical priorities for traditional distillery managers. Prevention should combine training, supervision, safe vessel handling procedures, routine inspections, and personal protective equipment with gradual engineering improvements, including pressure gauges, temperature indicators, safety valves, vessel repairs, safer floors, and residue handling tools. Recording accidents and near misses and periodically reviewing HIRADC assessments may support continuous risk control.

4. CONCLUSION

Occupational accidents were common among patchouli oil distillery workers, with 73.8% reporting at least one accident. Burns were the most frequent injury, while vessel opening and closing were the most accident-prone activities. Unsafe actions (OR=4.10) and unsafe conditions (OR=2.68) were significantly associated with accident occurrence. HIRADC identified vessel explosions, hot surfaces, unsafe residue removal, equipment leakage, inadequate maintenance, and the absence of safety instruments and operating procedures as priority risks. The main contribution of this study is the integration of worker level epidemiological analysis with task specific HIRADC assessment to provide an evidence-based safety management framework for traditional patchouli oil distilleries. This framework shifts accident prevention from reactive and behaviour focused responses toward proactive, system based risk management. Its implementation should prioritize engineering controls, equipment inspection and maintenance, standard operating procedures, training, supervision, personal protective equipment, and emergency preparedness.

Future research should use prospective controlled studies with 6–12 months of follow up to evaluate the effectiveness of engineering controls, operating procedures, training, supervision, maintenance, and personal protective equipment. Outcomes should include accident and near miss rates, residual HIRADC scores, unsafe actions and conditions, procedural compliance, and objective measurements of vessel temperature, pressure, and leakage. Multisite studies should also assess implementation fidelity, worker acceptance, costs, feasibility, and sustainability to determine which controls are most effective and practical for small scale patchouli oil distilleries.

ACKNOWLEDGEMENTS

The authors would like to express their sincere appreciation to Denarya Education Center for its valuable assistance and support during the preparation of this manuscript. The authors also thank all patchouli oil distillery workers who participated in this study and provided the information necessary for its completion

REFERENCES

Anshari, L. H., Azkha, N., & Ernawati, T. (2025). Hubungan Unsafe Action dan Unsafe Condition dengan Kecelakaan Kerja di PT X Padang. *Jurnal Kesehatan Komunitas (Journal of Community Health)*, *11*(3). https://doi.org/10.25311/keskom.vol11.iss3.2328

AS/NZS 4360. (2004). Risk Management Guidelines Companion to AS/NZS 4360:2004. *Standards Australia/Standards New Zealand*, *10*(5).

Badan Pusat Statistik. (2024). *Booklet Sakernas Februari 2024*. BPS-Statistics Indonesia.

Baldissone, G., Comberti, L., Bosca, S., & Murè, S. (2019). The analysis and management of unsafe acts and unsafe conditions. Data collection and analysis. *Safety Science*, *119*. https://doi.org/10.1016/j.ssci.2018.10.006

Basri, S., & Pirmah, N. A. (2023). Unsafe actions and unsafe conditions in cement production workers: A Cross Sectional Study. *Community Research of Epidemiology (CORE)*. https://doi.org/10.24252/corejournal.vi.38138

Bena, A., Giraudo, M., Leombruni, R., & Costa, G. (2013). Job tenure and work injuries: A multivariate analysis of the relation with previous experience and differences by age. *BMC Public Health*, *13*(1). https://doi.org/10.1186/1471-2458-13-869

Bravo, G., Viviani, C., Lavallière, M., Arezes, P., Martínez, M., Dianat, I., Bragança, S., & Castellucci, H. (2020). Do older workers suffer more workplace injuries? A systematic review. *International Journal of Occupational Safety and Ergonomics*. https://doi.org/10.1080/10803548.2020.1763609

Celik, Y., Sarı, G., Celik, N. M., Özban, V., Uzunget, S. C., & Şimşek, C. (2026). Occupational health literacy, injury risk, and temporary work disability: a multicenter cross-sectional study in Turkey. *BMC Public Health*.

Dyreborg, J., Lipscomb, H. J., Nielsen, K., Törner, M., Rasmussen, K., Frydendall, K. B., Bay, H., Gensby, U., Bengtsen, E., Guldenmund, F., & Kines, P. (2022). Safety interventions for the prevention of accidents at work: A systematic review. In *Campbell Systematic Reviews* (Vol. 18, Number 2). https://doi.org/10.1002/cl2.1234

Ekoodoh, E. E., & Aswar, P. (2020). Patron-Clien Pada Penyulingan Nilam Di Desa Awalo Kecamatan Benu Kabupaten Konawe Selatan. *KABANTI: Jurnal Kerabat Antropologi*, *4*(1), 30–40.

Gambacorta, G., Sharley, J. S., & Baxendale, I. R. (2021). A comprehensive review of flow chemistry techniques tailored to the flavours and fragrances industries. In *Beilstein Journal of Organic Chemistry* (Vol. 17). https://doi.org/10.3762/bjoc.17.90

Hoveidamanesh, S., Goharinezhad, S., Bagheri, T., Irilouzadian, R., Fatemi, M. J., Farokh Forghani, S., & Ghadimi, T. (2024). Why do people get burned? Qualitative analysis of the causes of burns in a large survey of burn survivors. *Burns*, *50*(5). https://doi.org/10.1016/j.burns.2024.02.004

International Labour Organization. (2023). Nearly 3 million people die of work-related accidents and diseases. *Occupational Safety and Health*.

International Organization for Standardization. (2018). ISO 31000:2018 Risk Management – Guidelines. In *ISO 31000: 2018 Risk management - Guidelines* (Vol. 2018).

Irkas, A. U. D., Fitri, A. M., Purbasari, A. A. D., & Pristya, T. Y. R. (2020). Hubungan Unsafe Action dan Unsafe Condition dengan Kecelakaan Kerja pada Pekerja Industri Mebel. *Jurnal Kesehatan*, *11*(3). https://doi.org/10.26630/jk.v11i3.2245

Jamil, J., Mallapiang, F., & Multazam, A. M. (2023). Analisis Unsafe Action dan Unsafe Condition dengan Kecelakaan Kerja pada Awak Kapal Penyeberangan Bira-Pamatata. *Journal of Muslim Community Health (JMCH) 2023*, *4*(1).

Matre, D., Skogstad, M., Sterud, T., Nordby, K. C., Knardahl, S., Christensen, J. O., & Lie, J. A. S. (2021). Safety incidents associated with extended working hours. A systematic review and meta-analysis. In *Scandinavian Journal of Work, Environment and Health* (Vol. 47, Number 6). https://doi.org/10.5271/sjweh.3958

Mian, M. A. H., Mullins, R. F., Alam, B., Brandigi, C., Friedman, B. C., Shaver, J. R., & Hassan, Z. (2011). Workplace-related burns. *Annals of Burns and Fire Disasters*, *24*(2).

National Institute for Occupational Safety and Health. (2024). *Hierarchy of controls*. Centers for Disease Control and Prevention.

Occupational safety and health in the informal economy. (2015). *International Labour Organization*. International Labour Organization.

Pejtersen, J. H., & Holt, H. (2022). Literacy and risk of occupational injury. *International Archives of Occupational and Environmental Health*, *95*(10). https://doi.org/10.1007/s00420-022-01898-w

Rahma, R. A. A., & Hasanudin, A. (2023). Risk Assessment Analysis in Boiler System with Hazard and Operability Study (HAZOP). *Jurnal Ilmiah Teknik Industri*, *22*(2).

Sandewa, S., & Adhiwijaya, A. (2014). Hubungan Perilaku Dengan Resiko Kecelakaan Kerja Pada Perawat Di Ruang Rawat Inap Rsud Labuang Baji Makassar. *Jurnal Ilmiah Kesehatan Diagnosisi*, *5*(4).

Siregar, M. H., Susanti, R., Indriawati, R., Panma, Y., Hanaruddin, D. Y., Adhiwijaya, A., Akbar, H., Nugraha, D. P., & Renaldi, R. (2022). *Metodologi penelitian kesehatan*. Yayasan Penerbit Muhammad Zaini.

Spector, J. T., Masuda, Y. J., Wolff, N. H., Calkins, M., & Seixas, N. (2019). Heat Exposure and Occupational Injuries: Review of the Literature and Implications. In *Current environmental health reports* (Vol. 6, Number 4). https://doi.org/10.1007/s40572-019-00250-8

Spellmen. (2023). Physical Hazard Control: Preventing Injuries in the Workplace, Second Edition. In *Physical Hazard Control: Preventing Injuries in the Workplace, Second Edition*.

Stang. (2018). *Cara Praktis Penentuan Uji Statistik dalam Penelitian Kesehatan dan Kedokteran* (2nd ed.). Mitra Wacana Media.

Wulandari, R., Rianse, U., & Abdullah, W. G. (2018). Analisis Harga dan Keuntungan Usahatani Nilam di Desa Benua Kecamatan Benua Kabupaten Konawe Selatan. *Jurnal Ilmiah Membangun Desa Dan Pertanian*, *3*(2), 43–49.