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Determinants of Workplace Accidents among Oil Palm Plantation Workers at PTPN IV Gunung Bayu, Simalungun, Indonesia

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Abstract

The palm oil industry in Indonesia operates under high occupational risk conditions, making occupational safety and health (OSH) a critical factor for ensuring both sustainability and productivity. This study aimed to identify factors significantly associated with workplace accidents among palm oil processing workers at PTPN IV Gunung Bayu, Simalungun. A descriptive, quantitative, cross-sectional design was employed, involving all 75 employees. Data were collected using questionnaires that assessed occupational accidents along with 6 independent variables: physical work environment, social work environment, use of personal protective equipment (PPE), machinery safety, work behavior, and participation in OSH training. These data were complemented by company accident reports from 2021 to 2024. Although workers reported generally positive perceptions of safety factors, 66.7% had experienced workplace accidents. Statistical analyses revealed significant associations between accidents and the physical work environment, PPE use, machinery safety, work behavior, and OSH training. Multivariate analysis identified the lack of OSH training as the most influential factor, increasing the risk of accidents by 5.1 times. These findings suggest that OSH training, specifically focusing on hazard awareness and safe work practices, is crucial for reducing workplace accidents. Key implementation challenges include engaging a diverse and experienced workforce. The study concludes that structured and periodic OSH training is vital for fostering a proactive safety culture and improving operational efficiency in the palm oil industry.

Keywords: occupational accidents; OSH training; palm oil industry; workplace safety

INTRODUCTION

The palm oil industry constitutes a strategic pillar of Indonesia's economy. Operating under high occupational risk conditions, occupational safety and health (OSH) serve as critical determinants of the sector's sustainability and productivity (Myzabella et al., 2019; Indonesian Palm Oil Association, 2025). Beyond individual well-being, effective OSH is intrinsically connected to the broader agricultural and food systems. It directly affects worker productivity, operational continuity, and the stability of oil palm production, a key commodity for national agri-food systems and food security (Combary and Traore, 2021; Galvis and Molina, 2023).

Ensuring worker safety through regulations such as Law No. 13 of 2003 and Government Regulation No. 50 of 2012 is therefore essential for maintaining the industry's economic contribution and supply chain resilience (Government of the Republic of Indonesia, 2003;

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2012). Consequently, identifying factors contributing to workplace accidents is a scientific imperative for transforming high-risk environments into safe and productive workplaces (Barkhordari et al., 2019; Azteria et al., 2024). Workplace accidents have severe consequences, leading to physical injury, income loss, and psychological distress among workers. At the same time, companies incur direct costs related to compensation and medical care, as well as indirect costs due to production delays, retraining expenses, and reputational damage affecting sustainability performance (Gu et al., 2020; Kim and Park, 2021; Debela et al., 2022).

National data reveal a concerning trend. Reports from the National Social Security Agency for Employment (BPJS Ketenagakerjaan) indicate a consistent increase in occupational accident insurance claims, rising from 182,835 in 2019 to 360,635 in 2023, with the plantation sector among the leading contributors (National Social Security Agency for Employment, 2024). This trend reflects persistent systemic shortcomings in OSH implementation (Hartati et al., 2024; Nugraheni and Susilo, 2025). The recurring nature of incidents indicates that accident causation is multifactorial and complex, extending beyond the mere provision of safety infrastructure (Rahmani et al., 2013). The selection of independent variables in this study is based on the socio-ecological framework, which posits that accidents result from interactions between individual, interpersonal or managerial, and organizational or environmental factors (Khanzode et al., 2012). This framework guides the examination of work behavior, the physical and social environment, machinery safety, the use of personal protective equipment (PPE), and training.

Previous studies across multiple industries have explored diverse determinants of workplace accidents (Pranitasari and Alfarius, 2023). Evidence indicates that workers' perceptions of occupational risks vary significantly by demographic factors such as age and experience (Nolte and Hanoch, 2024). Findings related to attitudes and knowledge remain inconsistent. One study found that both knowledge and attitudes were significantly associated with accident occurrence, while another reported that attitudes were significant but knowledge was insignificant (Anugrah et al., 2024; Pratiwi et al., 2024). A large-scale study in Spain demonstrated that safety attitudes accounted for 19% of the variability in accident rates (Tomás et al., 2011). Organizational, personal or behavioral, and environmental factors each exert statistically significant effects on accident rates (Alves et al., 2020). Cognitive dimensions have also been recognized as essential yet remain understudied components of human error in occupational contexts (Tanasievici et al., 2022).

This broader issue is evident at PTPN IV Gunung Bayu, Simalungun, a major palm oil processing enterprise. Despite the implementation of OSH policies, internal data reveal notable fluctuations in workplace accident rates: 56 cases in 2021, 105 in 2022, 98 in 2023, and 35 cases as of early 2024. These accidents, operationally defined as unplanned work-related events resulting in physical injury that requires medical attention or lost work time, include incidents such as slips, cuts, and machinery-related injuries. Although prior studies provide a theoretical foundation and company data indicate similar challenges, a clear research gap persists. While occupational safety has been extensively studied in industrial sectors, empirical evidence linking specific workplace safety determinants to agricultural productivity and plantation sustainability remains scarce, especially in worker-intensive perennial crop systems such as oil palm (Myzabella et al., 2019; Nugraheni and Susilo, 2025).

In particular, the relationships between work behavior, physical work environment conditions, OSH training, and accident incidence at this site have not been scientifically established. Preliminary surveys suggest potential associations; however, without comprehensive analysis, it is challenging to identify dominant influencing factors. This knowledge gap limits the development of targeted, evidence-based prevention strategies tailored to the distinctive risks of the plantation context. Addressing this gap is crucial for PTPN IV Gunung Bayu to transition from reactive safety responses to proactive, localized interventions that protect its workforce and ensure stable production.

Accordingly, this study aims to identify factors significantly associated with workplace accidents among palm oil processing workers at PTPN IV Gunung Bayu, Simalungun. It specifically examines the relationships among work behavior, the physical work environment, OSH training, and accident occurrence. The findings are expected to provide a scientific basis for management to

design targeted and effective OSH intervention programs that reduce accident rates and support sustainable productivity.

MATERIALS AND METHOD

Study design

This study used a descriptive quantitative approach with a cross-sectional design. Data were collected at a single point in time to determine the prevalence of workplace accidents and evaluate their associations with various risk factors. This design is appropriate for identifying prevalent factors and generating hypotheses in occupational health research (Setia, 2016).

Study setting and population

The study was conducted at the PTPN IV Gunung Bayu palm oil processing facility, located in Bosar Maligas Sub-district, Simalungun Regency, North Sumatra. The study population consisted of all permanent employees directly involved in processing operations, totaling 75 individuals. A total sampling (census) method was applied, including the entire accessible population. This approach is suitable in workplace settings with small, finite populations, as it enables a comprehensive enumeration of the target group and eliminates sampling error for that specific workforce (Cantwell, 2008; Taherdoost, 2016).

Data collection

Data were collected between June and July 2025 using both primary and secondary sources. Primary data were obtained through structured questionnaires administered directly to respondents. Secondary data consisted of anonymized occupational accident reports from the company's safety department covering the period from January 2021 to June 2024.

Ethical approval was granted by the Health Research Ethics Committee of Universitas Prima Indonesia (Approval No.: 151/KEPK/UNPRI/V/2025). All participants were informed of the study's objectives, procedures, potential risks, and benefits. Written informed consent was obtained from each participant before inclusion, ensuring voluntary participation.

Variables and measurement

The dependent variable was occupational accident. An occupational accident was operationally defined as any unplanned event occurring during work duties that resulted in physical injury requiring first aid or medical attention, and/or temporary incapacity to work. The variable was measured binomially (ever experienced vs. never experienced). This binary operationalization, although unable to capture the frequency or severity of incidents, was selected as a pragmatic approach to minimize recall bias, which tends to increase with more extended recall periods and can substantially underestimate injury rates (Landen and Hendricks, 1995).

Six independent variables were analyzed. The physical work environment was assessed using 5 items related to lighting, air quality, temperature, noise, and vibration, rated on a 3-point Likert scale and later dichotomized. The social work environment was measured using 4 items on peer and supervisor relations, similarly scaled and dichotomized. The use of PPE was assessed using 4 items that addressed availability, condition, enforcement, and effectiveness. Machinery safety was evaluated through 3 items concerning equipment condition, the presence of safety devices, and placement. Work behavior was measured using 5 items assessing compliance with procedures and vigilance toward hazards. OSH training participation was a binary variable based on self-reported attendance in any formal company training within the previous 3 years.

Validity and reliability

The questionnaire was developed through a literature review and expert consultation. A pilot test involving 20 workers from a comparable plantation facility (excluded from the main sample) was conducted to assess validity and reliability. Item validity was examined using Pearson's product-moment correlation, with all 35 items showing correlation coefficients ranging from 0.452 to 0.811, exceeding the critical value of 0.444 ($df = 18$, $\alpha = 0.05$). Internal consistency was evaluated using Cronbach's alpha, with coefficients ranging from 0.713 to 0.822, indicating acceptable to good reliability, which exceeds the recommended threshold of 0.70 (Sugiyono, 2017).

Data analysis

Data analysis was performed using IBM SPSS Statistics version 26. The study comprised 3 stages. First, univariate analysis was conducted to generate descriptive statistics (frequencies and percentages) for all variables. Second, bivariate analysis used the Chi-square test (or Fisher's exact test where appropriate) to examine

associations between independent variables and accident occurrence, with significance set at $p < 0.05$.

Third, multivariate analysis was conducted using binary logistic regression to identify key predictors while controlling for potential confounders. Variables with a p-value < 0.25 in the bivariate analysis were included in the initial model. A backward stepwise (likelihood ratio) approach was applied, sequentially removing variables with p-value > 0.05 until only statistically significant predictors remained. Model fit was evaluated using the Hosmer-Lemeshow test. Results are presented as adjusted odds ratios (OR) with 95% confidence intervals (CI) (Hosmer et al., 2013).

RESULTS AND DISCUSSION

Analysis of respondent profiles in this study revealed a workforce dominated by middle-aged adults. As shown in Table 1, most respondents were aged 46 to 54 years (52.0%), followed by those aged 35 to 45 years (29.3%). This group consisted almost entirely of males (97.3%), reflecting the physically demanding nature of the industry. Most workers had a high school education (57.3%). A notable finding was the long work tenure among participants, with the most significant proportion (44.0%) having 24 to 34 years of experience. This high workforce stability suggests substantial technical expertise but also corresponds with occupational safety literature that associates prolonged job tenure and routine work patterns with complacency and reduced risk awareness. Previous studies indicate that repeated exposure to workplace hazards can lead to risk habituation, whereby workers gradually underestimate risks and display diminished vigilance despite safety interventions (Lee and Kim, 2022). This behavioral mechanism is consistent with process safety analyses linking habitual practices to lower risk perception in routine environments, ultimately decreasing daily attention to occupational hazards (Hyten and Ludwig, 2017).

Table 1. Respondent demographic characteristics (n = 75)

Characteristic	Frequency (n)	Percentage (%)
Age (years)		
23-34	14	18.7
35-45	22	29.3
46-54	39	52.0
Sex		
Male	73	97.3
Female	2	2.7
Highest education		
Junior high school	21	28.1
Senior high school	43	57.3
Vocational high school	7	9.3
Bachelor's degree	4	5.3
Work duration (years)		
2-12	19	25.3
13-23	23	30.7
24-34	33	44.0

This complacency appears in the paradox between safety perceptions and actual incident rates, as presented in Table 2. Descriptively, most respondents viewed their physical work environment as safe (77.3%), reported using proper PPE (84.0%), and considered their work behaviors to be secure (81.3%). However, 66.7% reported prior occupational injuries. These findings suggest worker subjective perceptions often diverge from objective risks, supporting Ramdan and Wijayanti (2018), who noted that

Table 2. Descriptive statistics for study variables (n = 75)

Variable	Frequency (n)	Percentage (%)
Physical work environment		
Hazardous	17	22.7
Non-hazardous	58	77.3
Social work environment		
Hazardous	2	2.7
Non-hazardous	73	97.3
PPE use		
Poor	12	16.0
Good	63	84.0
Machinery safety		
Unsafe	15	20.0
Safe	60	80.0
Work behavior		
Poor	14	18.7
Good	61	81.3
OSH training		
Never	51	68.0
Ever	24	32.0
Occupational accident		
Ever	50	66.7
Never	25	33.3

Table 3. Association between risk factors and occupational accidents

Risk factor	Occupational accidents				Total n (%)	*p*	OR (95%CI)
	Ever		Never				
	n	%	n	%			
Physical work environment						0.013*	4.889
Hazardous	20	87.0	3	23.0	23 (100.0)		(1.290-18.529)
Non-hazardous	30	57.7	22	42.3	53 (100.0)		
Social work environment						0.550**	1.521
Hazardous	2	100.0	-	-	2 (100.0)		(1.289-1.795)
Non-hazardous	48	66.7	25	33.3	73 (100.0)		
Use of PPE						0.000*	0.026
Poor	1	8.3	11	91.7	12 (100.0)		(0.003-0.219)
Good	49	77.8	14	22.2	63 (100.0)		
Machinery safety						0.000*	0.069
Unsafe	3	20.0	15	80.0	15 (100.0)		(0.017-0.282)
Safe	47	78.3	60	21.7	60 (100.0)		
Work behavior						0.036*	0.290
Poor	6	42.9	8	57.1	14 (100.0)		(0.880-0.960)
Good	44	72.1	17	27.9	61 (100.0)		
OSH training						0.002*	5.091
Did not attend	40	78.4	11	21.6	51 (100.0)		(1.780-14557)
Attended	10	41.7	14	58.3	24 (100.0)		

Note: *Chi-square; **Fisher exact

Table 4. Results of multivariate analysis

Modelling stage	Variable	*p*	OR (95%CI)
Stage 1	Physical work environment	0.999	0.000
(Initial model)	Use of PPE	0.019	0.034 (0.002-0.591)
	Machinery safety	0.028	0.056 (0.004-0.742)
	Work behavior	0.999	0.000
	OSH training	0.001	16.929 (3.109-92.187)
Stage 2	Use of PPE	0.017	0.033 (0.002-0.559)
(After first elimination)	Machinery safety	0.026	0.056 (0.004-0.713)
	OSH training	0.001	16.125 (3.111-83.570)
Stage 3	Machinery safety	0.008	0.067 (0.008-0.566)
(After second elimination)	OSH training	0.001	27.791 (4.217-183.161)
Stage 4 (Final model)	OSH training	0.002	5.091 (1.780-14.557)

routine-induced safety feelings fail to protect without adequate safety competence. This gap worsens with 68.0% of respondents lacking formal OSH training.

Bivariate statistical tests in Table 3 confirmed significant associations among the physical work environment, machinery safety, and occupational accident ($p < 0.05$). Workers in hazardous physical work environments had a high injury rate (87.0%), underscoring unsafe conditions as a core trigger. These findings on machine interaction align with cognitive perspectives in Tanasievici et al. (2022), where cognitive failures during mechanical hazard exposure can precipitate accidents, especially in individuals with age-related focus decline or absent training. Poor work behavior and PPE use also showed significant links to incidents, consistent with Tomás et al. (2011), who found that safety attitudes were strong predictors of occupational accidents. Social work environment analysis was excluded due to skewed data that violated Chi-square assumptions (expected cell counts < 5).

Multivariate analysis in Table 4 identified OSH training as the dominant determinant of occupational accidents after controlling for other variables. Untrained workers faced over 5-fold higher risk (OR = 5.091). This high significance

reflects the role of training in building competence, as demonstrated in a systematic review by Robson et al. (2012), which found that OSH training is effective in enhancing knowledge and safe behaviors. These results reinforce Ricci et al. (2016) on continuous workplace learning and Yusriyanto and Asran (2025) on training as a key investment to break injury chains in high-risk industries.

CONCLUSIONS

The study conducted at PTPN IV Gunung Bayu identified OSH training as the most influential determinant of workplace accidents among palm oil processing workers. Employees without OSH training had a 5.091-fold higher risk of occupational accidents ($p = 0.002$). Hazardous physical work environments were significantly associated with increased odds of injury (OR = 4.889, $p = 0.013$). In contrast, deficiencies in machinery safety (OR = 0.069, $p < 0.001$) and unsafe work practices (OR = 0.290, $p = 0.036$) were also significant predictors, indicating that accident causation involves multiple interacting factors. These findings underscore that occupational accidents are multifactorial events shaped by environmental and behavioral elements rather than individual attributes alone. Implementing structured, periodic, and participatory OSH training specifically designed for experienced workers is recommended to strengthen the company's safety culture and effectively reduce workplace risks.

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