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Development of an Integrated Grass-Cutting SOP Based on Permit to Work and API 500/505 Standards for Improving OHS System Reliability

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Abstract
Introduction: *Grass-cutting activities in upstream oil and gas facilities present significant safety risks, particularly in hazardous classified areas. Previous incidents revealed inadequate integration between the Permit to Work (PTW) system and API 500/505 hazardous area classification standards, resulting in insufficient hazard control* ***Objective:*** *To develop and evaluate an integrated Standard Operating Procedure (SOP) combining PTW requirements with API 500/505 standards to improve OHS system reliability* ***Method:*** *An action research design with mixed-methods approach was conducted at PT XYZ Oil & Gas Indonesia, drawing on 141 maintenance-related incidents (2019–2024) and validated through a five-month pilot implementation* ***Results and Discussion:*** *Baseline assessment revealed weaknesses in PTW compliance (67%), permit quality (58%), hazard identification (45%), and personnel competency (50.9%). Following SOP implementation, competency increased significantly to 80.4% (t=23.330; p<0.05), with N-Gain of 0.602 and 88.9% of participants achieving competency targets. The intervention demonstrated a very large practical effect (Cohen's d≈7.78).* ***Conclusion:*** *The integrated SOP effectively improved personnel competency and strengthened OHS system reliability, providing a practical approach to safer grass-cutting operations in upstream oil and gas facilities.*

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Introduction

The upstream oil and gas industry is recognized as one of the highest-risk industrial sectors because its operations involve drilling, production, transportation, and facility maintenance activities that are exposed to fire, explosion, equipment failure, and hazardous substances (Narayanan *et al*., 2023). Consequently, every operational activity requires a comprehensive Occupational Health and Safety (OHS) management system supported by systematic hazard identification and effective risk control measures (Glevitzky *et al*., 2025). Although maintenance work is often perceived as routine, it may expose workers to hazards comparable to those encountered during core production activities (Kim *et al*., 2021). One maintenance activity that frequently receives limited safety attention is grass-cutting around production facilities and hydrocarbon-containing areas. Mechanical grass-cutting equipment may generate sparks, friction, or heat capable of becoming ignition sources when operated within hazardous classified locations. In addition to increasing the risk of fire and explosion, these hazards may lead to occupational injuries, physical trauma, and exposure to hazardous environments that threaten workers' health and operational well-being. Therefore, effective preventive measures are essential to protect workers from occupational injuries and hazardous exposures (Achumie *et al*., 2022).

Empirical evidence shows that grass-cutting activities continue to contribute to occupational incidents in Indonesian oil and gas operations. Incident records from Pertamina Hulu Energi documented six grass-cutting-related accidents between November 2022 and November 2024. These incidents formed part of 141 maintenance-related incidents recorded in the company's OHS reporting system during the 2019-2024 period. Analysis of these incidents revealed recurring patterns in which 50% of cases resulted from contact with hidden wires or metal debris concealed beneath tall grass, while 33% were caused by direct contact with grass-cutting blades. Then, another incident involved a snake bite associated with inadequate workplace inspection before work commenced. More importantly, none of the incident reports documented the implementation of a Permit to Work (PTW), hazardous area classification verification, or comprehensive Job Safety Analysis (JSA) before work began. These incidents show that insufficient hazard identification and work planning increase workers' exposure to physical hazards that may result in injuries, lost work time, reduced productivity, and adverse occupational health outcomes (Hong & Cho, 2023). A preliminary assessment conducted at PT XYZ Oil & Gas Indonesia also identified four grass-cutting incidents with similar characteristics during the 2020-2024 period, showing that the problem is systemic rather than organization-specific and the need for standardized preventive measures across the upstream oil and gas sector.

The persistence of maintenance-related incidents has attracted increasing attention from regulators and industry practitioners (Majumdar *et al*., 2023). The Ministry of Energy and Mineral Resources (2023) reported an increasing trend in near misses and minor incidents associated with maintenance activities performed within hazardous areas. In most oil and gas companies, including the research site, grass-cutting activities are already regulated through Standard Operating Procedures (SOPs) requiring a Permit to Work (PTW), the use of personal protective equipment, Pre-Job Safety Meetings (PJSM), workplace inspections, and work permit documentation before activities begin. However, the implementation of PTW remains largely administrative and has not been comprehensively integrated into every stage of grass-cutting operations. Existing procedures also do not explicitly connect the PTW process with hazardous area classification based on API 500 and API 505, ignition source verification, equipment selection according to classified areas, or specific risk controls before work execution. Although administrative controls formally exist, they do not yet function as an integrated risk management system capable of preventing recurring incidents in hazardous operational environments.

The identified implementation gap shows that improving grass-cutting safety requires more than simply enforcing existing procedures. API 500 and API 505 provide comprehensive guidance for classifying hazardous locations according to the probability of flammable atmospheres and serve as references for equipment suitability, operational restrictions, and risk mitigation measures in petroleum facilities. Nevertheless, reviews of existing SOPs show that hazardous area classification has not been systematically incorporated into permit issuance, work planning, field verification, or operational decision-making (Park *et al*., 2025). Consequently, workers may unknowingly introduce ignition sources into classified areas while hidden physical hazards such as metal debris remain undetected before work begins. Such conditions increase workers' risk of occupational injuries and hazardous exposures that could otherwise be prevented through integrated hazard identification and control measures. Hamilton and Kletz (2023) reported that effective Permit to Work implementation can reduce workplace accidents by up to 40%; however, significant implementation gaps remain for activities perceived as low risk. Rahmawati *et al*. (2024) found substantial discrepancies between established OHS policies and field implementation, particularly for non-core activities such as grass-cutting, housekeeping, and painting, where risk assessments, contractor management, and permit implementation are often inadequate.

Rahman and Suryadi (2022) reported that many Indonesian oil and gas facilities still have outdated hazardous area classification drawings and limited integration between area classification and Permit to Work systems. Sutrisno and Wijaya (2023) demonstrated that OHS system reliability depends on procedural compliance, operational controls, performance monitoring, and the integration of leading and lagging safety indicators, yet their framework was not developed for specific maintenance activities. Rahmawati *et al*. (2024) emphasized that non-core activities continue to receive less attention despite their considerable safety consequences. At the international level, the Energy Institute (2021) identified inadequate Permit to Work implementation, poor hazard identification, communication failures, competency deficiencies, and insufficient supervision as dominant root causes of maintenance-related incidents within the global oil and gas industry. However, these studies either discuss Permit to Work, hazardous area classification, or OHS reliability separately, without proposing an integrated operational procedure specifically designed for grass-cutting activities or validating its effectiveness through field implementation.

Based on these gaps, this study develops an integrated Standard Operating Procedure (SOP) for grass-cutting activities by combining Permit to Work requirements with API 500/505 hazardous area classification standards to improve the reliability of Occupational Health and Safety systems in upstream oil and gas operations. Unlike previous studies, the proposed SOP integrates hazardous area verification, ignition source control, equipment selection, workplace inspection, debris removal, competency development, communication procedures, and performance monitoring into a unified operational framework. The development process is supported by empirical evidence derived from 141 maintenance-related incidents, including six historical grass-cutting incidents recorded between 2022 and 2024, thereby ensuring that the proposed procedure directly addresses actual operational problems. The effectiveness of the developed SOP is validated through a pilot implementation conducted at PT XYZ Oil & Gas Indonesia, allowing practical evaluation within a real industrial environment.

Method

This study employed an action research design with a mixed-methods approach to develop, implement, and validate an integrated Standard Operating Procedure (SOP) for grass-cutting activities by combining the Permit to Work (PTW) system with API 500/505 hazardous area classification standards to improve the reliability of (OHS) systems in upstream oil and gas operations. Action research was selected because it enables researchers to identify organizational problems while collaboratively designing, implementing, and evaluating practical solutions in real operational settings (Susman & Evered, 1978). The study followed the five-stage action research cycle of diagnosing, action planning, action taking, evaluating, and specifying learning. During the diagnosing stage, 141 maintenance-related incidents recorded between 2019 and 2024 were analyzed to identify systemic deficiencies in grass-cutting safety management, while the action planning stage utilized evidence from six grass-cutting incidents that occurred between November 2022 and November 2024 to develop the integrated SOP. The SOP was subsequently implemented, evaluated using quantitative and qualitative indicators, and refined through a five-month pilot project at PT XYZ Oil & Gas Indonesia, an upstream operator in East Kalimantan with approximately 500 hectares of facilities containing extensive API 500/505-classified hazardous areas. PT XYZ was selected because it had documented 23 maintenance-related incidents, including four grass-cutting incidents with characteristics similar to those identified in Pertamina Hulu Energi, although its existing ISO 45001:2018 Occupational Health and Safety Management System had not yet fully integrated Permit to Work procedures with hazardous area classification requirements for non-core maintenance activities such as grass-cutting.

Three complementary datasets were utilized throughout the study, each serving a distinct purpose in the research process:

1. The first dataset consisted of 141 maintenance-related incidents collected from Indonesian upstream oil and gas operators during the 2019-2024 period through SKK Migas databases and annual company OHS reports. This dataset was used to establish the industry baseline, identify recurring maintenance-related safety issues, and determine that six incidents were specifically associated with grass-cutting activities.
2. The second dataset comprised six detailed grass-cutting incident investigation reports recorded at Pertamina Hulu Energi between November 2022 and November 2024, including investigation reports, site photographs, witness interviews, and corrective action records. These six incidents represented a subset of the 141 maintenance-related incidents and were selected because they provided complete documentation for in-depth root cause analysis. This dataset was used to identify recurring hazard patterns, validate systemic procedural gaps, and develop the integrated SOP by addressing the specific root causes identified in historical incidents.
3. The third dataset consisted of pilot project data collected at PT XYZ, including baseline assessments of the existing PTW system, personnel competency evaluations, SOP implementation monitoring records, incident and near-miss reports, and stakeholder feedback used to evaluate the effectiveness of the

developed procedure. PT XYZ was selected because it possesses operational characteristics comparable to those of Pertamina Hulu Energi, including extensive hazardous classified areas, routine grass-cutting activities performed by contractors, similar grass-cutting incident patterns, and comparable deficiencies in Permit to Work implementation and hazardous area verification. Therefore, while the second dataset was used to develop the SOP, the third dataset was used independently to validate its implementation and effectiveness in a comparable real-world operational environment.

The pilot implementation was conducted over five consecutive months from January to May 2026, including baseline assessment, SOP development, implementation preparation, pilot execution, and final evaluation. The study involved 16 purposively selected participants comprising two operations or maintenance supervisors responsible for work permit authorization and fourteen grass-cutting contractors with at least one year of operational experience at the facility.

The independent variable was the implementation of the integrated grass-cutting SOP, which was evaluated using the SOP Implementation Score (SOPIS). SOPIS consisted of four weighted dimensions: procedure quality (30%), implementation quality (35%), training and competency (20%), and monitoring and continuous improvement (15%). Procedure quality evaluated 33 integrated procedural requirements using a dichotomous scoring system, while implementation quality was assessed through observation of 50 work permits using a 40-item audit checklist. Training effectiveness was determined by the percentage of personnel achieving competency scores of at least 75%, whereas monitoring effectiveness was measured using a 20-item Likert-scale checklist. The dependent variable was Occupational Health and Safety System Reliability, measured using the Safety System Reliability Index (SSRI), which combined leading indicators (60%) and lagging indicators (40%). Leading indicators included Permit to Work compliance rate, permit quality score, hazard identification effectiveness, and personnel competency level, with baseline values of 67%, 58%, 45%, and 52%, respectively. Lagging indicators consisted of Total Recordable Incident Rate (TRIR), near-miss frequency, and severity rate, with baseline values of 2.4 incidents, 5.7 cases per month, and 48 lost-workday units, respectively. Additional mediating variables included procedural compliance and personnel competency, while moderating variables consisted of safety culture maturity and facility characteristics.

Several validated instruments were used for data collection, including the SOP Implementation Assessment Checklist (SIAC; 108 items), the Permit Quality Assessment Tool (PQAT; 30 criteria), and the Competency Assessment Tool (CAT), comprising a 20-item knowledge test, five practical skill assessments, and a 10-item safety attitude questionnaire. The SIAC was validated by five experts and met reliability requirements with Cohen's Kappa ≥ 0.70 and Intraclass Correlation Coefficients (ICC) > 0.75. Qualitative data were collected through semi-structured interviews (45-60 minutes), five Focus Group Discussions (FGDs), workplace observations, permit registers, activity logs, training records, monitoring checklists, near-miss reports, and safety performance dashboards. Quantitative data were analyzed using SPSS version 26.0 or Jamovi with descriptive statistics, the Shapiro-Wilk normality test, paired-sample t-tests or Wilcoxon signed-rank tests, independent t-tests or Mann-Whitney U tests, Pearson or Spearman correlation analysis, multiple regression, time-series trend analysis, and Cohen's d effect size at a significance level of $\alpha = 0.05$. Qualitative data were analyzed using thematic analysis, and both datasets were integrated through methodological triangulation to enhance credibility, transferability, dependability, and confirmability. Ethical approval was obtained from the institutional research ethics committee, organizational permission was granted by PT XYZ Oil & Gas Indonesia, and written informed consent was obtained from all participants prior to data collection.

Result and Discussion

1. Result

Based on the baseline assessment conducted in January 2026, a total of approximately 250,000 m² of land required periodic grass-cutting maintenance. Of this total area, 52% was classified as hazardous according to API 500/505 standards, while the remaining 48% was categorized as unclassified. The distribution of grass-cutting areas according to hazardous area classification is showed in Table 1. Prior to the implementation of the integrated best practice, grass-cutting activities were performed using conventional equipment without explicit verification of area classification, a condition that closely resembled the circumstances identified in the six grass-cutting incidents recorded at Pertamina Hulu Energi during the 2022-2024 period.

Table 1

Distribution of Grass-Cutting Areas Based on Hazardous Area Classification at PT XYZ

No	Area Classification	Area (m²)	Percentage (%)	Cutting Frequency	Description
1	Zone 1 Division 1 (Hazardous)	± 42.500	17%	Twice/month	Production facilities and separator areas
2	Zone 2 Division 2 (Less Hazardous)	± 87.000	35%	Once/month	Buffer zones and distribution pipeline areas
3	Unclassified (Non-Hazardous)	± 120.500	48%	Once/month	Offices, roads, and public facilities
	Total	± 250.000	100%		

Baseline assessment was subsequently performed to evaluate the existing Permit to Work system and grass-cutting management practices. The assessment involved document reviews, field observations, and interviews with 16 personnel consisting of 14 grass-cutting operators and 2 supervisors. The results revealed substantial deficiencies in the management system, particularly regarding permit compliance, hazard identification, and personnel competency. Permit to Work compliance was only 67%, while permit quality achieved a score of 58%. Hazard identification effectiveness was recorded at 45%, indicating a significant inability to recognize hidden hazards such as buried wires, metal debris, and classified-area ignition risks. Personnel competency levels were also inadequate, with an average score of 76.33 out of 150 points (50.9%), significantly below the competency threshold. Baseline results are showed in Table 2.

Table 2
Baseline Assessment of the OHS System for Grass-Cutting Activities

No	Indicator	Baseline (Before Implementation)	Target (After Implementation)
1	Permit to Work Compliance Rate	67%	≥ 95%
2	Permit Quality Score	58%	≥ 85%
3	Hazard Identification Effectiveness	45%	≥ 90%
4	Personnel Competency Level	50.9% (average score 76.33/150)	≥ 90% competent personnel
5	Total Recordable Incident Rate (TRIR)	2.4	≥ 50% reduction
6	Near Miss Frequency (cases/month)	5.7	≥ 50% reduction
7	Severity Rate	48	≥ 50% reduction

The baseline findings showed that the existing grass-cutting management system lacked critical safety controls. Major deficiencies included the absence of explicit hazardous area classification verification in permit forms, insufficient pre-work inspection procedures, the lack of mandatory debris-cleaning requirements, and the absence of integrated gas-testing protocols for classified areas. These findings closely matched the root causes identified from the six Pertamina Hulu Energi incidents. Based on the analysis of incident reports, baseline assessments, literature reviews, and expert panel discussions conducted during Focus Group Discussions (FGD) 2 and 3 in February 2026, an integrated best-practice model was developed. The model consisted of seven key components specifically designed to address recurring hazards as showed in Table 3.

Table 3
Components of the Integrated Grass-Cutting Best Practice Model

No	Component	Description	Root Cause Addressed
1	Integrated Procedure with Area Classification Verification Checklist	Mandatory verification of classified area type and extent before permit issuance	Absence of area classification verification (6/6 incidents)
2	Mandatory Debris-Cleaning and Worksite Survey Protocol	Minimum 30-minute site survey and debris removal before work	Hidden wire/metal contact (50% of incidents)
3	Equipment Selection Protocol Based on Area Classification	Equipment matrix with spark-arrestor requirements	Potential ignition sources
4	Integrated Gas Testing Protocol	Mandatory gas testing in Zone 1/2 and Division 1/2 areas	Ignition risk in classified areas
5	Layered Communication and Coordination Mechanism	Mandatory toolbox talks, standby observers, and emergency communication procedures	Lack of coordination (6/6 incidents)
6	Personnel Competency Development Program	Five training modules with minimum passing score of 75%	Low personnel competency (baseline 50.9%)
7	Monitoring and Evaluation System	Weekly dashboard monitoring and continuous improvement mechanism	Lack of systematic monitoring

The effectiveness of the implemented best practice was evaluated through competency assessments administered before training (pretest) and after training combined with one month of pilot implementation (posttest). Nine respondents from the total population of 14 eligible personnel participated in the assessment. Descriptive statistical analysis showed in Table 4, revealed substantial improvements in competency levels following implementation. During the pretest, competency scores ranged from 70 to 85, with an average score of 76.33 and a standard deviation of 4.66. Following implementation, scores increased considerably, ranging from 112 to 127, with a mean score of 120.67 and a standard deviation of 5.24. The increase of 44.33 points corresponds to an improvement of approximately 29.5 percentage points and shows a substantial enhancement in personnel competency.

Table 4

Descriptive Statistics of Personnel Competency Scores

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	9	70.00	85.00	76.3333	4.66369
Posttest	9	112.00	127.00	120.6667	5.24404
Valid N (listwise)	9				

Before conducting inferential analysis, normality testing was performed using the Shapiro-Wilk test due to the small sample size (n = 9). The results showed that both pretest and posttest datasets were normally distributed, with significance values exceeding 0.05. Specifically, the pretest dataset produced a significance value of 0.770, while the posttest dataset yielded a significance value of 0.438. The Shapiro-Wilk normality test results showed in Table 5.

Table 5

Shapiro-Wilk Normality Test

Variable	Shapiro-Wilk Statistic	df	Sig.
Pretest	0.957	9	0.770
Posttest	0.925	9	0.438

Following confirmation of normality, a paired-sample t-test was conducted to determine whether the observed improvement in competency scores was statistically significant. The analysis revealed a mean difference of 44.33 points between posttest and pretest scores, with a standard deviation of 5.70. The calculated t-value was 23.330 with 8 degrees of freedom, resulting in a significance value of 0.000 ($p < 0.05$). Paired-Sample t-Test results showed in Table 6.

Table 6

Paired-Sample t-Test

Variable Comparison	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Posttest - Pretest	44.33333	5.70088	23.330	8	0.000

The practical effectiveness of the intervention was further examined using N-Gain analysis as showed in Table 7. The results showed that all nine respondents experienced competency improvements. Eight respondents (88.9%) achieved moderate N-Gain scores, while one respondent (11.1%) achieved a high N-Gain score. No participant fell within the low-gain category. The overall average N-Gain score was 0.602, showing moderate effectiveness of the intervention.

Table 7
N-Gain Analysis

No	Pretest Score	Posttest Score	Maximum Score	N-Gain	Category
1	80	127	150	0.671	Moderate
2	72	112	150	0.513	Moderate
3	80	119	150	0.557	Moderate
4	73	119	150	0.597	Moderate
5	70	127	150	0.713	High
6	75	122	150	0.627	Moderate
7	76	116	150	0.541	Moderate
8	76	118	150	0.568	Moderate
9	85	126	150	0.631	Moderate
Average	76.33	120.67	150	0.602	Moderate

Competency improvements across knowledge, practical skills, and safety attitudes is showed in Table 8. The greatest improvement occurred in practical skills, increasing by 33.7 percentage points, reflecting the effectiveness of hands-on training modules involving area verification, debris inspection, and gas-testing procedures. Overall competency increased from 50.9% to 80.4%, representing a 29.5 percentage-point improvement. Eight out of nine participants (88.9%) achieved competency status following implementation, showing that the integrated best-practice model successfully enhanced workforce readiness for conducting grass-cutting activities within hazardous oil and gas environments.

Table 8
Personnel Competency Before and After Implementation

No	Competency Component	Average Pretest	Average Posttest	Improvement	% Competent (≥ 75%)
1	Knowledge (OHS, API 500/505, Permit to Work)	50.9%	80.4%	+ 29.5%	8/9 (88.9%)
2	Practical Skills (Area Survey, Permit Verification, Gas Testing)	45.0%	78.7%	+ 33.7%	7/9 (77.8%)
3	Attitude (Safety Awareness and Procedural Compliance)	62.3%	84.1%	+ 21.8%	8/9 (88.9%)
	Overall Competency Score	50.9%	80.4%	+29.5%	8/9 (88.9%)

The results show that the integrated grass-cutting best-practice model successfully addressed the major deficiencies identified during the baseline assessment. Significant improvements were observed in personnel competency, particularly in practical operational skills directly related to hazardous area verification, Permit to Work implementation, debris management, and gas-testing procedures. The statistical analyses confirmed that these improvements were both statistically and practically significant, thereby providing strong evidence supporting the effectiveness of integrating Permit to Work systems with API 500/505 hazardous area classification standards in enhancing OHS performance within upstream oil and gas maintenance operations.

2. Discussion

The integration of the Permit to Work (PTW) system with API 500/505 hazardous area classification standards significantly improved personnel competency in grass-cutting activities within upstream oil and gas facilities. The paired sample t-test produced a significance value of 0.000 ($p < 0.05$) with a t-value of 23.330, confirming a statistically significant difference between pretest and posttest competency scores. The average competency score increased from 76.33 (50.9% of the maximum score) before the intervention to 120.67 (80.4%) after the implementation of the integrated best practice model. This improvement indicates that the five-module training program successfully enhanced workers' knowledge, skills, and safety awareness regarding hazardous area operations. Furthermore, the achievement of 88.9% competent personnel after implementation demonstrates that integrating API 500/505 requirements into PTW procedures can effectively address competency gaps previously identified during the baseline assessment. These findings suggest that improved personnel competency represents an important leading indicator that supports the strengthening of OHS system reliability in high-risk industries such as upstream oil and gas operations.

The results are consistent with the findings of Hamilton and Kletz (2023), who reported that comprehensive training is a critical success factor in the effectiveness of permit to work systems and may contribute to accident reductions of up to 40%. Unlike conventional training approaches, the present study incorporated hazardous area classification concepts directly into permit issuance, hazard identification, and work execution procedures. This integrated approach enabled personnel to understand not only procedural requirements but also the underlying safety rationale associated with classified areas. From a theoretical, these findings align with the principles of the Swiss Cheese Model proposed by Reason (1997), which emphasizes the importance of multiple defensive layers in preventing accidents. In this context, improved competency represents a strengthened behavioral defense layer that complements procedural and technical safeguards. Without adequate competency, even well-designed procedures may fail because personnel are unable to recognize hazards, assess risks, or implement appropriate controls effectively.

The average N-Gain score of 0.602, categorized as moderate effectiveness, provides additional insight into the impact of the training intervention. Although the result indicates that the program was effective, it also suggests that further improvement is possible before achieving the high-effectiveness category (N-Gain $\geq$ 0.7). One contributing factor may be the relatively short pilot implementation period of one month, which limited opportunities for repeated practice and knowledge reinforcement. According to Rahmawati *et al*. (2024), behavioral change and competency development in non-core operational activities within the oil and gas sector generally require continuous reinforcement over a period of at least three to six months to achieve optimal internalization. Nevertheless, the relatively narrow N-Gain range among participants (0.513-0.713) indicates that the training program was able to benefit personnel with diverse educational backgrounds and varying levels of prior experience. The use of actual incident cases from six grass-cutting incidents recorded in Pertamina Hulu Energi between 2022 and 2024 enhanced the practical relevance of the training content.

The competency improvements observed in this study are particularly relevant when compared with the root causes identified in the six historical incidents analyzed during the research. None of the six incidents documented the existence of hazardous area verification, debris-clearing procedures, or comprehensive pre-work assessments before grass-cutting activities commenced. This shows that personnel lacked both procedural guidance and sufficient knowledge regarding risk management in classified areas. Following implementation, 88.9% of personnel achieved competency status, reflecting a substantial transformation in their ability to identify hazards, verify area classifications, conduct site surveys, and implement appropriate controls. The largest improvement was observed in the practical skills component, which increased by 33.7%. This finding is highly relevant because 50% of the historical incidents involved contact with hidden wires or metal debris concealed in tall grass. The newly introduced mandatory debris-clearing and area-survey procedures directly address this recurring hazard by ensuring that potential dangers are identified and removed before work begins. Consequently, the results support the premise that training programs developed from actual incident analyses are more targeted and effective than generic safety training programs that fail to address specific operational risks. Although the present study primarily evaluated improvements in personnel competency, these improvements provide an important base for strengthening OHS system reliability through better hazard recognition, procedural compliance, and safer work practices.

Despite the positive outcomes, several limitations should be considered when interpreting the findings:

1. First, the pilot project was conducted over only one month and involved competency assessments for nine personnel, limiting the ability to observe long-term effects on lagging indicators such as Total Recordable Incident Rate (TRIR), Near Miss Frequency, and Severity Rate. As suggested by Hamilton and Kletz (2023), improvements in leading indicators often require a time lag of approximately three to six months before measurable reductions in accident rates become evident. Therefore, the findings should be interpreted as evidence of improvement in a leading indicator of OHS system reliability rather than confirmation of improvements across all system-level safety outcomes.
2. Second, the relatively small sample size limits the generalizability of the findings to broader populations within the oil and gas industry.
3. Third, the possibility of a Hawthorne Effect cannot be entirely excluded because participants were aware that they were being observed during the pilot implementation period.
4. Fourth, historical baseline data may underestimate actual incident frequencies because reporting rates for non-core activities are generally lower than those for core operational activities, as reported by Rahmawati *et al*. (2024).

Conclusion

The development and implementation of an integrated Standard Operating Procedure (SOP) for grass-cutting activities, combining the Permit to Work (PTW) system with API 500/505 hazardous area classification standards, significantly improved personnel competency and strengthened the reliability of the occupational health and safety (OHS) system in upstream oil and gas operations. Statistical analysis confirmed a significant increase in competency scores ($t = 23.330$; $p < 0.05$), with the average score improving from 76.33 (50.9% of the maximum score) before implementation to 120.67 (80.4%) after implementation. The integrated training program achieved moderate effectiveness (average N-Gain = 0.602), with 88.9% of participants reaching the competency threshold.

The developed SOP comprises seven integrated components that directly address the root causes identified from six historical grass-cutting incidents, including hazardous area verification, mandatory debris-clearing and worksite surveys, equipment selection based on area classification, gas testing, communication and coordination mechanisms, competency development, and continuous monitoring. Baseline assessment also revealed substantial weaknesses in the existing safety management system, including PTW compliance (67%), permit quality (58%), hazard identification effectiveness (45%), and personnel competency (50.9%), confirming the need for a more comprehensive and integrated approach. The study hypothesis that integrating PTW requirements with API 500/505 standards enhances the reliability of OHS systems, as evidenced by a very large practical effect (Cohen's d ≈ 7.78), although longer-term monitoring of at least 3-6 months is still required to verify improvements in lagging safety indicators such as incident and severity rates.

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