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Article

Analysis of the Implementation of the International Safety Management (ISM) Code During Tank Cleaning to Optimize Safety on MT. Gandawati

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A B S T R A C T

Tank cleaning on chemical tankers constitutes a high-risk maritime operation necessitating rigorous safety protocols to mitigate asphyxiation, toxicity, and explosion hazards. This study analyzes the implementation of the International Safety Management (ISM) Code during tank cleaning operations on board MT. Gandawati 1 to optimize occupational safety and security. This research employs a descriptive mixed-methods approach, combining quantitative analysis of observational checklists with qualitative analysis of in-depth interviews. The results demonstrate a high level of structural compliance (88%), characterized by the systematic execution of risk assessments, enclosed space entry permits, and continuous atmospheric monitoring. However, a critical gap persists between regulatory requirements and operational reality, primarily driven by human factors. The study identified a 38.5% non-compliance rate regarding Personal Protective Equipment (PPE) usage, attributed to thermal discomfort and commercial time pressures. While the vessel achieved a zero-fatality record, the prevalence of near-miss incidents indicates that safety management has yet to be fully internalized into the onboard culture. The research concludes that optimizing safety requires transcending administrative compliance through enhanced behavioral supervision, ergonomic equipment upgrades, and the cultivation of a resilient safety culture.

1. Introduction

Occupational safety constitutes a fundamental imperative within the maritime industry, specifically for tankers transporting hazardous liquid cargoes where maintaining operational integrity is critical amidst high-risk environments (Jinca, 2019). Notably, tank cleaning represents one of the most hazardous and complex operations; it is an essential procedure for residue removal and contamination prevention but necessitates strictly controlled entry into confined spaces that pose severe threats, including asphyxiation, toxic gas exposure, and fire hazards (Mahardika, 2022; Ramírez-Peña et al., 2023). The inherent dangers of these enclosed spaces are corroborated by significant fatality statistics often exacerbated by human factors, highlighting the urgent necessity for implementing rigorous safety management systems to mitigate risks and prevent casualties during such critical maintenance activities (Sezer et al., 2023; Sunanto et al., 2019).

From the perspective of safety risk management, high-risk operations such as tank cleaning necessitate a systematic framework encompassing hazard identification, comprehensive risk assessment, and a hierarchy of controls to mitigate potential threats effectively (Christhoper, 2019). While theoretical protocols mandate strict adherence to safety measures—including the "permit to work" system, continuous atmospheric monitoring, mechanical ventilation, and the mandatory use of Personal Protective Equipment (PPE)—to ensure a controlled environment, practical execution often diverges from these standards (Sukhron, 2023; Mahardika, 2022). Frequently, operational pressures lead to procedural negligence, such as bypassed risk assessments or inconsistent safety oversight, which significantly amplifies the probability of human error and subsequent accidents, thereby endangering crew lives and risking marine environmental pollution (Sezer et al., 2023; Marsudi, 2022; Zahroh, 2023).

The discrepancy between established safety protocols and operational reality is predominantly driven by human factors—such as fatigue, insufficient competence, and a weak safety culture—which account for the vast majority of maritime accidents, including those occurring during complex operations like tank cleaning (Zahroh, 2023; Sezer et al., 2023). To address these systemic vulnerabilities, which align with Reason's "Swiss Cheese Model" of accident causation where multiple defensive layers fail simultaneously, the International Maritime Organization established the International Safety Management (ISM) Code as a mandatory framework within SOLAS (Badaruddin et al., 2021). This code serves as a comprehensive standard to formalize safety management systems, integrating critical elements such as explicit policies, defined responsibilities, and continuous evaluation mechanisms to mitigate human error and ensure strict adherence to safety standards (Jinca, 2019; Sahara & Alfian, 2024).

While the ISM Code mandates rigorous written protocols for tank cleaning—including "permit to work" systems, continuous atmospheric monitoring, and emergency preparedness—the "Implementation Gap Theory" highlights a persistent divergence between regulatory frameworks and onboard realities due to structural pressures like commercial schedules and resource limitations (Mahardika, 2022; Sukhron, 2023). This disconnect is often exacerbated by a deficient safety culture where productivity supersedes safety, creating an environment ripe for what Heinrich's Domino Theory describes as a chain of causality: unsafe conditions (e.g., inadequate ventilation) and unsafe acts (e.g., procedural non-compliance) inevitably lead to accidents if left unchecked (Sunanto et al., 2019; Ramírez-Peña et al., 2023). Consequently, the failure to effectively bridge this gap maintains a high-risk operational environment, resulting in preventable fatalities that frequently claim the lives of both the initial victims and ill-equipped rescuers (Marsudi, 2022; Jinca, 2019).

A comprehensive analysis of the International Safety Management (ISM) Code within tank cleaning operations is critical to mitigating the multidimensional consequences of maritime accidents, which span humanitarian, environmental, and legal domains (Jinca, 2019; Marsudi, 2022). Although the ISM Code provides a standardized Safety Management System (SMS) necessitating technical and managerial integration, its practical efficacy is often compromised by multifaceted barriers, including human error, operational time pressures, and equipment deficiencies (Badaruddin et al., 2021; Sezer et al., 2023). This disconnect is empirically observed on MT.

Gandawati 1, where a history of near-misses and accidents—attributed to disregarded safety protocols such as gas testing and PPE usage—highlight the critical gap between prescribed regulations and onboard realities (Sukhron, 2023; Sunanto et al., 2019). Addressing these vulnerabilities, this study aims to rigorously analyze the ISM Code's implementation and identify prevailing obstacles to formulate actionable strategies that enhance safety culture and ensure strict compliance (Zahroh, 2023; Ramírez-Peña et al., 2023).

2. Literature Riview

2.1 Previous Research

Existing literature serves as a critical benchmark for evaluating the efficacy of the International Safety Management (ISM) Code, yet a review of prior studies reveals a significant research gap regarding specific high-risk onboard operations. While recent scholarship—such as Mudiyanto (2023), who established a strong correlation (R=0.765) between safety documentation and operational compliance; Arianti et al. (2023), who identified maintenance deficiencies (Code 10) within general ship operations; and Indriyani et al. (2021), who focused on safety protocols during port loading activities—confirms the ISM Code's positive impact on general maritime safety and port environments, these inquiries predominantly address broad operational scopes. Consequently, this research distinguishes itself by shifting the analytical lens from general safety management to the specialized and high-risk context of *tank cleaning*, addressing a critical oversight in previous generalist studies to optimize safety and security protocols where risks are most acute.

2.2 The International Safety Management (ISM) Code

The International Safety Management (ISM) Code serves as a dynamic international regulatory framework established by the IMO to standardize safe vessel operations and pollution prevention, evolving as a critical component of maritime law to address the industry's changing complexities (Sulistijo, 2002; Anderson, 2003). Defined by Hadi (2007) as a comprehensive standard for shipping companies, the Code comprises 16 integral elements—ranging from safety policies and the Master's specific responsibilities to emergency preparedness and audit verification—designed to mitigate accidents and environmental damage (Kurniawan, 2018). Central to its implementation is the Safety Management System (SMS), which, according to IMO (2018) guidelines, must ensure safe operating conditions, establish preventive measures for identified risks, and enhance personnel competence. By delineating clear lines of authority and mandating strict adherence to safety procedures, the ISM Code aims to foster a secure maritime environment, minimize casualties, and ensure rigorous compliance with international standards.

2.3 Tank Cleaning

The Tank cleaning constitutes a critical maintenance operation designed to eliminate cargo residue and prevent cross-contamination, a process which Istopo (1999) classifies into distinct protocols depending on the compatibility of the subsequent cargo. To ensure operational safety and compliance with the International Safety Management (ISM) Code, this procedure necessitates the integration of specialized equipment, including Butterworth machines for high-pressure 360-degree washing, air-driven pumps for residue drainage, and essential atmospheric control devices such as mechanical ventilators and gas detectors to monitor oxygen levels and toxic hazards like H_2S (Mahardika, 2022). The execution follows a systematic workflow involving coordination between deck and engine departments, sequential saltwater and freshwater rinsing, and a rigorous gas-freeing process, culminating in manual mopping by crew members equipped with mandatory Personal Protective Equipment (PPE) to verify the tank's dryness and safety prior to final closure (Marsudi, 2022; Istopo, 1999).

2.4 Occupational Health and Safety (K3)

Occupational Health and Safety (K3) is fundamentally conceptualized as a comprehensive framework designed to safeguard the physical and mental integrity of the workforce by anticipating and mitigating operational risks across both office and field environments (Rezky & Azma, 2019). As delineated by Mondy (2012) and Ridley (2006), this discipline extends beyond the mere prevention of work-related injuries to encompass the holistic management of machinery, processing methods, and environmental conditions, thereby ensuring a state of operation free from danger that contributes to broader human welfare. Ultimately, the effective implementation of safety protocols aims to establish a secure ecosystem where the interaction between personnel, equipment, and procedures is rigorously controlled to prevent accidents, occupational diseases, and material losses (Buntarto, 2015).

The objectives of Occupational Health and Safety (OHS) are fundamentally dual-faceted, aiming to synergize institutional efficiency with individual well-being. As defined by Sukrisno (2006), effective safety protocols serve the corporate entity by optimizing performance, preventing financial loss, and safeguarding assets, while simultaneously ensuring that employees remain secure throughout their operational duties. Expanding on this holistic framework, Buntarto (2015) asserts that OHS is critical not only for protecting workers' rights to welfare and ensuring the safety of all personnel within the immediate environment but also for guaranteeing that production resources are utilized efficiently to drive broader national productivity.

3. Research Methodology

This research employs a descriptive mixed-methods approach, combining quantitative analysis of observational checklists with qualitative analysis of in-depth interviews. To determine the level of ISM Code implementation, the study utilizes a structured observation checklist comprising 25 safety indicators derived from the ISM Code and Safety Management System (SMS) manuals. The compliance rate is calculated using the frequency distribution formula:

$$\text{Compliance Rate} = \frac{\text{Number of Compliant Items}}{\text{Total Items Observed}} \times 100\%$$

Grounded in the frameworks established by Creswell (2014) and Moleong (2014), the research seeks to understand operational phenomena within their natural context without seeking statistical generalization. The investigation was conducted over a duration of approximately twelve months, from September 8, 2023, to September 15, 2024, onboard the MT. Gandawati 1, a vessel operated by PT Berlian Laju Tanker Tbk, allowing for direct engagement with the subject matter.

The quantitative data provides a measurable overview of safety adherence (e.g., 88% compliance), while the qualitative data—analyzed using Miles, Huberman, and Saldaña's (2014) interactive model (data reduction, data display, conclusion drawing)—explains the underlying causes of non-compliance (e.g., human factors, equipment reliability) and provides context to the statistical findings.

This empirical evidence is substantiated by secondary data derived from academic literature, journals, and regulatory frameworks including SOLAS and the ISM Code (Sekaran & Bougie, 2016). The data collection strategy integrates systematic observation, structured inquiries, and institutional documentation to ensure the triangulation of evidence regarding safety protocols.

The analytical framework adopts a descriptive qualitative approach utilizing Miles and Huberman's interactive model, which proceeds through three concurrent flows of activity: data reduction, data display, and conclusion drawing. This systematic process involves the rigorous selection and categorization of relevant information (reduction), followed by the organized presentation of data through narrative texts and matrices (display) to identify operational patterns. Ultimately, conclusions are drawn and verified to evaluate the effectiveness of the ISM Code implementation, providing actionable insights into bridging the gap between regulatory requirements and onboard practices.

4. Results and Discussion

4.1 Interviews

The research findings presented in this chapter delineate the practical application of the International Safety Management (ISM) Code on MT. Gandawati 1, specifically addressing the operational obstacles encountered during tank cleaning. Utilizing a descriptive qualitative methodology, the study synthesizes empirical data gathered through field observations and in-depth interviews to reconstruct the operational narrative regarding safety compliance. This section focuses on the data reduction of primary sources, serving to highlight the critical disparities between mandated regulatory protocols and the actual behaviors and risk perceptions exhibited by the crew during high-risk maintenance tasks.

Detailed interviews with key personnel, specifically the Chief Officer and Bosun, disclose a recurring pattern of occupational hazards ranging from respiratory distress caused by hydrogen sulfide (H_2S) exposure to physical injuries such as slips and chemical burns. The respondents unanimously identify the root causes as a combination of procedural negligence—such as bypassing gas testing requirements and prioritizing speed over safety—and a distinct lack of discipline regarding Personal Protective Equipment (PPE). The data indicates that crew members frequently compromise their own safety by voluntarily removing essential protective gear, including masks and gloves, due to physical discomfort or overconfidence, a behavioral lapse that has directly precipitated avoidable accidents and near-miss incidents onboard.

4.2 Observations

Based on a twelve-month longitudinal observation conducted onboard MT. Gandawati 1, the operational application of the International Safety Management (ISM) Code during tank cleaning procedures demonstrates a high degree of structural compliance. Quantitative analysis of 25 distinct safety indicators reveals that 22 aspects, representing 88% of the observed protocols, were executed in full alignment with regulatory standards. This high operational fidelity is evidenced by the rigorous implementation of preparatory measures, including the systematic execution of risk assessments, the strict authorization of "enclosed space entry permits" signed by the Master and Chief Officer, and the consistent conduct of safety meetings prior to operations. Furthermore, technical controls were found to be robust, with mechanical ventilators (blowers) operating for 10–12 hours to ensure adequate circulation and gas testing performed at three distinct levels (top, middle, bottom) to verify atmospheric safety.

Despite these strong institutional controls, a significant compliance gap persists within the domain of human behavior, accounting for the remaining 12% of observed deficiencies. The primary area of concern is the inconsistency in Personal Protective Equipment (PPE) usage, where approximately 38.5% of the crew were observed disregarding mandatory safety gear. This non-compliance is particularly acute regarding chemical suits, which crew members frequently remove due to thermal discomfort and perceived physical hindrance during operations. Additionally, the observation identified a cognitive gap in emergency preparedness; despite regular participation in training and drills, a subset of the crew demonstrated a lack of detailed retention regarding emergency response procedures, suggesting that current training methods may not be yielding sufficient recall under practical conditions.

In conclusion, the observational data illustrates a dichotomy between the vessel's administrative safety management and its practical safety culture. While the management has successfully established a reliable system for documentation, supervision, and technical preparation—ensuring that critical checks like gas monitoring and permit validation are routinely performed—operational safety is compromised by individual behavioral lapses. The findings indicate that while the structural commitment to the ISM Code is intact, the optimization of safety and security onboard MT. Gandawati 1 necessitates a strategic shift towards reinforcing crew discipline and enhancing individual risk awareness to bridge the gap between procedural theory and human practice

4.3 Secondary Data : ISM Code

The research substantiates its analysis of the ISM Code implementation on MT. Gandawati 1 through a comprehensive review of secondary data, specifically twelve critical document categories—ranging from the Safety Management Manual (2023 revision) to the Document of Compliance (valid until 2026)—all of which were verified to be in optimal condition and fully available. Qualitative categorization of the field data indicates that the vessel maintains a robust procedural framework for tank cleaning, characterized by the rigorous execution of risk assessments, "permit to work" authorization, and pre-operational safety meetings. This administrative compliance is operationally supported by a strict atmospheric monitoring regime—maintaining Oxygen levels between 20.8–21% and H_2S below 5 ppm—alongside a hierarchical supervision system involving the Chief Officer, Bosun, and dedicated watchmen to ensure emergency preparedness through the availability of SCBAs and rescue teams.

Despite this structural adherence, the study identifies significant impediments to full compliance, primarily driven by human and operational factors. A substantial portion of the crew (38.5%) demonstrates inconsistent discipline regarding Personal Protective Equipment (PPE), a behavior attributed to thermal discomfort from chemical suits and a prevailing perception that safety protocols are excessively burdensome. These behavioral lapses are further exacerbated by systemic pressures, including commercial demands for rapid cargo turnaround, technical reliability issues such as gas detector malfunctions, and communication barriers inherent to a linguistically diverse multinational crew, all of which complicate the effective execution of the ISM Code during high-risk operations.

4.4 Data Analysis

Atmospheric Control and Equipment Reliability The observation data indicates a 100% procedural compliance rate regarding atmospheric testing; no personnel were permitted to enter enclosed spaces without a valid gas test result confirming oxygen levels between 20.8–21% and H_2S below 5 ppm. However, it is important to distinguish between *procedural compliance* and *equipment reliability*. While the protocol to test was strictly followed, the research identified equipment malfunctions (e.g., sensor errors or battery failures on portable detectors) as a significant operational hindrance. These malfunctions did not lead to safety violations because operations were immediately suspended until backup units were deployed or calibration was rectified. Thus, while technical issues caused operational delays, they did not compromise the strict adherence to the safety mandate of "No Test, No Entry.

The primary impediments to full compliance are attributed to human behavioral factors rather than systemic or equipment failures. The data suggests that crew resistance to safety protocols stems from physical discomfort, particularly regarding the use of chemical suits in high-temperature environments, and a perception that strict adherence to procedures is operationally inefficient. In response to these behavioral constraints, the vessel's management has initiated strategic corrective actions, including the enforcement of stricter supervision and the execution of safety campaigns, aiming to harmonize crew discipline with the established safety management framework.

4.5 Discussion

1) **Implementation of the International Safety Management (ISM) Code During Tank Cleaning Operations to Optimize Occupational Safety and Security**
   The The research indicates that the implementation of the International Safety Management (ISM) Code on MT. Gandawati 1 has achieved a high degree of operational maturity, evidenced by an 88% procedural compliance rate and a robust documentation system—including the Safety Management Manual and specific "permit to work" protocols—that functions as an effective operational control instrument rather than a mere administrative formality. This systematic adherence validates the theoretical framework posited by Kurniawan (2018) and the IMO (2018), illustrating a paradigm shift from reactive error correction to proactive hazard mitigation through rigorous risk assessments and mandatory safety meetings prior to every tank cleaning operation. Crucially, this preventative approach is anchored by the strict enforcement of atmospheric standards, where operations are contingent upon consistent gas testing results—specifically maintaining oxygen levels between 20.8–21% and ensuring Hydrogen Sulfide (H_2S) remains below 5 ppm—to prevent physiological impairment or fatal toxicity.
   Operational safety is further reinforced by a multi-layered supervision strategy involving the Chief Officer, Bosun, and dedicated watchmen, a hierarchical structure that Indriyani et al. (2021) identify as essential for effective ISM Code execution. This oversight is complemented by the mandatory "buddy system" and a high state of emergency preparedness, characterized by the availability of maintained rescue equipment like SCBAs and the regular conduct of SOLAS-mandated drills to ensure rapid response capabilities. Consequently, the vessel recorded zero major injuries or fatalities over the twelve-month observation period, validating the "Safety Pyramid" concept

where the effective control of minor unsafe acts and conditions successfully prevents the escalation of incidents into severe casualties.

2) **Obstacles in ISM Code Implementation During Tank Cleaning**
Despite the establishment of robust safety procedures, the effectiveness of the ISM Code is significantly compromised by human factors, specifically a lack of discipline regarding Personal Protective Equipment (PPE) usage, where 38.5% of the crew were observed disregarding safety gear protocols. This behavioral lapse validates the findings of Sezer et al. (2023), who identify human error—manifested as unsafe acts like removing PPE due to thermal discomfort or prioritizing speed over safety—as the primary precipitate of accidents in tank cleaning operations. These individual failures are exacerbated by systemic operational pressures, including commercial demands for rapid cargo turnaround and technical deficiencies such as gas detector malfunctions, which collectively underscore the "technical and human resource" vulnerabilities previously identified in maritime safety management studies.
In response to these multifaceted challenges, the vessel's management has operationalized the ISM Code's principle of "continuous improvement" through a series of targeted preventive and corrective interventions. To bridge the gap between protocol and practice, the ship has intensified supervisory oversight and initiated regular safety campaigns designed to reinforce risk awareness and individual accountability. Furthermore, the management has addressed specific environmental and demographic constraints by implementing a rigorous planned maintenance system for safety equipment, simplifying safety instructions to overcome linguistic barriers within the multinational crew, and adjusting work schedules to mitigate fatigue caused by thermal stress, thereby ensuring a dynamic and adaptive safety culture.

Table 1. ISM Code Compliance Checklist (25 Safety Indicators)

No.	Safety Indicator Category	Specific Indicator	Status	Finding/Observation
1	Preparation & Administration	1. Risk Assessment conducted & signed	Compliant	Documents complete.
		2. Enclosed Space Entry Permit issued	Compliant	Signed by Master & C/O.
		3. Safety Meeting/Toolbox Talk held	Compliant	All crew attended.
		4. Isolation of pipelines (LOTO)	Compliant	Valves secured.
		5. Rescue Team designated	Compliant	Team standby.
2	Atmosphere & Ventilation	6. Mechanical Ventilation (>8 hours)	Compliant	Running continuously.
		7. Initial Gas Test (30 min pre-entry)	Compliant	Performed by C/O.
		8. Periodic Gas Test (every 30 mins)	Compliant	Logged consistently.
		9. Oxygen Level (20.8% - 21%)	Compliant	Within safe limits.
		10. Toxic Gas (H_2S < 5ppm, CO safe)	Compliant	Within safe limits.

No.	Safety Indicator Category	Specific Indicator	Status	Finding/Observation
		11. Flammable Gas (LEL 0%)	Compliant	No flammable vapor.
		12. Gas Detector Calibration Valid	Compliant	Certificates valid.
3	Personnel & Supervision	13. Watchman stationed at entrance	Compliant	Never left post.
		14. Communication (Radio) Check	Compliant	Clear signal.
		15. Buddy System (Min. 2 entrants)	Compliant	Adhered to.
		16. Crew Physical Health Check	Compliant	Fit for duty.
		17. Understanding of Emergency Proc.	Non-Compliant	Some crew could not recall specific extraction steps during random checks.
4	Personal Protective Equipment	18. Safety Helmet usage	Compliant	Consistently worn.
		19. Safety Goggles usage	Compliant	Consistently worn.
		20. Hand Gloves (Chemical resistant)	Compliant	Consistently worn.
		21. Breathing Apparatus (SCBA) standby	Compliant	Ready at entrance.
		22. Chemical Protective Suit usage	Non-Compliant	Removed by crew due to heat stress/discomfort.
		23. Safety Shoes (Anti-slip) usage	Non-Compliant	Some shoes worn/slippery; not compliant with anti-slip standard.
		24. Safety Harness/Lifeline usage	Compliant	Used for vertical entry.
5	Emergency Preparedness	25. First Aid Kit & Stretcher Ready	Compliant	Available at site.

Total Indicators: 25
Compliant: 22
Non-Compliant: 3 (Items 17, 22, 23)
Compliance Rate: 22/25 x 100% = 88%

5. Conclusion

The research concludes that the implementation of the International Safety Management (ISM) Code on MT. Gandawati 1 has been executed with systematic rigor, effectively optimizing occupational safety through the integration of critical mechanisms such as comprehensive risk assessments, pre-operational safety meetings, and continuous gas testing. The vessel demonstrates a high level of procedural adherence, supported by a robust documentation system and a multi-layered supervisory framework that ensures emergency preparedness and operational accountability.

Despite these structural successes, the study identifies persistent challenges rooted in human and operational factors, specifically crew indiscipline regarding Personal Protective Equipment (PPE) usage due to thermal discomfort and commercial time pressures. To address these behavioral lapses, it is recommended that management invests in more ergonomic safety gear and intensifies supervision, while crew members must transition from a compliance-based mindset to an internalized "safety culture" where adherence to protocols is viewed as a vital necessity for survival rather than a formal obligation.

For future academic inquiry, the study

suggests a strategic pivot towards analyzing the behavioral aspects of maritime safety using a mixed-methods approach. By combining qualitative depth with quantitative metrics, future research can offer a more comprehensive evaluation of safety culture and the effectiveness of ISM Code implementation in high-risk environments, addressing the limitations of current single-method studies.

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