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Original Article

Improving occupational safety through the implementation of a management system based on ISO 45001 in a primary forest processing plant – Puno, Peru

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ABSTRACT

Introduction: This study assessed the impact of implementing an Occupational Health and Safety Management System (OHSMS) based on ISO 45001:2018 at a primary forest processing facility in Puno, Peru—an industrial site characterized by high occupational risks.

Methods: A quasi-experimental design with pre-test and post-test measurements was applied to a census of 37 employees (n=37). Data collection involved a 22-item structured survey mapped to the ISO 45001 clauses, the IPERC matrix for risk assessment, and direct observations.

Results: Post-intervention results showed significant improvements ($p < 0.001$) across all clauses, with safety perception increasing by 45%, leadership participation by 41%, and proper use of personal protective equipment by 52%. The most significant progress was observed in Planning ($Z = 4.47$), Support ($Z = 4.99$), and Performance Evaluation ($Z = 4.55$).

Conclusion: Implementing ISO 45001:2018 produced measurable advancements in preventive culture and risk mitigation. These findings provide empirical support for adopting the standard in Small and Medium-sized Enterprises (SMEs) within developing economies

Keywords: ISO 45001; Occupational Safety; Forest Industry; Risk Management; Peru

Introduction

Work is the means through which individuals meet their basic needs, pursue personal goals, and actively contribute to society.[1] However, in this context, occupational health and safety (OHS) remains a critical challenge. Research indicates that workplace accidents are frequently linked to human factors and a lack of systematic interventions.[2–4] emphasizing the urgent need for structured prevention strategies.[5] This situation is particularly critical in industries where workers face daily hazards that affect health and productivity, such as the forest processing sector.[6–9]

To address these risks, implementing an Occupational Health and Safety Management System (OHSMS) based on ISO 45001 ensures compliance with legal requirements and improves the efficiency of accident prevention.[10–13] Furthermore, complementary tools such as the IPERC matrix (Hazard Identification, Risk Assessment, and Control Measures) allow organizations to systematically identify hazards

and have been shown to significantly reduce risk levels.[14–21] In the Peruvian context, Law No. 29783 provides the mandatory guidelines for OHS implementation.[22,] serving as the essential foundation for policies protecting worker well-being in the region.[23–27]

Research Gap: While the benefits of OHS systems and digital tools are increasingly recognized in the literature. [28–32] There is a notable lack of empirical research regarding the practical application of ISO 45001 in Small and Medium-sized Enterprises (SMEs) within high-risk sectors in Latin American developing economies. This study addresses this gap by providing quantitative evidence of the standard's efficacy in a primary forest processing plant in the Peruvian Andes.

Methods

The study was conducted at the primary forest processing plant of Corporación Caliz S.A.C., located in an industrial zone in the district of Puno, Peru. This location is significant because of the forest industry's relevance and its environmental and occupational safety impacts

Study Design and Population:

A quasi-experimental design with pretest and posttest measurements was used to evaluate the intervention.[33] The study population comprised a census of 37 workers (n=37), representing 100% of the operational and administrative staff. A non-probabilistic convenience sampling method was used, as the study aimed to evaluate the intervention across the entire existing workforce rather than a randomized subset. While this approach limits the generalizability of findings to the broader forestry industry, it ensures high internal validity for this specific case study.

Data collection relied on three main tools. First, a situational assessment was conducted through direct observation with a structured checklist, identifying unsafe acts, hazardous conditions, and deficiencies in PPE use, signage, and machine safeguards. Second, the IPERC matrix was applied to classify risks by severity, probability, and exposure, following National Institute for Occupational Safety and Health guidelines. Third, a 22-item survey based on ISO 45001:2018 clauses was used, with a three-point Likert scale (3 = Always, 2 = Sometimes, 1 = Never); its validity was confirmed through expert judgment, and its reliability was assessed in a pilot test. The internal reliability of the instrument was determined using Cronbach's alpha, with excellent values: Pre-test = 0.982 and Post-test = 0.977. These values exceed the recommended threshold of 0.70, confirming the instrument's internal consistency.

Intervention Procedure:

The OHSMS implementation followed the ISO 45001:2018 framework over a four-month period. The process was structured in three key phases: (1) Initial Diagnosis using the IPERC matrix and direct observation; (2) Design and Implementation, which included adopting an OHS policy, staff training, hazard control, and emergency planning; and (3) Post-implementation Evaluation, where the survey and risk assessments were repeated to measure impact.For data analysis, the normality of average scores per clause was first assessed using the Shapiro-Wilk test for both pre-test and post-test data. Since the data did not follow a normal distribution, the non-parametric Wilcoxon signed-rank test was applied to compare pre- and post-intervention results. A significance level of $p = 0.05$ was used. Additionally, effect sizes (r) were calculated for the Wilcoxon signed-rank tests to quantify the magnitude of the intervention's impact, interpreted as small (<0.3), medium (0.3–0.5), or large (>0.5). All statistical analyses were performed using the R environment (version 4.3.0), with packages such as tidyverse, readxl, openxlsx, and ggplot2 for data organization, analysis, and visualization, following similar methodological approaches used in applied occupational safety research.[34,35]

Direct Observation

The situational diagnosis conducted at Corporación Caliz S.A.C. through direct observation revealed several deficiencies in occupational safety practices. A critical finding was the absence of Personal Protective Equipment (PPE) during high-risk tasks such as handling timber logs, sharpening the band saw, and processing and storing wood. This exposed workers to musculoskeletal injuries, cuts, as well as eye and hearing damage. Infrastructure-related issues were also identified, including a lack of machine guarding, the absence of safety signage, inadequate fire protection measures, uneven flooring, and poor hygienic conditions. These deficiencies significantly increased workers' vulnerability to occupational accidents.

Table 1: Positive aspects and areas for improvement in working conditions at the primary forest processing plant

Category	Description
Positive Aspects	- The work environment has good ventilation and lighting, which enhances worker safety and comfort. - The limited space encourages communication and collaboration among employees.
Areas for Improvement	- The office has a small area, which affects comfort and functionality. - There is a lack of personal protective equipment (PPE), increasing the risk of workplace accidents. - There are no protective guards on the band saw and other equipment, posing a safety hazard. - There is a lack of safety signage and fire protection measures. - Uneven floors create tripping and falling hazards. - The electrical panel lacks proper protection, increasing the risk of electric shock.

The assessment of working conditions at the primary forest processing plant revealed both positive aspects and critical areas requiring intervention. Among the favorable elements, proper ventilation and lighting stand out, contributing to greater operational safety and thermal comfort for workers. The limited space also facilitates interaction among personnel, enhancing communication throughout the processes. However, several deficiencies were identified that compromise occupational health and safety, including the lack of personal protective equipment (PPE), the absence of guards on the band saw, and the lack of safety signage and fire prevention measures Table 1. Physical hazards were also reported due to uneven and unlevel floors, as well as electrical hazards caused by exposed installation.

IPERC Matrix

This process was carried out on-site, with the active collaboration of the company's supervisors, who contributed their valuable experience and knowledge in the identification and assessment of hazards and risks. The Hazard Identification, Risk Assessment, and Risk Control (IPERC) was conducted comprehensively, taking into account the variety of environments present in each area of the facility.

Hazard Identification, Risk Assessment, and Control Measures – Baseline Study

Management: Primary Wood Transformation Plant "Corporación Caliz S.A.C."							**Code: 002**	
Safety Manager: Fanny Luz Calizaya Llatasi							**Versión:**	
Proceso: Operacional							**Date:**	
Actividad	**Task**	**Hazard**	**Risk**	**Evaluation**	**Contról de Ingeniería**	**Control administrativo**	**Reevaluación**	**Acción de mejora**
Reception and Storage of Logs Using a Forklift	Log Unloading from the Trailer	Fall from height	Impacts and collisions		Safe unloading platform with rollers	Training; Develop unloading plan		Installation of unloading ramp
	Transfer from Trailer to Warehouse	Crushing	Musculoskeletal injuries		Lifting unloading platform	Ergonomic training on log handling		Strong and elevating carts
	Log Reception	Log slipping	Upper limb injuries		Anti-slip rollers on the platform	Uso obligatorio de huantes de protección		Implementation of platforms with handrails
Cutting and Sizing	Operate band saw machine	Machine entrapment	Limb entrapment		Guards and barriers around the machine	Mandatory use of protective gloves		Presence detection and emergency stop
	Cutting and sizing logs	Entrapment in cutting machine or equipment	Entrapments, cuts and amputations		Guard installation on cutting machine	Extensive operator training		Implementation of cranes and clamping devices
Sorting, Packaging, and Storage	Bundling wooden pieces with wire	Cuts or puncture injuries	Injuries to upper limbs		Appropriate PPE (gloves, hand tools)	Exhaustive training and instruction		Ergonomic-handled tools and/or packaging machines
	Organized storage of products	Falling stacked wood	Injuries by crushing, impacts, or entrapment		Adequate PPE (safety boots)	Safe storage procedure		Strong and elevating carts

Figure 1: Hazard identification, risk assessment, and control measures in the baseline scenario

Figure 1 presents the Hazard Identification, Risk Assessment, and Control (IPERC) matrix applied to the baseline scenario of the operational process at Corporación Caliz S.A.C.'s primary forest processing plant. This tool enabled the identification of critical tasks within the log reception, cutting, and storage activities, where significant risks such as entanglement, falls, impacts, musculoskeletal injuries, and amputations were identified. Risk levels were represented using a color-coded system (red, yellow, and green) based on severity. Among the most notable findings were high-risk levels (red) in tasks related to log handling and machinery operation, indicating deficiencies in engineering and administrative controls. For each identified hazard, control measures were proposed, including secure unloading platforms, machine guards, comprehensive training programs, mandatory PPE use, and ergonomic improvements—all aligned with the requirements of Clause 6 of the ISO 45001:2018 standard.

Ethical Considerations

The study was conducted in accordance with the ethical standards of the Universidad Nacional del Altiplano (UNA-Puno). The research protocol was reviewed and approved by the Research Ethics Committee of the Vice-Rectorate for Research (VRI) under the institutional registration number PILAR 2023-0321. Additionally, the study was institutionalized through Rectoral Resolution N° 1652-2024-R-UNA. Informed consent was obtained from all participants prior to data

collection, ensuring the voluntary nature of their participation and their right to withdraw at any time. The confidentiality of individual responses was guaranteed by anonymizing survey data, and the intervention posed no physical or psychological risk to participants.

Results

The Wilcoxon test results showed statistically significant differences between the pre-test and post-test in most clauses. The W, Z, and p significance values were calculated for each clause. Positive Z values and significant p-values ($p < 0.001$) confirm an increase in scores after the intervention. Notable improvements were observed in Clauses 6 (Planning: $Z = 4.47$, $p < 0.001$), 7 (Support: $Z = 4.99$, $p < 0.001$), and 9 (Performance Evaluation: $Z = 4.55$, $p < 0.001$). This indicates a general improvement in perceptions of occupational safety following the adoption of the ISO 45001 system.

Table 2: Wilcoxon Test Results by ISO 45001 Clauses.

Clausula	W	Z	p_valor
4. Organizational Context	84	3.38	< 0.001
5. Leadership and Worker Participation	43	4.26	< 0.001
6. Planning	15.5	4.47	< 0.001
7. Support	2	4.99	< 0.001
8. Operation	84.5	3.64	< 0.001
9. Performance Evaluation	11.5	4.55	< 0.001
10. Improvement	32	4.23	< 0.001

The Wilcoxon signed-rank test showed significant differences ($p < 0.001$) between the pre-test and post-test across all ISO 45001 clauses, with Z values ranging from 3.38 to 4.99, confirming substantial improvements in occupational safety perception following the implementation of the OHSMS.

The pre-test results revealed significant deficiencies in key aspects of occupational health and safety before the implementation of the Management System. Most questions received a high number of "Never" responses, indicating the absence of formal safety practices, limited employee involvement, and inadequate training. These findings guided the design of targeted improvement actions aligned with the ISO 45001 clauses, as detailed in Table 3. The implemented actions included developing a Hazard Identification and Risk Assessment (IPERC), strengthening leadership, providing Personal Protective Equipment (PPE), standardizing safe operating procedures, and creating emergency response plans.

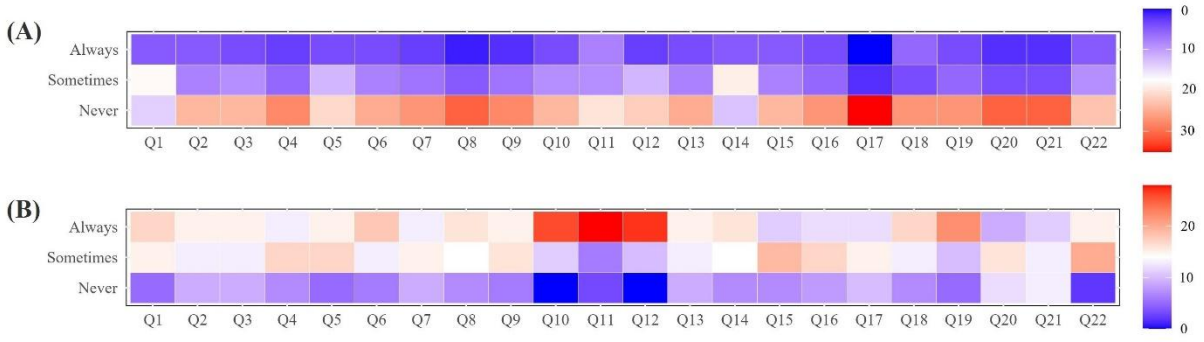

Figure 2. Frequency distribution of responses: (A) Pre-test phase and (B) Post-test phase.

These heatmaps illustrate the response frequency across 22 items for 37 workers. Darker red tones indicate higher frequency, while blue represents lower frequency. In the pre-test (Panel A), significant deficiencies were observed in items such as Q17, Q20, and Q21, where "Never" responses were prevalent. In contrast, the post-test (Panel B) shows a visual transition where red tones shifted to the "Always" category. For instance, in question Q11 (PPE use), the concentration of red tones in the "Always" row indicates consistent adherence to safety regulations.

Table 3. Comparative analysis of survey results before and after ISO 45001 implementation (n=37).

ISO 45001 Clause	Item	Question (Condensed)	Pre-test (A / S / N)*	Improvement Action Implemented	Post-test (A / S / N)*
4. Context	Q1	Informed about OHS?	5 / 18 / 14	Safety bulletins & information posters.	17 / 15 / 5
	Q2	Aware of risks?	5 / 8 / 24	Hazard identification workshops.	15 / 13 / 9
	Q3	Feedback considered?	4 / 9 / 24	Formal suggestion channel established.	15 / 13 / 9
5. Leadership	Q4	Mgt. promotes culture?	3 / 6 / 28	Visible leadership & safety meetings.	13 / 17 / 7
	Q5	Active participation?	4 / 12 / 21	Workers involved in safety committees.	15 / 17 / 5
	Q6	Suggestions heard?	4 / 8 / 25	Supervisor training on active listening.	18 / 13 / 6
6. Planning	Q7	Risks assessed before tasks?	3 / 7 / 27	IPERC applied before critical tasks.	13 / 15 / 9
	Q8	Emergency plans in place?	1 / 5 / 31	Emergency plan developed & drills conducted.	16 / 14 / 7
	Q9	Preventive measures in changes?	2 / 7 / 28	Risk analysis integrated into changes.	15 / 16 / 6
7. Support	Q10	Regular OHS training?	4 / 9 / 24	Annual training plan implemented.	26 / 11 / 0
	Q11	PPE access and use?	8 / 9 / 20	PPE supply & supervision enforced.	28 / 6 / 3
	Q12	Signs visible/clear?	3 / 12 / 22	Standardized signage installed.	27 / 10 / 0
8. Operation	Q13	Safe procedures followed?	4 / 8 / 25	Safe Operating Procedures (SOPs) implemented.	15 / 13 / 9
	Q14	Cleanliness/Order (5S)?	5 / 19 / 13	Routine cleaning & layout organization.	16 / 12 / 9
	Q15	Equipment inspection?	5 / 8 / 24	Inspection schedule & logs created.	11 / 15 / 11
	Q16	Rules followed consistently?	4 / 6 / 27	Reinforced supervision & compliance.	12 / 17 / 8

9. Perf. Eval.	Q17	Informed of audit results?	0 / 2 / 35	Audit findings shared with staff.	12 / 15 / 10
	Q18	Incidents investigated?	6 / 4 / 27	Root cause analysis applied.	18 / 13 / 7
	Q19	Improvements communicated?	4 / 6 / 27	Feedback meetings on actions taken.	22 / 10 / 5
10. Improvement	Q20	Corrective actions seen?	2 / 4 / 31	Corrective actions logged & displayed.	9 / 12 / 16
	Q21	Continuous improvement promoted?	2 / 3 / 32	Periodic progress reports & policy update.	11 / 14 / 12
	Q22	Motivated to report acts?	5 / 9 / 23	Anonymous reporting & positive reinforcement.	16 / 12 / 9

The results in Table 3 of the post-test reflect a significant improvement in workers' perception, knowledge, and application of occupational health and safety practices compared to the pre-test. This improvement is a direct result of implementing the Occupational Health and Safety Management System (OHSMS) in accordance with the requirements of ISO 45001:2018. Concrete progress was observed in key areas, including training (item Q10), where 100% of workers reported receiving instruction; access to and condition of personal protective equipment (Q11); and visibility and understanding of safety signage (Q12). These results demonstrate that the "Support" section (Clause 7) is an effective intervention, contributing to a safer environment and better working conditions. There was also a reported increase in participation in safety-related activities (Q5) and a greater appreciation of worker input by supervisors and management (Q6), indicating strengthened leadership and active involvement (Clause 5). The implementation of feedback mechanisms and consultation spaces played a key role in these advancements.

Regarding planning and operational control (Clauses 6 and 8), improvements were noted in the application of safe procedures and emergency preparedness (Q8). However, weaknesses persist in areas such as the frequency and effectiveness of technical inspections (Q15) and the timely implementation of corrective actions (Q20), with "Never" responses remaining significant. It suggests that although the system has been implemented, specific actions still require ongoing follow-up and operational reinforcement.

Concerning continual improvement (Clause 10), while there is progress in workers' perception of the company's efforts (Q21), there remains to strengthen a culture of sustained improvement. It includes institutionalizing the periodic review of results and expanding recognition and motivation mechanisms for reporting unsafe conditions (Q22). The post-test results demonstrate that implementing the OHSMS has led to positive, measurable changes in occupational safety management. Nonetheless, the findings also highlight areas that require attention during the system consolidation phase. These outcomes support the effectiveness of ISO 45001:2018 as a strategic tool for reducing risks, improving preventive culture, and protecting worker health in industrial environments such as the primary forest transformation plant.

Radar chart comparing the degree of compliance with ISO 45001:2018 clauses (Context, Leadership, Planning, Support, Operation, Performance, Improvement) between the Pre-test and Post-test is shown in Figure 3. The expansion of the plot area in the post-test demonstrates a comprehensive improvement in management system performance, particularly in Planning and Support.

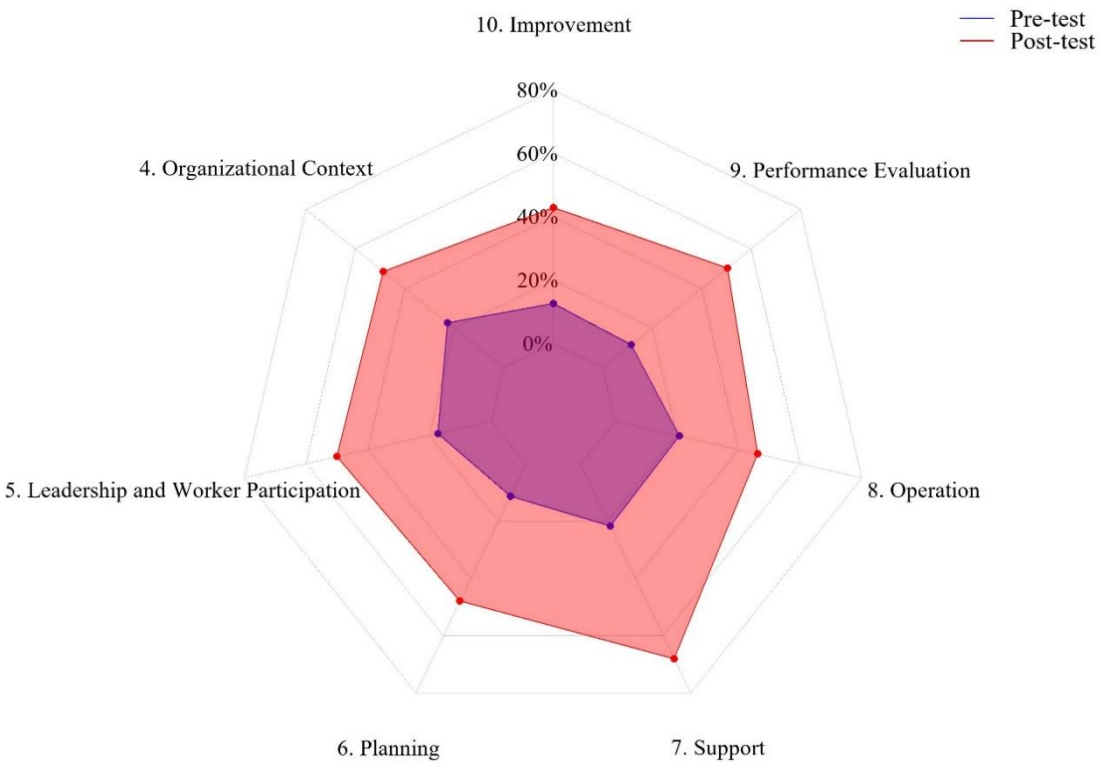

Figure 3. Comparative radar chart of compliance by ISO clause (Pre-test vs. Post-test).

Discussion

The findings of this study demonstrate that implementing the Occupational Health and Safety Management System (OHSMS) in accordance with ISO 45001:2018 led to significant improvements in safety perception, practices, and culture at the primary forestry processing plant of Corporación Caliz S.A.C. in Puno. This improvement aligns with previous studies highlighting the positive impact of this standard in similar industrial environments.[36,37,38]

Impact of ISO 45001 Clauses on Organizational Behavior. First, the pre-test analysis revealed several structural and managerial shortcomings, including a lack of visible leadership and a weak risk-reporting culture. These weaknesses are consistent with the study that argues that the lack of organizational integration in safety systems limits their effectiveness, especially in small and medium-sized enterprises (SMEs).[36] The intervention effectively addressed these critical areas. The emphasis on Leadership and Worker Participation (Clause 5) fostered a positive organizational shift, aligning with findings by Malinda & Soediantono, who emphasize the role of supervisors as facilitators of a preventative culture.[40] Furthermore, strengthening internal communication and participatory leadership proved key to reducing occupational accidents, as suggested by international literature.[41,42]

Operational Improvements and Risk Management The rigorous application of the IPERC matrix (Hazard Identification, Risk Assessment, and Risk Control) was crucial for prioritizing corrective actions and mitigating specific hazards.[43,44] This strategy enabled effective intervention in high-risk processes, such as machine handling (e.g., the band saw), for which incidents had been recorded prior to the intervention. Additionally, the observed effects not only benefit workers but also increase productivity and reduce losses from accidents or downtime, consistent with findings in high-risk industrial settings.[45]

Challenges in System Maturity. Despite the overall success, limitations persisted after implementation, particularly regarding perceptions of efficiency in corrective action management (Clause 10). These challenges are in line with findings that improvement actions often require more time to mature and produce sustained impacts on organizational culture.[46] This reinforces the need for ongoing training and leadership renewal, especially in the Peruvian context, where SMEs face resource constraints. Similar outcomes have been reported in forestry and industrial sectors, which found that the cultural co-creation of safety practices enhances long-term performance, while identifying managerial engagement as a key factor in risk reduction.[47,48]

Limitations and Future Directions

It is important to acknowledge certain limitations. First, the reliance on self-reported survey data introduces the risk of social desirability bias, in which workers may overreport positive behaviors to align with perceived management expectations. Second, the sample size (n=37), while representing a census of the specific plant, limits the generalizability of findings. Future research should address these gaps by employing a mixed-methods approach that triangulates perception surveys with objective data sources, such as official accident records. This approach would verify if interventions translate into lasting organizational learning rather than isolated compliance.[49]

Conclusion

The implementation of the Occupational Health and Safety Management System (OHSMS), following ISO 45001:2018, significantly strengthened the safety culture and operational discipline in the studied plant, confirming the effectiveness of structured management approaches.

The comparative pre–post design validated the system's positive impact and supports its scalability to other industrial contexts. Despite the positive outcomes, the study identified ongoing challenges in managing corrective actions and fostering a culture of continuous improvement, highlighting the need for sustained follow-up and periodic system review. It aligns with findings from other studies, which suggest that the benefits of constant improvement in management systems require time, organizational commitment, and ongoing evaluation.

Beyond the case of Puno, these findings contribute to strengthening Occupational Health and Safety (OHS) practices and policies in Latin America, where many small and medium-sized industries face similar structural limitations. The evidence obtained may inform national strategies for adopting ISO 45001 as a framework for preventive culture and institutional governance. Future research should focus on longitudinal monitoring to evaluate sustained behavioral and organizational change, as well as on integrating ISO 45001 with complementary standards such as ISO 9001 (quality management) and ISO 14001 (environmental management) to promote comprehensive, sustainable performance.

This work contributes to the scientific literature by demonstrating the tangible benefits of implementing ISO 45001:2018 in high-risk industrial environments, supporting its adoption as a key strategy for risk mitigation, accident reduction, and safer workplaces. Building on these results, future research should expand longitudinal analyses and inter-system integration to consolidate preventive management at a regional scale. Assessing the long-term impact of such interventions and their integration with other management systems (e.g., ISO 9001 for Quality, ISO 14001 for Environment) will provide a more holistic approach to organizational safety and sustainability.

Author Contributions

Conceptualization: FC, DS; Methodology: FC, LP; Formal analysis: VA, FC; Investigation: FC; Writing – original draft preparation: FC, DS; Writing – review and editing: LP, VA. All authors have read and agreed to the published version of the manuscript.

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