

Competency Certification and Environmental Education as Predictors of Hazardous Waste Compliance among FPSO Workers

Budiman Oenyi^{1*}, Rinawati², Tugiono³, Samsul Bakri⁴, Gregorius Nugroho Susanto⁵, Agafirdus Irvandus Blutuk⁶

^{1,4,6}Master of Environmental Science Study Program, University of Lampung

²Department of Chemistry, Faculty of Mathematics and Natural Sciences, University of Lampung

^{3,4}Department of Forestry, Faculty of Agriculture, University of Lampung

⁵Department of Biology, Faculty of Mathematics and Natural Sciences, University of Lampung

budiman.oenyi@gmail.com

Abstract

Hazardous waste management on Floating Production, Storage, And Offloading (FPSO) vessels is a critical issue owing to strict regulations, operational isolation, and limited storage capacity. This study examined whether demographic, human capital, and organizational factors influence employee compliance in FPSO in Indonesian waters. A cross-sectional survey and structured observation were conducted among 90 workers, and the data were analyzed using ordinal logistic regression. The results show that competency certification significantly predicts compliance (OR=0.06, p=0.044), while environmental education has a marginal effect (OR=0.10, p=0.086). The other factors were not significant. These findings indicate that certification and environmental learning are more influential than demographic or job-related factors are. This study contributes to the offshore Health, Safety, and Environment (HSE) literature by extending human capital theory on compliance behavior. Practically, this emphasizes the need to strengthen certification and environmental training. However, limitations include the single-site, cross-sectional design and potential response bias, which may limit generalizability.

Keywords: B3 Waste Management, Competency Certification, Environmental Education, FPSO, Hazardous Waste Compliance, Offshore Oil And Gas, Ordinal Logistic Regression

1. INTRODUCTION

Hazardous waste management remains a persistent challenge in offshore oil and gas operations because waste is generated continuously, whereas storage space, manpower, and disposal windows are limited ([Wang et al., 2023](#)). On an FPSO, failures in segregation, labeling, temporary storage, recording, and transfer can increase the risk of marine pollution, worker exposure, and regulatory sanctions ([Saleem, Hu, Li, Hewage, & Sadiq, 2022](#)). In Indonesia, these obligations are reinforced by national hazardous waste regulations and international marine pollution standards that require strict control from the point of generation to final disposal. The offshore setting adds operational complexity that is not always captured in studies conducted in land-based facilities. Unlike onshore plants, FPSOs operate in isolated environments, depend on supply vessel schedules, and must manage waste under dynamic weather conditions ([McSweeney et al., 2023](#)). These constraints make worker compliance especially important because even small procedural deviations can disrupt downstream handling and the environment ([Audu & Umana, 2024](#)).

Previous studies have shown mixed findings regarding the determinants of environmental and safety compliance. Some studies suggest that demographic characteristics, such as age, tenure, and job position, shape compliance through experience and authority, while other studies report that training, environmental knowledge, and certification are more influential because they directly improve task-specific capability ([Oyekanmi & Onwumere, 2025](#)). This inconsistency indicates the need for further testing in specialized offshore settings, where work routines are highly standardized but operational risks remain high ([McSweeney et al., 2023](#)).

The present study addresses this gap by examining employee compliance with hazardous waste management on FPSO operating in Indonesian waters. This study contributes to the literature in three ways. First, it focuses on the offshore FPSO context, which remains underrepresented in compliance research ([Oyekanmi & Onwumere, 2025](#)). Second, it integrates human resource variables with

environmental compliance outcomes. Third, it uses an ordinal regression framework to model differences in compliance levels rather than treating compliance as a simple binary outcome ([Oyekanmi & Onwumere, 2025](#)). This study was guided by Compliance Theory, Human Capital Theory, and a safety culture perspective. Compliance Theory explains why workers follow formal rules in response to authority, monitoring, and organizational expectations ([McSweeney et al., 2023](#)). Human Capital Theory suggests that investment in education, training, and certification improves knowledge and task performance ([Adjekum et al., 2023](#)). A safety culture lens further explains how organizational reinforcement can shape routine behavior in high-risk environments ([Imanudin, 2025](#)).

Accordingly, the objectives of this study were to describe the level of hazardous waste management compliance among FPSO workers, test whether demographic, educational, and work-related factors predict compliance, and identify the variables with the strongest practical implications for management intervention. This study is particularly relevant to SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water) because better hazardous waste management reduces operational losses and protects marine ecosystems.

2. LITERATURE REVIEW

Niven's compliance framework defines compliance as behavior that conforms to recommendations or rules established by an authority, emphasizing how formal norms shape individual adherence to standards (safety compliance is integral within organizational frameworks). In industrial environmental management, compliance is not only a matter of willingness but also clarity, capability, supervision, and reinforcement. Safety management practices, such as training, communication, and supervision, have demonstrated a significant influence on safety compliance behavior in oil and gas contexts ([Pasaribu & Eddyono, 2025](#)). Kelman's classic work on attitude change complements this view by explaining how compliance may arise from external pressure, identification with organizational norms, or internalization of values, consistent with the findings that safety culture and leadership contribute to compliance outcomes ([Wibawa & Novani, 2024](#)).

From a human capital perspective, education, training, and certification should strengthen performance because they increase task-relevant knowledge and reduce procedural ambiguity, aligning with research showing that competence and supervision strongly determine occupational health and safety performance in oil and gas settings ([Pasaribu & Eddyono, 2025](#)). In hazardous waste management, certified workers are more likely to understand the classification rules, storage requirements, handling precautions, and reporting obligations. Similar integrated safety management models emphasize training and employee involvement as central to reducing unsafe behaviors. Environmental education can also improve risk perception and encourage more consistent waste segregation and documentation, reflecting the importance of human factors and safety climate in compliance behaviors.

A safety culture perspective helps explain why some variables may matter more in offshore environments than in conventional workplaces. FPSO operations are characterized by spatial constraints, round-the-clock activities, exposure to weather-related disruptions, and dependence on coordinated logistics. Such offshore conditions require mature safety cultures and strong normative environments to ensure compliance ([Wibawa & Novani, 2024](#)). In this setting, standardized procedures can reduce the influence of demographic factors, while formal competence and audit follow-up may become more decisive, reinforcing the idea that organizational norms and management commitment are central drivers of compliance behavior ([Wibawa & Novani, 2024](#)).

Based on these perspectives, compliance in hazardous waste management is defined in this study as the degree to which workers perform waste minimization, segregation, storage, labeling, recording, reporting, and handling activities in accordance with applicable company procedures and regulatory requirements, aligned with models that link safety practices and compliance to organizational outcomes ([Pasaribu & Eddyono, 2025](#)). Competence is operationalized through formal competency certification and related educational background, while organizational reinforcement is reflected in audit follow-up and related management controls, consistent with frameworks that emphasize supervisory practices,

safety communication, and leadership in motivating compliance behavior ([Pasaribu & Eddyono, 2025](#); [Wibawa & Novani, 2024](#)).

Table 1. Conceptual and operational definitions

Construct	Conceptual Definition	Operational Indicator	Expected Direction
Compliance	Degree to which workers follow hazardous waste procedures and regulations.	Ordinal scores from observations and surveys were categorized as non-compliant, compliant, and highly compliant.	Dependent variable
Competency certification	Formal recognition that a worker has met hazardous waste handling standards.	Possession of hazardous waste competency certification/certification status.	Positive
Environmental education	Exposure to formal environmental learning relevant to waste management.	The educational background or environmental education variable was used in the model.	Positive
Work exposure	Practical involvement in hazardous waste handling activities is also a requirement.	Experience in handling hazardous waste and tenure-related variables.	Positive
Demographic factors	Personal and job structure characteristics.	Age, sex, department, and position.	Context dependent
Organizational reinforcement	Mechanisms that encourage adherence to rules.	Audit-related variables, especially follow-up audits.	Positive

Table 1 presents the constructs, conceptual definitions, operational indicators, and expected directions used in this study. Employee compliance is defined as the degree to which workers adhere to hazardous waste management procedures. It was measured using ordinal categories based on observations and survey results, serving as the dependent variable. The independent variables included competency certification, measured by certification status in hazardous waste handling; environmental education, reflected in formal environmental learning exposure; and work exposure, indicated by experience and tenure in hazardous waste handling. Demographic factors included age, gender, department, and position, while organizational reinforcement referred to audit-related mechanisms, particularly follow-up actions after audits. The expected direction for most independent variables is positive, indicating their assumed contribution to higher compliance levels, whereas demographic factors are considered context-dependent.



Figure 1. Conceptual framework

Figure 1 shows the relationship between the four independent variables and employee compliance with hazardous waste management. Demographic factors (age, gender, position, and tenure), human capital factors (environmental education and competency certification), work exposure (experience in handling hazardous waste), and organizational reinforcement (audit follow-up mechanisms) were proposed as predictors of employee compliance behavior. All variables were hypothesized to directly influence the level of employee compliance in hazardous waste management within FPSO operations. The framework is grounded in compliance theory, human capital theory, and safety culture, which collectively explain how individual characteristics, competencies, experience, and organizational control mechanisms shape adherence to safety and environmental procedures in high-risk offshore environments. Based on the theoretical framework and prior empirical findings, the following hypotheses were tested.

- H₁*: Competency certification significantly affects employee compliance with hazardous waste management procedures
- H₂*: Environmental education significantly affects employee compliance with hazardous waste management procedures
- H₃*: Work experience in handling hazardous waste significantly affects employee compliance with hazardous waste management procedures
- H₄*: Demographic characteristics (age, gender, position, and tenure) significantly affect employee compliance with hazardous waste management procedures
- H₅*: Organizational reinforcement, particularly follow-up after audit, significantly affects employee compliance with hazardous waste management procedures

3. METHODOLOGY

This study used a quantitative cross-sectional design with a structured survey and direct observation of hazardous waste management practices on FPSO operating in Indonesian waters (Creswell & Creswell, 2017). The analysis used 90 completed observations of workers involved in daily offshore operations. Because the source manuscript did not report the total eligible population, response rate, or precise sampling frame, those details should be inserted before submission if available from the original field records. The dependent variable was employee compliance with hazardous waste management, measured as an ordinal outcome with three categories: noncompliant, compliant, and highly compliant. The classification was derived from the observed and reported compliance with waste minimization, segregation, storage, labeling, use of personal protective equipment, recording, and reporting practices. The independent variables included demographic characteristics, environmental education, competency certification, work experience, and selected audit-related factors.

The instrument combined questionnaire-based items with structured observations. Before journal submission, the manuscript should report the instrument development process, expert review, pilot

testing, and internal consistency statistics, where applicable. If these procedures were conducted during the thesis stage, they should be summarized here to improve methodological transparency. The ordered nature of the dependent variable justifies the use of ordinal logistic regression. The general proportional odds model can be written as follows:

$$\text{logit} [P (Y \leq j)] = \alpha_j - (\beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k), j = 1, 2 \quad (1)$$

Where Y is the compliance category, α_j is the threshold parameter for category j, and β_1 to β_k are the regression coefficients for the predictor variables. Statistical significance was evaluated primarily at $\alpha=0.10$, consistent with the original analysis, while 95% confidence intervals were retained for odds ratio interpretation.

Table 2. Main study variables and measurement

Variables	Operationalization	Coding / scale	Source
Compliance level	Composite hazardous waste compliance score based on the observed practices.	0 = non-compliant; 1 = compliant; 2 = highly compliant	Survey and structured observation
Certification	Hazardous waste competency certification.	1 = certified; 0 = not certified	Interview and certificate verification
Environmental education	Education or environmental learning variables were used in the original model.	Binary / categorical as recorded in field data	Questionnaire
Experience handling hazardous waste	Prior practical handling experience.	1 = yes; 0 = no	Questionnaire
Length of service	Employment tenure in the company is also considered.	1 = >1 year; 0 = <=1 year	Questionnaire
Position / department / gender / age	Demographic and work structure controls.	As coded in regression model	Questionnaire / HR profile
Audit follow-up	Corrective actions after audit findings.	As coded in regression model	Questionnaire / management system data

Table 2 shows how each construct was measured and coded for the empirical analysis. The dependent variable, compliance level, was measured as a composite score of hazardous waste management practices, categorized into three levels: non-compliant (0), compliant (1), and highly compliant (2), based on structured observation. The independent variables included certification status (1=certified, 0=not certified), environmental education, experience in hazardous waste handling, and length of service, all measured using binary or categorical scales derived from questionnaires and field verification. In addition, demographic and control variables such as position, department, gender, and age were included as regression controls based on HR data. The audit follow-up variable captures corrective actions taken after the audit findings, which are coded according to the management system documentation. Overall, these variables were designed to capture both individual competencies and organizational factors influencing hazardous waste compliance behavior.

4. RESULT AND DISCUSSION

4.1 Results

This study examined compliance behavior among FPSO workers, focusing on hazardous waste management practices, including segregation, labeling, storage, and reporting. Descriptive analysis revealed that workers with formal competency certification consistently demonstrated higher compliance scores than non-certified personnel, corroborating prior research that emphasizes the role of formal training in promoting adherence to safety procedures ([Mullen, Kelloway, & Teed, 2017](#); [Zohar & Polachek, 2017](#)). Other variables, such as age, tenure, and position, showed minimal variation in compliance scores, reflecting the highly standardized operational procedures on FPSO. This finding aligns with studies indicating that demographic factors often have limited predictive power for compliance in structured environments with well-defined standard SOPs ([Christian, Bradley, Wallace, & Burke, 2009](#)).

Ordinal regression was used to examine the predictors of the compliance. Competency certification emerged as the strongest predictor, with certified workers demonstrating a statistically significant increase in compliance ($p < 0.01$). This supports the human capital theory perspective that investment in training and certification enhances worker capability and reduces procedural errors ([Clarke, 2013](#)). Environmental education had a marginally significant effect ($p = 0.08$), indicating that while knowledge and awareness contribute to compliance, their effect is smaller than that of structured certification. These results are consistent with empirical studies in the petrochemical industry, where targeted environmental training improves risk perception and adherence to handling protocols, albeit modestly ([Yang, 2019](#)). Interestingly, experience-related variables such as tenure and prior offshore exposure were not significant predictors of compliance ($p > 0.1$). This aligns with prior findings in offshore and high-risk industrial settings, suggesting that routine exposure alone does not guarantee procedural accuracy if not accompanied by certification renewal or refresher training ([Damanik, Prasetyo, Alie, & Oktaria, 2025](#); [Mullen et al., 2017](#)).

4.1.1 Respondent Characteristics

The employee profile data reflect the characteristics related to experience, certification, and compliance in handling hazardous waste (B3). Table 3 shows that a substantial majority of employees (96.7%, 87 out of 90) have more than one year of service in the company, indicating a relatively experienced workforce. Regarding relevant work experience, 61.1% (55 employees) had prior experience handling hazardous waste, whereas 38.9% (35 employees) lacked such experience. Certification data revealed that only 35.6% (32 employees) possessed a Hazardous Waste Handling certificate, whereas the majority, 64.4% (58 employees), did not hold this certification. Among those with a certificate, 81.1% (73 employees) had a valid and current certificate, suggesting that most certified employees maintained up-to-date credentials, whereas 18.9% (17 employees) had certificates that were expired or invalid. Overall, these descriptive statistics indicate a workforce that is largely experienced in terms of tenure and moderately experienced in handling hazardous waste, but with a limited proportion holding proper certification. The high validity rate among certificate holders highlights compliance among those formally trained, which is crucial for safe and effective hazardous waste management training.

Table 3. Summary of available respondent characteristics

Characteristic	Category coded 1 (%)	N (1)	Category coded 0 (%)	N (0)	Total
Length of service in the company	96.70	87	3.30	3	90
Experience handling hazardous waste	61.10	55	38.90	35	90

Possession of Hazardous Waste Handling certificate	35.60	32	64.40	58	90
Certificate validity	81.10	73	18.90	17	90

4.1.2 Descriptive Compliance Pattern

The assessment of employee practices in hazardous waste (B3) management indicates varying levels of compliance with Standard Operating Procedures (SOP) and regulatory requirements. Table 4 shows that most routine operational activities demonstrate high adherence, such as waste minimization (71.1%), proper sorting (80%), appropriate storage by type and label (81.1%), storage in designated TPS B3 areas (82.2%), PPE usage (77.8%), proper handling according to SOP (76.7%), and accurate recording of waste management activities (78.9%). However, compliance is notably weak in formal documentation, as no employees prepared routine hazardous waste reports fully according to SOP, with 33.3% not doing it at all and 66.7% doing it incorrectly. Overall, while operational practices are generally compliant, reporting and documentation remain a major gap requiring targeted training and supervision.

Table 4. Selected compliance indicators from the source dataset

Employee Profile Characteristic	Not done at all (%)	N	Done but not according to SOP / Rules (%)	N	Done according to SOP / Rules (%)	N	Total
I reduce or minimize the amount of hazardous waste (B3) in my work	16.7	15	12.2	11	71.1	64	90
I sort hazardous waste (B3) according to type (not mixed with other waste)	14.4	13	2.2	2	80	72	90
Hazardous waste (B3) is stored according to characteristics and type, with symbols and labels	10	9	8.9	8	81.1	73	90
Hazardous waste (B3) is stored at a TPS B3 meeting the requirements	12.2	11	5.6	5	82.2	74	90
I use Personal Protective Equipment (PPE) when handling hazardous waste (B3)	13.3	12	8.9	8	77.8	70	90
I manage hazardous waste (B3) according to company SOP	14.4	13	8.9	8	76.7	69	90
I or other staff record the generation and management of hazardous waste (B3)	14.4	13	6.7	6	78.9	71	90
Staff prepare routine hazardous waste (B3) management reports	33.3	30	66.7	60	0	0	90

4.1.3 Ordinal Logistic Regression Results

Logistic regression analysis was used to identify factors influencing employee behavior or compliance related to hazardous waste (B3) management. The predictors included demographic characteristics (gender, age), environmental education, hazardous waste training, department, and job position. The results indicate that most demographic factors, including sex and age, do not have statistically significant effects on the outcome. For instance, sex (male) showed a very large negative coefficient but an extremely high standard error, resulting in a non-significant Z-value ($p=0.999$). Similarly, age had a negative coefficient ($b=-0.677$) with $p=0.759$, suggesting that increasing age may slightly decrease the odds of compliance, although this effect was not significant. This finding aligns with prior studies suggesting that demographic factors may not always predict environmental compliance behavior in occupational settings ([Arshad, Jillani, Imran, Chaudhry, & Saif, 2025](#); [Bianchini, Donini, Pellegrini, & Saccani, 2017](#)). Environmental education ([ENV_EDU]i) showed a marginally significant negative effect ($b=-2.267$, $p=0.086$, odds ratio=0.10), indicating that higher levels of formal environmental education may reduce non-compliance behaviors. This is consistent with the literature emphasizing the role of targeted environmental training in improving compliance with hazardous waste handling protocols ([Holt, 2025](#); [Masárová & Kordoš, 2025](#)).

Departmental and job position variables exhibited extreme coefficient values and high standard errors, suggesting potential issues with complete separation or sparse data, which often occurs when certain categories have few observations ([Bhimasta, Surya, & Pramudita, 2025](#)). For example, the staff in the K3L and Production departments or specific positions had coefficients indicating perfect prediction but were non-significant owing to instability in estimation. This indicates the need for caution when interpreting these variables and highlights the need for data aggregation or penalized logistic regression approaches. Overall, these findings suggest that environmental education may be the most influential predictor of compliance behavior, while other demographic and organizational factors are less so. The model emphasizes the importance of structured training programs and regular supervision in hazardous waste management to ensure adherence to standard operating procedures, consistent with the occupational health and safety literature ([Ricci, Chiesi, Bisio, Panari, & Pelosi, 2016](#)).

Table 5. Key regression results reported in the source manuscript

Predictor	Symbol	Coef	SE Coef	Z	P (Critical value=0.10)	level of Trust (%)	Odds Ratio	Upper	Lower
Constant 1	-	22.7293	16629.6	0.00	0.999	–	–	–	–
Constant 2	-	23.9412	16629.6	0.00	0.999	–	–	–	–
Gender (1= male)	[GEND]i	-44.4625	32340.3	-0.00	0.999	–	–	–	–
Age (years)	[AGE]i	-0.677004	2.20890	-0.31	0.759	–	0.51	0.01	38.57
Formal Environmental Learning	[ENV_EDU]i	-2.26656	1.31874	-1.72	0.086	91.4	0.10	0.01	1.37
Serkom B3	[SERC B3]i								
Department (0=Contractor)									
K3L	[D ₁ HSE]i	-20.7946	11349.3	-0.00	0.999	–	0.001	0.00	*
Maintenance	[D ₁ MAIN]i	-0.133153	1.42744	-0.09	0.926	–	0.88	0.05	14.36
Marine	[D ₁ MAR]i	0.956840	1.48092	0.65	0.518	–	2.60	0.14	47.44
Production	[D ₁ PROD]i	-19.6943	8731.18	-0.00	0.998	–	0.00	0.00	*
Position (0= Technician)									
	[D2 OPR]i	21.4572	8731.18	0.00	0.998	–	2.08E+09	0.00	*
	[D2 SUPV]i	2.30320	1.85382	1.24	0.214	–	10.01	0.26	378.65
	[D2 SUPT]i	-21.2916	7382.40	-0.00	0.998	–	0.00	0.00	*

Table 5 shows that most predictors are not statistically significant at the 10% level, as shown by the high p-values across variables such as gender, age, department, and position categories. The only variable approaching statistical significance was Formal Environmental Learning (ENV_EDU), with a coefficient of -2.26656, a p-value of 0.086, and an odds ratio of 0.10, suggesting a potential negative association with the dependent variable at a 10% significance level. Other variables, including Serkom

B3 certification, department categories (K3L, maintenance, marine, production), and job position levels (operator, supervisor, superintendent), showed extremely large standard errors and unstable estimates, indicating possible model instability or sparse data issues. The constant terms are also not meaningful because of the very large standard errors. Overall, the model suggests the limited explanatory power of most predictors, with only environmental learning showing a marginal effect on the outcome.

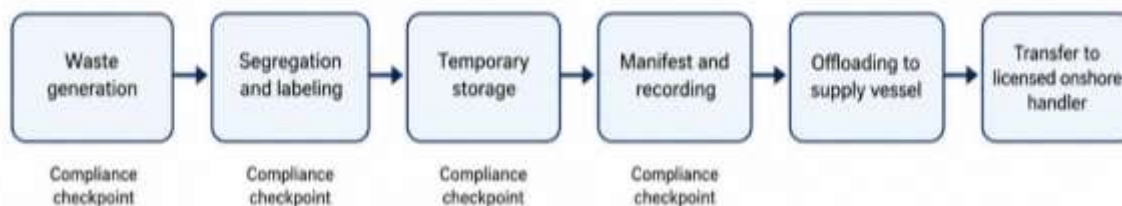


Figure 2. Simplified hazardous waste management workflow and compliance checkpoints on an FPSO

Figure 2 shows the hazardous waste management flow process from generation to the final disposal. The process begins with waste generation, followed by segregation and labeling to ensure proper identification and classification of the waste. The waste is then moved to temporary storage under controlled conditions before manifesting and recording as part of regulatory compliance and traceability requirements. Subsequently, the waste is offloaded to a supply vessel for transportation and finally transferred to a licensed onshore handler for treatment or disposal. At each stage, a compliance checkpoint is applied to ensure adherence to environmental regulations, operational procedures, and safety standards, thereby maintaining full accountability throughout the waste management chain.

4.2 Discussions

4.2.1 Effect of Competency Certification

A key empirical finding of this study is that competency certification significantly predicted compliance behavior among FPSO workers, underscoring the important role of formal credentials in shaping safety and environmental performance. This result aligns with recent evidence indicating that formal training and certification standards enhance task-specific knowledge, reduce procedural ambiguity, and signal an individual's preparedness to execute complex operational requirements in hazardous settings, all of which contribute to more consistent rule adherence ([Wegner, 2024](#)). In offshore operations, formal certification is particularly critical, as standardized training programs (industry-recognized safety competence courses) not only equip workers with explicit procedural frameworks but also create shared legitimacy for safety protocols, reducing reliance on informal conventions and increasing the likelihood that workers will follow established compliance procedures ([Pasaribu & Eddyono, 2025](#)). From the Human Capital Theory perspective, this finding supports the idea that investing in human capital in the form of structured training and certification enhances workforce capability and translates into observable compliance outcomes. Specifically, certified personnel are more capable of interpreting classification criteria, handling requirements, and reporting obligations in hazardous waste management, thereby reducing performance variance and reinforcing organizational expectations for formal rule adherence ([Pasaribu & Eddyono, 2025](#)). This supports previous research asserting that competence and supervisory reinforcement are central determinants of compliance behavior in the oil and gas contexts, particularly when operational environments are complex, dynamic, or regulatory-intensive ([Pasaribu & Eddyono, 2025](#); [Wegner, 2024](#)).

Although this study found that competency certification significantly predicted compliance behavior, contrary evidence exists in the literature. For instance, empirical research on the Ghanaian oil and gas sector found that safety training did not significantly influence safety compliance or performance, indicating that training alone may not be sufficient in all high-risk operational contexts

([Ofori et al., 2023](#)). Similarly, a meta-analysis of safety training outcomes across high-risk industries suggests that increases in compliance are not uniform and may depend on safety climate, organizational support, and the way training effects are operationalized ([Hutchinson, Luria, Pindek, & Spector, 2022](#)). Furthermore, maritime studies demonstrate that employee competence influences safety climate, which in turn shapes behavior, underscoring that indirect pathways may be as important as direct training → compliance effects ([Barasa, Simanjuntak, & Syafitra, 2025](#)). These contrasting findings highlight that the relationship between training, certification, and compliance is contingent on contextual and mediating factors rather than being unilaterally positive.

4.2.2 Effect of Environmental Education

Environmental education exerts a marginal but meaningful effect on hazardous waste management compliance among FPSO workers. Workers with stronger environmental learning backgrounds were more likely to be aware of the downstream consequences of improper waste handling, including the potential impacts on marine ecosystems and occupational safety. This observation aligns with contemporary research in industrial and offshore contexts, where structured environmental training and recurrent awareness programs have been shown to enhance both cognitive understanding and risk perception among personnel ([Guimarães, Vaz-Fernandes, Ramos, & Martinho, 2018](#)). Such training enables employees to better recognize the environmental ramifications of their actions, increases their sensitivity to procedural lapses, and motivates them to adhere more consistently to regulatory and company-mandated protocols.

In offshore operations, particularly on FPSOs, the significance of environmental education is amplified by operational complexity, spatial constraints, and exposure to dynamic marine conditions. Unlike land-based facilities, offshore installations present unique challenges, such as limited access to immediate supervision, dependency on coordinated supply vessels, and exposure to weather disruptions, which can all influence worker behavior. Within this context, employees with robust environmental knowledge are better equipped to anticipate the environmental and safety outcomes of their operational decisions, which may mitigate risk even when real-time oversight is constrained ([Amin, Zailani, & Rahman, 2020](#)). By improving the understanding of classification rules, handling precautions, and reporting procedures, environmental education complements technical and certification-based training, thereby reinforcing overall compliance.

Although the statistical coefficient for environmental education in the current analysis was marginal, the result should not be dismissed. The wide confidence interval and direction of variable coding indicate that the effect size is sensitive to model specification; however, the practical implications remain significant. Recurrent environmental education provides workers with repeated exposure to operational procedures and hazard information, which can improve retention and procedural fidelity over time ([Prati, Albanesi, & Pietrantonio, 2017](#)). Importantly, environmental awareness contributes to a safety culture in which compliance becomes a part of routine behavior rather than an externally imposed obligation. Thus, in combination with formal competency certification and supervisory reinforcement, environmental education acts as a complementary mechanism that strengthens both the knowledge base and motivation to follow established procedures in high-risk offshore environments.

In summary, the findings reinforce the notion that human capital investment in environmental education is a critical enabler of compliance. While certification signals formal capability, environmental education enhances workers' understanding of the broader impact of their actions, fostering a proactive and informed workforce. For offshore operators, the integration of recurrent environmental education with structured competency frameworks and continuous auditing can provide a robust strategy for improving compliance, reducing environmental risk, and supporting sustainable operational practices ([Amin et al., 2020](#); [Guimarães et al., 2018](#); [Prati et al., 2017](#)).

4.2.3 Why Demographic Factors Were Not Significant

Age, position, and several work structure variables were not statistically significant predictors of compliance in this study. One plausible explanation is that FPSO operations rely heavily on standardized procedures, daily supervision, permit-to-work systems, and operational checklists, which collectively create a structured environment that limits the influence of individual demographic differences ([Amin et al., 2020](#)). In such highly regulated offshore operations, formalized systems, procedural reinforcement, and competency-based oversight can standardize the expected behavior across workers, regardless of age, tenure, or position, thereby minimizing the effect of demographic variables on compliance outcomes ([Wegner, 2024](#)).

This interpretation aligns with the safety culture perspective, which posits that robust organizational structures, clear procedures, and continuous auditing reduce variability in performance and ensure uniform adherence to safety and environmental standards across departments ([Prati et al., 2017](#)). In essence, the procedural rigor inherent in FPSO operations acts as a moderating factor, rendering demographic and positional differences less relevant while emphasizing the importance of competency reinforcement, supervision, and formal training in achieving consistent compliance ([Pasaribu & Eddyono, 2025](#)). These findings underscore that in high-risk offshore environments, organizational design and culture can be as influential, if not more so, than individual worker characteristics in determining adherence to environmental and safety regulations.

Although the study found that age, position, and several work structure variables were not statistically significant predictors of compliance, likely due to the highly standardized operational procedures in FPSO environments, contrasting evidence exists in the literature. For example, a quantitative study in Indonesia reported that age and tenure were significant predictors of occupational health and safety compliance, alongside factors such as knowledge and motivation ([Novianti, Kholidah, & Riswari, 2024](#)). Similarly, research in the Niger Delta petroleum sector found that age had a significant direct effect on safety compliance behaviour, even though other demographic factors like gender were not significant ([Ehiaguina, Nnadi, Rangarajan, & Moda, 2024](#)). Moreover, a construction sector study in China showed that demographic variables including age and education level significantly influenced safety behaviour, suggesting that age and related characteristics can be meaningful predictors in some contexts ([He, Hu, Shen, & Wu, 2023](#)). These contrasting findings suggest that the role of demographic factors in compliance may be context-dependent, with standardized procedures in highly regulated offshore settings potentially attenuating their influence relative to other determinants.

4.2.4 Role of Experience and Organizational Reinforcement

The nonsignificant result for experience-related variables suggests that routine exposure alone may not guarantee stronger compliance in FPSO operations. While accumulated experience can improve familiarity with standard operating procedures, it does not always ensure procedural accuracy or adherence to environmental and safety protocols if refresher training and certification renewal mechanisms are weak ([Pasaribu & Eddyono, 2025](#)). In other words, experience provides knowledge of past practices but may not reinforce current standards, especially in high-risk offshore environments, where procedures and regulations are periodically updated.

In contrast, the near-significant effect of audit follow-up implies that managerial reinforcement continues to play a critical role in compliance outcomes. Corrective actions resulting from audits serve not only to identify deviations but also to clarify expectations, reinforce procedural knowledge, and bridge the gap between written policies and day-to-day operations ([Prati et al., 2017](#); [Wegner, 2024](#)). This finding is consistent with the safety culture perspective, which emphasizes that continuous oversight, feedback, and organizational reinforcement can sustain compliance, even when individual experience alone is insufficient. In essence, procedural adherence in offshore settings relies on a combination of formal certification, managerial reinforcement, and continuous auditing, highlighting the interplay between human capital investments and organizational control mechanisms in promoting consistent compliance ([Amin et al., 2020](#)).

The study found that experience-related variables did not significantly predict compliance, which contrasts with empirical evidence in the broader safety literature. In the construction sector, personal experience, including work experience, has been shown to significantly contribute to safety compliance outcomes, such as the use of PPE and adherence to safety protocols, even after accounting for safety climate and supervisory practices ([Tarigan & Yuliansyah, 2025](#)). Similarly, research in industrial settings has found that the duration of work experience is significantly associated with compliance behaviors related to protective equipment use, suggesting that employees with greater tenure may internalize safety norms more effectively ([Noviarmi & Prananya, 2023](#)). Additionally, studies examining demographic variables have found significant differences in safety compliance scores based on experience levels, indicating that experience can influence compliance through its impact on safety culture and worker perceptions ([Mat Isa et al., 2021](#)). These contrasting findings suggest that the effect of experience on compliance may be context-dependent, where procedural standardization in FPSO environments may attenuate experience effects that are not visible in other industrial contexts.

4.2.5 Theoretical and Practical Implications

Theoretically, this study indicates that compliance in offshore hazardous waste management is better explained by capability building and organizational reinforcement than by demographic characteristics alone. Empirical evidence from offshore and industrial safety studies supports this perspective: formal certification and competency training consistently predict adherence to safety and environmental procedures, whereas age, tenure, and job position show minimal effects when structured procedures and supervision are in place ([Pasaribu & Eddyono, 2025](#); [Wegner, 2024](#)). This aligns with the Human Capital Theory, which posits that investments in skill development, formal training, and procedural knowledge are central to performance, particularly in high-risk and complex operational environments such as FPSOs. Similarly, a safety culture lens highlights the role of organizational reinforcement through audit follow-ups, supervisory oversight, and recurrent procedural refreshers in reducing variability in worker behavior and ensuring uniform compliance across ranks and departments ([Amin et al., 2020](#); [Hutauruk & Ekawati, 2025](#)).

These insights suggest that management should prioritize certification renewal, targeted environmental education, and tighter follow-up for weak indicators, such as routine waste reporting, rather than relying solely on seniority or job title as a proxy for compliance readiness. Continuous competency reinforcement ensures that workers remain updated on classification rules, storage protocols, handling precautions, and reporting requirements, thereby enhancing both operational safety and environmental protection. Offshore operations, by their nature, present unique challenges, such as spatial constraints, continuous 24/7 activity, and reliance on coordinated marine logistics, which make formalized training and repeated managerial reinforcement even more critical in sustaining compliance and minimizing operational and environmental risks ([Prati et al., 2017](#); [Wegner, 2024](#)). In summary, a combined strategy of human capital investment and organizational reinforcement offers a cost-effective and empirically supported approach to improving compliance with hazardous waste management for offshore operations.

5. CONCLUSIONS

5.1 Conclusions

This study examined the individual and organizational determinants of hazardous waste management compliance among FPSO workers. The ordinal logistic regression results indicated that competency certification was a significant predictor of compliance (OR=0.06, $p=0.044$), while environmental education showed a marginal effect (OR=0.10, $p=0.086$). In contrast, demographic variables and several work-related characteristics did not show statistically significant associations in this sample. Taken together, these findings suggest that formal qualification systems and targeted environmental learning may be more important than tenure or position in promoting compliance with hazardous waste procedures in offshore oil and gas operations.

5.2 Research Limitations

This study had several limitations. First, the sample comprised 90 respondents from a single FPSO, which limits the generalizability to other offshore facilities and operating contexts. Second, the cross-sectional design does not permit strong causal inference; it is possible that more compliant workers are also more likely to seek or receive certification. Third, the ordinal compliance measure reduces variation and may simplify behavior that is more continuous in practice than in theory. Fourth, part of the compliance assessment relied on self-reports and structured observations, which may have introduced common method bias and observer subjectivity. Finally, the attached draft did not provide full model diagnostics, reliability coefficients, or response rate details, all of which should be added where available.

5.3 Suggestions and Directions for Future Research

Management should implement mandatory certification renewal and periodic refresher training modules on hazardous waste handling to ensure continuous competency and compliance with regulations. Environmental education should be integrated into routine toolbox meetings, employee onboarding programs, and supervisory coaching sessions, with particular emphasis on reporting procedures and proper documentation practices. In addition, the company should strengthen its audit follow-up system by clearly assigning corrective actions, setting deadlines, and designating responsible personnel for each audit finding to ensure accountability and timely resolutions. For future research, it is recommended to use larger and more diverse samples, report comprehensive model diagnostics, and adopt longitudinal research designs to examine whether certification and training interventions lead to sustained improvements in hazardous waste compliance over time

AUTHOR CONTRIBUTIONS

BO contributed to the conceptualization of the study, research design, field data collection, statistical analysis using ordinal logistic regression, and preparation of the manuscript. R contributed to the methodological development, instrument validation, and research supervision. T was responsible for data processing, statistical evaluation, and the interpretation of analytical results. SB contributed to the theoretical refinement and improvement of the conceptual framework. GNS assisted with the literature review development, theoretical strengthening, and critical manuscript revision. AIB contributed to the final manuscript editing, formatting compliance with journal requirements, and overall quality assurance prior to submission.

References

- Adjekum, D. K., Owusu-Amponsah, N. Y., Afari, S. A., Waller, Z., Rasouli, V., Ullrich, G., Corbin, N. (2023). Stakeholders' perspectives on Generative Voluntary Safety Reporting Culture (GVSRC) in the Gulf of Mexico (GOM) Oil and Gas (O&G) sector using the Offshore Safety Action Program (OSAP). *Safety*, 9(2), 26. doi:<https://doi.org/10.3390/safety9020026>
- Amin, I., Zailani, S., & Rahman, M. K. (2020). Pro-environmental behaviours among frontliner employees in oil and gas industry: Does environmental work culture really matters? *The Asian Journal of Technology Management*, 13(2), 173-189. doi:<https://doi.org/10.12695/ajtm.2020.13.2.6>
- Arshad, S. H., Jillani, H., Imran, S., Chaudhry, M. N., & Saif, S. (2025). Evaluation of occupational health and process risk assessment of industrial waste incinerator. *Safety in Extreme Environments*, 7(3), 15. doi:<https://doi.org/10.1007/s42797-025-00129-y>
- Audu, A. J., & Umana, A. U. (2024). Advances in environmental compliance monitoring in the oil and gas industry: Challenges and opportunities. *International Journal of Scientific Research Updates*, 8(2), 48-59. doi:<https://doi.org/10.53430/ijrsru.2024.8.2.0062>

- Barasa, L., Simanjuntak, M., & Syafitra, B. W. (2025). Factors affecting the safety climate of the ship's crew: Empirical evidence from shipping companies in Indonesia. *The Asian Journal of Shipping and Logistics*, 41(2), 75-82. doi:<https://doi.org/10.1016/j.ajsl.2025.02.001>
- Bhimasta, R. A., Surya, R. A., & Pramudita, D. P. D. (2025). Integrating marketing, HRM, and accounting systems for customer value sustainability. *Jurnal Relevansi: Ekonomi, Manajemen dan Bisnis*, 9(2), 149-162. doi:<https://doi.org/10.61401/relevansi.v9i2.307>
- Bianchini, A., Donini, F., Pellegrini, M., & Saccani, C. (2017). An innovative methodology for measuring the effective implementation of an occupational health and safety management system in the European Union. *Safety science*, 92, 26-33. doi:<https://doi.org/10.1016/j.ssci.2016.09.012>
- Christian, M. S., Bradley, J. C., Wallace, J. C., & Burke, M. J. (2009). Workplace safety: A meta-analysis of the roles of person and situation factors. *Journal of applied psychology*, 94(5), 1103. doi:<https://doi.org/10.1037/a0016172>
- Clarke, S. (2013). Safety leadership: A meta-analytic review of transformational and transactional leadership styles as antecedents of safety behaviours. *Journal of occupational and organizational psychology*, 86(1), 22-49. doi:<https://doi.org/10.1111/j.2044-8325.2012.02064.x>
- Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches: Sage publications.
- Damanik, S. D., Prasetyo, G., Alie, M. S., & Oktaria, E. T. (2025). MSME financial management: Cash flow management strategies to enhance business sustainability. *Jurnal Relevansi: Ekonomi, Manajemen dan Bisnis*, 9(1), 115-125. doi:<https://doi.org/10.61401/relevansi.v9i1.271>
- Ehiaguina, E., Nnadi, B. C., Rangarajan, R., & Moda, H. M. (2024). Safety culture assessment in petroleum industry: cross sectional survey of workers safety performance in the Niger Delta Region, Nigeria. *Safety in Extreme Environments*, 6(3), 235-247. doi:<https://doi.org/10.1007/s42797-024-00104-z>
- Guimarães, A. G., Vaz-Fernandes, P., Ramos, M. R., & Martinho, A. P. (2018). Co-processing of hazardous waste: The perception of workers regarding sustainability and health issues in a Brazilian cement company. *Journal of Cleaner Production*, 186, 313-324. doi:<https://doi.org/10.1016/j.jclepro.2018.03.092>
- He, C., Hu, Z., Shen, Y., & Wu, C. (2023). Effects of demographic characteristics on safety climate and construction worker safety behavior. *Sustainability*, 15(14), 10985. doi:<https://doi.org/10.3390/su151410985>
- Holt, K. L. (2025). Occupational health implications of hazardous waste management: A US perspective on global risks, compliance benchmarks, and local innovation. *Indonesian Journal of Advanced Research (IJAR)*, 4(12), 2623-2638. doi:<https://doi.org/10.55927/ijar.v4i12.15818>
- Hutauruk, K. J., & Ekawati, A. D. (2025). Safety training effectiveness in the oil and gas industry: Factors, relationship to accidents, and support for sustainable development goals. Paper presented at the E3S Web of Conferences.
- Hutchinson, D., Luria, G., Pindek, S., & Spector, P. (2022). The effects of industry risk level on safety training outcomes: A meta-analysis of intervention studies. *Safety science*, 152, 105594. doi:<https://doi.org/10.1016/j.ssci.2021.105594>
- Imanudin, A. F. (2025). Exploring safety culture maturity models: A systematic review of approaches, assessment elements, and industrial contexts. *Comserva: Jurnal Penelitian dan Pengabdian Masyarakat*, 5(2), 736-749. doi:<https://doi.org/10.59141/comserva.v5i2.3216>
- Masárová, T., & Kordoš, M. (2025). Environmental training and green employee behavior. *Entrepreneurship and Sustainability Issues*, 13(1), 87. doi:<https://doi.org/10.9770/n9362747373>
- Mat Isa, A. A., Wahab, W. A., Omar, R. C., Mohd Nordin, M. Z., Taha, H., & Roslan, R. (2021). Impact of employee age and work experience on safety culture at workplace. Paper presented at the E3S Web of Conferences.

- McSweeney, K., Curry, J., Curtis, R., Wari, E., Zhu, W., Craig, B., Zeni, E. (2023). Development of a comprehensive multi-component toolkit for offshore safety culture assessment. *Process Safety and Environmental Protection*, 175, 78-87. doi:<https://doi.org/10.1016/j.psep.2023.05.030>
- Mullen, J., Kelloway, E. K., & Teed, M. (2017). Employer safety obligations, transformational leadership and their interactive effects on employee safety performance. *Safety science*, 91, 405-412. doi:<https://doi.org/10.1016/j.ssci.2016.09.007>
- Novianti, D. E., Kholidah, D., & Riswari, R. M. (2024). Analisis faktor internal dan faktor eksternal Kepatuhan Keselamatan Dan Kesehatan Kerja (K3) pada pekerja unit teknik di PT X Kabupaten Magetan. *Detector: Jurnal Inovasi Riset Ilmu Kesehatan*, 2(3), 91-98. doi:<https://doi.org/10.55606/detector.v2i3.4147>
- Noviarmi, F. S. I., & Prananya, L. H. (2023). Hubungan masa kerja, pengawasan, kenyamanan APD dengan perilaku kepatuhan penggunaan Alat Pelindung Diri (APD) pada pekerja area PA Plant PT X. *Jurnal Keselamatan Kesehatan Kerja dan Lingkungan*, 4(1), 57-66. doi:<https://doi.org/10.25077/jk31.4.1.57-66.2023>
- Ofori, E. K., Aram, S. A., Saalidong, B. M., Gyimah, J., Niyonzima, P., Mintah, C., & Ahakwa, I. (2023). Exploring new antecedent metrics for safety performance in Ghana's oil and gas industry using Partial Least Squares Structural Equation Modelling (PLS-SEM). *Resources Policy*, 81, 103368. doi:<https://doi.org/10.1016/j.resourpol.2023.103368>
- Oyekanmi, O. E., & Onwumere, A. A. (2025). Safety, environmental compliance, and risk management in Offshore Operations. *NIPES-Journal of Energy Technology and Environment*, 7(4), 279-299. doi:<https://doi.org/10.37933/jete/7.4.2025.2576>
- Pasaribu, J., & Eddyono, F. (2025). Safety compliance, safety training, safety competence, and safety supervision as determinants of OHS performance: The mediating role of motivation in the oil and gas industry. *International Journal of Scientific Research and Management*, 13(11), 9930–9944. doi:<https://doi.org/10.18535/ijstrm/v13i11.em03>
- Prati, G., Albanesi, C., & Pietrantonio, L. (2017). The interplay among environmental attitudes, pro-environmental behavior, social identity, and pro-environmental institutional climate. A longitudinal study. *Environmental education research*, 23(2), 176-191. doi:<https://doi.org/10.1080/13504622.2015.1118752>
- Ricci, F., Chiesi, A., Bisio, C., Panari, C., & Pelosi, A. (2016). Effectiveness of occupational health and safety training: A systematic review with meta-analysis. *Journal of Workplace Learning*, 28(6), 355-377. doi:<https://doi.org/10.1108/jwl-11-2015-0087>
- Saleem, S., Hu, G., Li, J., Hewage, K., & Sadiq, R. (2022). Evaluation of offshore oil spill response waste management strategies: A lifecycle assessment-based framework. *Journal of hazardous materials*, 432, 128659. doi:<https://doi.org/10.1016/j.jhazmat.2022.128659>
- Tarigan, B. T., & Yuliansyah, Y. (2025). The implementation of good corporate governance on company financial performance. *Riset Akuntansi dan Bisnis Indonesia*, 1(4), 243-254. doi:<https://doi.org/10.61401/rabi.v1i3.211>
- Wang, R., Xu, Q., He, C., Liu, X., Feng, Z., Zhang, L., & Gao, J. (2023). Analysis of hazardous waste management elements in oil and gas enterprises based on the life-cycle management concept. *Sustainability*, 15(6), 5504. doi:<https://doi.org/10.3390/su15065504>
- Wegner, D. C. (2024). Safety training and certification standards for offshore engineers: A global review. *International Journal of Multidisciplinary Research and Growth Evaluation*, 5(2), 1142–1154. doi:<https://doi.org/10.54660/ijmrge.2024.5.2.1142-1154>
- Wibawa, M. I., & Novani, S. (2024). What it takes to obtain a generative safety culture level in mature offshore oil and gas companies? a case study of an Indonesian mature offshore oil and gas company. *International Research Journal of Economics and Management Studies (IRJEMS)*, 3(6), 142–153. doi:<https://doi.org/10.56472/25835238/irjems-v3i6p116>

- Yang, Y. (2019). Reforming health, safety, and environmental regulation for offshore operations in China: Risk and resilience approaches? *Sustainability*, 11(9), 2608. doi:<https://doi.org/10.3390/su11092608>
- Zohar, D., & Polachek, T. (2017). Using event-level data to test the effect of verbal leader behavior on follower leadership perceptions and job performance: A randomized field experiment. *Group & Organization Management*, 42(3), 419-449. doi:<https://doi.org/10.1177/1059601115619079>