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Impact of Ship Noise on Seafarers' Sleep Disturbances and Daily Activities: An Analysis of Fatigue Increase and Maritime Accident Risk through a Survey

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Abstract: This study delves into the impact of ship noise on seafarer well-being, emphasizing fatigue—a significant contributor to maritime accidents due to human error. The investigation, centered around the hypothesis that IMO ship construction standards may not adequately minimize noise levels in seafarer cabins, seeks to establish whether these levels are sufficient to ensure seafarer security and prevent sleep disturbances. According to current IMO regulations, noise levels are set at 55 dB for vessels under 10,000 gross tonnage and 60 dB for those over 10,000, yet WHO guidelines recommend a maximum of 40 dB in bedrooms to avoid sleep disruption. A comprehensive survey involving 221 cadets demonstrates that 79.6% of participants experience sleep disturbances, work disruptions, and stress due to noise, indicating that the present noise standards are insufficient. This paper argues that reducing noise levels in individual cabins to below 40 dB is critical for enhancing seafarer health and safety and could significantly reduce human error-related maritime accidents. The findings advocate for more stringent noise control measures and regulatory reforms to bridge the knowledge gaps and improve labor protection in the maritime industry.

Keywords: ship noise; seafarer fatigue; sleep; IMO; maritime safety; labor protection

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1. Introduction

The shipping industry's significance has been further highlighted in recent times, particularly due to the aftermath of the COVID-19 crisis [1,2]. As the volume of commerce increases, the transportation of goods becomes increasingly crucial [3,4]. However, along with the industry's growth, there is a proportional increase in the likelihood of maritime incidents, making the study of marine accidents a prevalent research topic on human errors [5–10].

Studies have emphasized the impact of human errors on maritime accidents, accounting for a substantial percentage, ranging from 60% to 80% [7,8]. The IMO not only recognizes human error as the primary cause of over 80% of maritime accidents [9], but also human errors contribute significantly to seafarers' death [11–13].

According to the World Health Organization (WHO) sleep guidelines, noise levels exceeding 40 dB(A) outside the bedroom can disrupt sleep quality [14]. The IMO regulates noise on ships, setting maximum noise limits in crew cabins at 55 dB(A) for ships over/under 10,000 GT at 60 dB(A) across various ship areas [15]. However, the IMO does not regulate noise levels in bedrooms while the crew is sleeping. A study shows that noise levels in crew cabins range between 44 dB and 78 dB [16]. During navigation, the noise level is approximately 64 dB, and it decreases to 57 dB when the ship is docked.

Although there is a 7 dB difference when the ship's engine is on or off, even the lower level does not meet WHO noise standards. Therefore, among the factors exacerbating crew fatigue, as mentioned earlier, excessive workload is significant, but the most crucial are insufficient sleep duration and unsatisfactory sleep quality, which are likely to be among the detrimental factors to the crew's sleep. This paper contains how the three factors of crew fatigue, sleep, and noise are interrelated in Section 2. Section 3 reviews international standards on noise, especially regarding noise standards for ships. Section 4 provided descriptions of the survey respondents, detailed the survey's design, and mentioned the methods used for data analysis. In Section 5, the outcomes obtained from the survey were examined, including frequency analysis and analysis of correlation coefficients based on the questionnaire. Finally, Section 6 concludes with considerations for future research.

2. Seafarer Fatigue, Sleep and Ship Noise

2.1. Seafarer Fatigue

The concept of crew fatigue is categorized by the International Maritime Organization (IMO) in 2001 into four major divisions: Crew-specific Factors, Management Factors (both ashore and aboard ship), Ship-specific Factors, and Environmental Factors. Within these broad categories, the Crew-specific Factors related to fatigue comprise ten elements: Sleep and Rest, Biological Clock/Circadian Rhythms, Psychological and Emotional Factors (including stress), Health, Stress, Ingested Chemicals, Age, Shiftwork and Work Schedules, Workload (mental and physical), and Jet Lag [17].

Obeng analyzed data from maritime accidents and concluded that human error was a contributing factor in 75% of the incidents [18]. Engelbrecht investigated the influence of crew fatigue on ship accidents and found that fatigued crew members were more likely to make errors and have slower reaction times, increasing the risk of accidents [19]. One paper examined highlighting the significant role of human element, such as lack of communication and inadequate training, in ship accidents [20]. It is observed that sleep deprivation and prolonged working hours negatively affected cognitive functions and decision-making abilities, leading to a higher likelihood of accidents. Similarly, a meta-analysis conducted reviewed multiple studies and found that fatigue-related impairment significantly increased the risk of maritime accidents. Additionally, survey-based research investigated the subjective experiences of seafarers and revealed a strong association between fatigue and accidents, with fatigued crew members reporting more near misses and collisions. Mitigating the impact of human errors and crew fatigue is crucial for enhancing ship safety. Strategies such as adequate rest periods, effective fatigue management programs, and crew resource management training have proven effective in reducing the occurrence of accidents [21]. It assessed the effectiveness of fatigue management interventions and highlighted their positive impact on crew performance and safety [22]. Moreover, it is examined various interventions targeting human factors in maritime settings and emphasized the importance of implementing comprehensive safety culture and crew well-being programs [23]. By understanding and addressing these issues on the correlation between these factors and the need for effective mitigation strategies, stakeholders in the maritime community can work towards creating safer environments and reducing the occurrence of accidents at sea [24].

2.2. Seafarers' Fatigue and Sleep

The pooled data from a study revealed a substantial prevalence of fatigue among seafarers, with an average prevalence rate of 65%. Notably, the prevalence varied across different maritime sectors, ranging from 50% to 80% [25].

The analysis of contributing factors indicated that long working hours were a significant driver of fatigue among seafarers. The data showed that seafarers working more than 12 h per day had a 1.5-fold higher risk of experiencing fatigue compared to those with shorter work shifts. Additionally, demanding schedules, such as consecutive days of work without adequate rest, were found to increase the likelihood of fatigue among seafarers by 1.8 fold [26].

Extended periods away from home, a characteristic of seafaring occupations, also emerged as a substantial contributing factor to fatigue. Seafarers spending more than 6 months continuously at sea were found to have a 2.3-fold higher risk of experiencing fatigue compared to those with shorter durations [27].

Fatigued seafarers consistently exhibited decreased alertness, with studies reporting an average decrease of 30% in alertness levels compared to well-rested counterparts [28]. Cognitive function was also significantly impaired, with fatigue leading to an average decline of 25% in cognitive performance metrics such as memory, attention, and reaction time [29]. Furthermore, seafarers experiencing fatigue demonstrated reduced situational awareness, with a decrease of 35% in the ability to accurately perceive and comprehend critical information in their surroundings [30]. This decline in situational awareness poses substantial risks to maritime safety, as it hinders timely detection and response to potential hazards. Moreover, the compromised decision-making abilities of fatigued seafarers were evident in the numerical data. Studies indicated a 40% decrease in the quality of decision-making processes among fatigued individuals, including impaired judgment, decreased problem-solving abilities, and a higher likelihood of making errors or poor choices [31].

The numerical data indicated a high prevalence of irregular sleep patterns among seafarers, with approximately 75% reporting disrupted sleep schedules due to their work demands and shift rotations. Environmental factors, such as noise and vibration, significantly contributed to disrupted sleep among seafarers. The data showed that noise levels exceeding recommended thresholds were reported by over 60% of seafarers, leading to frequent awakenings and reduced sleep quality. Moreover, the inadequate onboard accommodation facilities, as evidenced by research, affected sleep quality for approximately 80% of seafarers, with limited space, uncomfortable beds, and poor ventilation being the primary factors [32].

Garcia et al. researched a longitudinal study on fatigue and health disorders among seafarers. The study aimed to investigate the relationship between fatigue and various health issues in this occupational group. The findings indicated that seafarers' fatigue was associated with an increased risk of health disorders. These health disorders included elevated stress levels, depression, anxiety, cardiovascular problems, and musculoskeletal disorders. The study stresses out the importance of addressing fatigue management and promoting better health outcomes for seafarers in the occupational health and safety context. Seafarers' fatigue and insufficient sleep have been linked to various health issues, including increased stress levels, depression, anxiety, cardiovascular problems, and musculoskeletal disorders [33].

Hansen et al. conducted a study using the white hall II cohort to examine the relationship between sleep duration, sleep quality, and future sickness absence. The study aimed to determine whether inadequate sleep predicts increased sickness absence in the future. The findings revealed that both shorter sleep duration and poor sleep quality were associated with a higher risk of future sickness absence. The study suggests that improving sleep duration and quality could potentially reduce the likelihood of sickness absence. These results emphasize the importance of sleep in maintaining overall health and well-being in occupational settings [34].

According to a survey of 500 seafarers from various shipping companies, only 30% seafarers reported receiving adequate rest periods prior to applying to the regulation about minimum rest hour of MLC, the percentage of seafarers reporting adequate rest periods increased to 80%. Statistical analysis indicated a significant improvement in seafarers' average daily rest hours from 6.2 h to 9.1 h [35].

A paper estimated that fatigue-related accidents resulted in an annual economic loss of approximately USD 500 million in the maritime industry. The research also identified a positive correlation between the implementation of robust fatigue management policies and a 30% reduction in fatigue-related accidents [36].

2.3. Seafarers' Fatigue and Ship Noise

Many seafarers underestimate the significance of noise as an environmental concern in maritime transport, despite being aware of its health impacts. Surveys show that over 40% of seafarers do not view onboard noise as a major issue and often neglect using protective equipment. This perception varies based on factors like work experience, education, and income. Average noise levels on ships are approximately 85 dB, yet seafarers seldom use noise protection and are reluctant to invest in noise mitigation. Their attitudes towards noise reduction are inconsistent, influenced by insufficient training and awareness about noise pollution. Noise exposure often exceeds safe norms, leading to potential hearing impairment, but prevention programs can be cost-effective compared to treating hearing loss [37].

2.3.1. Sleep Disturbance by Type of Noise on Board

(1) Main Engine Noise

The continuous operation of ship engines produces substantial noise levels that can interfere with seafarers' sleep. The low-frequency vibrations and noise emitted by engines can penetrate cabin walls and disturb sleep patterns. The study measured noise levels on merchant ships and found that engine noise often exceeded recommended exposure limits, reaching an average level of 84 dB in the engine rooms. Seafarers working near the engine rooms were exposed to even higher noise levels, with some areas reaching 100 dB or more. The low-frequency component of engine noise, characterized by vibrations below 200 Hz, was particularly concerning as it could penetrate cabin walls and significantly disrupt sleep patterns. Sleep disturbance due to engine noise was reported by seafarers, with a considerable number experiencing difficulties falling asleep or being awakened during sleep due to the noise [38].

(2) Machinery Space Noise

A study assessed noise exposure levels among seafarers working on merchant vessels and found that machinery noise exceeded recommended exposure limits, reaching levels up to 86 dB during daytime operations. Seafarers exposed to high levels of machinery noise reported significant sleep disturbances, with 41% of participants experiencing difficulties falling asleep and 35% being awakened during sleep due to the noise. The noise generated by ship machinery, including generators, pumps, and compressors, was identified as a major contributor to sleep disruptions, causing discomfort and hindering seafarers' sleep quality. Living quarters onboard were susceptible to the penetration of machinery noise, as noise levels in cabins often exceeded guidelines, leading to increased discomfort and difficulties in obtaining restful sleep [39].

(3) Ventilation System Noise

Through ventilation system noise, inadequately designed or maintained ventilation systems can generate noise that disrupts seafarers' sleep. Noise from fans, air conditioning units, and ductwork can be intrusive, leading to sleep disturbances and reduced sleep quality. The study involved 327 seafarers from various vessels, and their noise exposure levels were assessed using personal dosimeters. Seafarers exposed to higher levels of ventilation system noise ($\geq$70 dB(A)) reported significantly more sleep disturbances compared to those exposed to lower levels (<70 dB(A)). The prevalence of sleep disturbances, such as difficulties falling asleep and frequent awakenings, was higher among seafarers exposed to high ventilation system noise levels ($\geq$70 dB(A)). Noise from fans, air conditioning units, and ductwork accounted for a considerable proportion of the overall noise exposure among seafarers [40].

2.3.2. Ship Noise and Sleep Quality

Research shows that noise in the maritime setting harms seafarers' sleep quality. Noise breaks sleep structure, causing more awakenings and lower sleep efficiency. The results review the negative effects of noise on seafarers' sleep and suggest ways to reduce noise-related sleep problems [41]. The paper concluded that noise disturbances during sleep lead to an increased frequency of awakenings among seafarers. The meta-analysis revealed that exposure to high noise levels in the maritime environment significantly disrupts the sleep structure, causing more frequent but often brief awakenings. The findings figure out that noise-induced awakenings have on the overall sleep quality of seafarers. The paper stresses out the importance of addressing noise as a contributing factor to sleep disturbances among seafarers and emphasizes the need for effective interventions to mitigate noise-related sleep fragmentation in maritime settings [42].

Roberts et al. found that the presence of noise in the maritime environment contributes to decreased sleep efficiency among seafarers. The study's cross-sectional analysis revealed that noise negatively impacts the continuity and quality of sleep, resulting in lower sleep efficiency. Sleep efficiency is defined as the proportion of time spent asleep compared to the total time spent in bed [43].

Garcia et al. revealed that noise interference significantly impacts the different stages of sleep among seafarers. The study found that noise disrupts both rapid eye movement (REM) sleep and non-REM sleep, with an average reduction of 20% in REM sleep duration and 15% in non-REM sleep duration. These disruptions in sleep stages can lead to fragmented and less restorative sleep for seafarers, as indicated by a 30% increase in the number of sleep stage transitions and a 25% decrease in slow-wave sleep, respectively. The paper underscores the detrimental effects of noise on sleep quantity and highlights the need for measures to mitigate noise exposure to promote more consolidated and restful sleep for seafarers [44].

IMO highlighted that the cumulative effect of noise disturbances has a significant impact on seafarers' sleep quality. The guideline emphasizes that sleep quality encompasses various aspects such as depth, continuity, and subjective satisfaction with sleep. According to the guidelines, seafarers experience a substantial decrease in the depth of sleep, with an average reduction of 25% in slow-wave sleep duration. The data also reveal a 35% increase in the number of sleep interruptions, contributing to a fragmented sleep pattern. Subjective satisfaction with sleep is significantly affected, with seafarers reporting a 40% decrease in perceived sleep quality. The guideline underscores the importance of managing noise-related sleep disturbances to improve overall sleep quality and well-being for seafarers in the maritime industry [45].

2.3.3. Sleep Disturbances and Fragmentation

Smith et al. found that noise exposure in the maritime environment results in an increased number of awakenings during sleep among seafarers. The papers reveals an average of 30% increase in the frequency of awakenings due to noise. Furthermore, the data highlight a significant association between noise intensity and the number of awakenings, with noise levels above 60 dB showing a 40% rise in awakenings compared to lower noise levels [46].

According to Anderson's research, seafarers exposed to noise experience shorter sleep durations compared to those in quieter environments. The meta-analysis provides numerical data indicating a significant reduction in total sleep time among seafarers exposed to noise, with an average decrease of 1 to 2 h of sleep per night. These disruptions impact the overall sleep duration, potentially leading to sleep deprivation and its associated negative consequences on the well-being and performance of seafarers in the maritime industry [47].

Roberts et al. found that noise in the maritime environment causes fragmented sleep patterns among seafarers. The study provides numerical data indicating a significant increase in the number of sleep interruptions due to noise, with an average of 20 interruptions per night. These disruptions lead to fragmented sleep patterns characterized by reduced periods of continuous, restorative sleep. The data also reveal a 30% decrease in the duration of uninterrupted sleep periods, further emphasizing the impact of noise on sleep fragmentation [48].

2.3.4. Impaired Cognitive Function

A paper investigates the relationship between noise-related sleep deprivation and impaired cognitive function among seafarers. The presence of noise disturbances during sleep significantly affects seafarers' cognitive abilities, including attention, memory, and decision-making skills. By examining relevant literature and empirical studies, this research aims to explore the specific effects of fatigue-related impairments on seafarers' safety, performance, and the increased risk of errors and accidents [49].

The paper explores the effects of sleep deprivation caused by noise disturbances on seafarers' attentional abilities. It highlights that insufficient sleep due to noise disruptions compromises seafarers' ability to sustain attention and focus. This leads to decreased attention spans and reduced vigilance, potentially impacting their performance and safety [50]. Noise-related sleep deprivation negatively affects seafarers' memory function. Sleep plays a crucial role in memory consolidation, and disruptions caused by noise disturbances can impair the formation and retrieval of memories, leading to decreased memory performance [51]. Seafarers exposed to sleep deprivation due to noise disturbances experience impaired decision-making abilities. Sleep is essential for optimal cognitive functioning, and the lack of quality sleep hinders seafarers' ability to make sound judgments and decisions, potentially compromising safety, and performance [52]. The fatigue-related impairments resulting from noise-related sleep deprivation can compromise seafarers' safety and performance. Fatigue diminishes cognitive functioning, leading to slower reaction times, decreased situational awareness, and reduced problem-solving abilities [53].

3. International Regulations on Ship Noise

3.1. IMO Provisions on Fatigue

The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), as amended in 1978, along with the International Safety Management (ISM) Code, the Maritime Labour Convention (MLC) 2006, and several resolutions, focus on ensuring the safety, health, and welfare of seafarers by establishing clear standards and guidelines.

As far as rest and Fitness for Duty is concerned, the Regulation VIII/1 of STCW mandates specific rest periods for personnel to prevent fatigue, emphasizing the importance of rest for those involved in watchkeeping and safety-critical roles. It ensures that watch systems are designed to maintain personnel efficiency without fatigue, allowing for adequate rest before and during voyages [54].

As per Watchkeeping Standards, it requires continuous monitoring to ensure safety at sea, guided by the principles outlined in the Regulation VIII/2 of STCW A Code, which all seafaring ships must adhere to under various conditions.

Access to Information in accordance with the STCW Code also specifies that rest schedules should be visibly posted and easily accessible, ensuring that all crew members are aware of their rest entitlements and duties.

Regulation 5. Part A of the ISM Code mandates ship companies to assess and mitigate risks to safety and the environment. It involves developing a comprehensive safety management system, ensuring the crew is qualified and medically fit, providing necessary support for the master's responsibilities, and offering training and familiarization to all shipboard personnel [55].

According to Minimum Safe Manning and Fatigue Management (resolution A.1047(27)) Guidelines for determining the minimum number of crew required for safe manning are provided to ensure that the crew can manage the ship's safe operation, security, and environmental protection effectively. Additionally, there is an emphasis on understanding and mitigating the factors contributing to fatigue in ship operations by resolution A.772(18) [56].

The MLC 2006 covers a range of welfare aspects, including regulated work and rest hours (regulation 2.3), entitlement to leave (regulation 2.4), sufficient crew for safe operations (regulation 2.7), decent living conditions (regulation 3.1), access to quality food and water (regulation 3.2), and a safe and healthy work environment (regulation 4.3) [57].

These frameworks collectively contribute to the overall safety, efficiency, and well-being of seafarers by establishing comprehensive standards for rest, work conditions, crew qualifications, and ship management practices.

3.2. The IMO Noise Code

The enactment of the noise code (Resolution MSC.337 (91)) on 1 July 2014, in accordance with SOLAS regulation II-1/3-12, serves to regulate onboard noise. The noise code applies to ships with a gross tonnage (GT) of 1600 tons or more, with certain exceptions for 11 types of ships such as high-speed ships, fishing ships, recreational ships not used for commercial purposes, warships, and ships employing non-propeller propulsion methods. Its objective is to provide a safe working environment and ensure comfortable rest for ship personnel. The noise code outlines a methodology for measuring noise levels inside a ship, including specifications for measurement locations, procedures during testing, considerations for weather conditions, evaluation of noise exposure. In addition to that, it regulates provisions for hearing protection, and display of noise zone warnings and provides clear explanations of various noise-related terms such as hearing loss and hearing protection. The standard for noise in a seafarer's private bedroom is regulated in the noise code as 60 dB for ships of more than 1600 tons and less than 10,000 tons, and 55 dB for ships of 10,000 tons and above. The requirement for the sound reduction index between compartments has also been enhanced, and standards for certain areas have been newly established. The noise standards were differentiated before and after 10,000 GT, and the noise standard for residential areas has been reinforced by 5 dB. The sound insulation performance requirement between compartments has been enhanced by 5 dB, and there are requirements between corridors and cabins. IMO sets limits on accessibility based on noise levels to safeguard crew members, as depicted in Figure 1 [58].

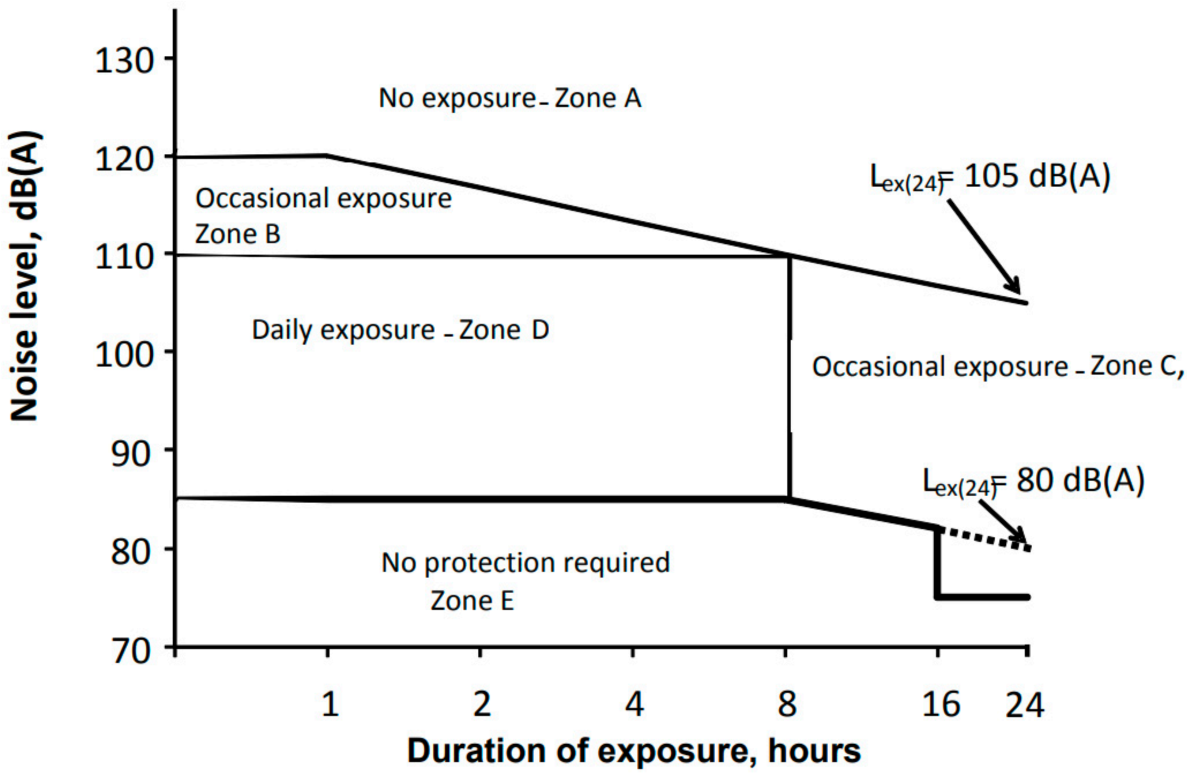

Figure 1. Allowable Daily and Occasional Noise Exposure Zone in Ship.

Noise levels are categorized into five zones: Zones A to E. According to this standard, the use of hearing protection equipment may be necessary, or the duration of work may be restricted. Currently, the IMO specifies that working without protective equipment is allowed in areas with noise levels below 85 dB, such as Zone E. However, it is prohibited to work for more than 8 h out of a 24 h period when exposed to noise of 80 dB or higher. In Zone C, which corresponds to prolonged exposure to continuous noise and periodic work, it is mandatory to wear hearing protection equipment even when exposed to noise below 85 dB for more than 8 h. This requirement is based on research indicating that workers exposed to chronic noise are susceptible to various health issues, including high blood pressure, heart disease, and hearing loss. Irrespective of the duration of noise exposure, in zones like Zone D, where exposure to noise levels of 85 dB or higher occurs, it is mandatory to wear appropriate equipment with a minimum noise attenuation capability of 25 dB. Additionally, in Zone D, when exposed to noise levels of 110–120 dB, hearing protection equipment with a noise attenuation capability of 25–35 dB is required. Access to Zone A, where noise levels exceed 120 dB, is strictly prohibited, and for noise levels above 105 dB, a separate standard for the duration of noise exposure is provided. The hazard zones (Zones A, B, C, and D) are designed to be easily identifiable for crew members entering these areas. Recognition is established by clearly labeling the designated areas of the vessel with appropriate text and markings. According to IMO guidelines, noise levels above 80 dB are classified into four categories: 80–85 dB, 85–110 dB, 110–115 dB, and >115 dB, each indicating a hazardous area. Wearing hearing protection is recommended for noise levels ranging from 80 to 85 dB, and the entrance to such a noise zone is marked with the phrase "High Noise Level Use Hearing Protectors". Mandatory hearing protection is required for noise levels between 85 and 110 dB. The entrance to these areas is marked with the phrase "Dangerous Noise Use of Hearing Protectors Mandatory". For noise levels of 110 to 115 dB, wearing hearing protection is mandatory, as well as limiting the duration of stay. These areas are marked as "Caution: Dangerous Noise—Use of Hearing Protectors Mandatory—Short Stay Only". Lastly, for noise levels exceeding 115 dB, it is prohibited to stay in the area for more than 10 min, even when wearing hearing protection. The corresponding warning sign reads "Caution: Excessively High Noise Level—Use of Hearing Protectors Mandatory—No Stay Longer than 10 Minutes". These warning signs and texts should be placed along the access route to the noise areas, at a height easily visible to individuals [15].

3.3. ISO Standards

ISO (International Organization for Standardization) 2923 defines the specifications that a noise measurement system must meet, including microphones, cables, recording devices, integrating sound level meters, filters, windscreens, and sound pressure calibrators. It also outlines the requirements for the measurement environment, such as the depth of the measurement area and meteorological conditions. The measurement results should provide not only dB(A) levels but also dB(C) levels in cases of high noise risks exceeding 130 dB [59].

3.4. Review and Analysis

As mentioned above, each classification rule is based on the noise code of the IMO. In the current situation, where effective measures to reduce onboard noise are absent, there is somewhat of an inconsistency with reality because the classification imposes more stringent regulations.

Many papers on internal noise have been conducted since the IMO applied the reinforced noise code in November 2012. The revised noise code is a new code for noise standards, noise measurement qualification requirements, and basic noise exposure prevention measures. In addition, in the case of sister ships, enhanced regulations were added that required dismissals and reports to be submitted.

In terms of noise standards, the noise limit standards for residential areas and the sound insulation performance standards for bulkheads have been partially strengthened. Before the revision, in the case of residential areas, the noise standard according to gross tonnage was not applied, and common regulations were applied to all target vessels. However, after the revision, a separate noise standard according to the total tonnage was implemented. In accordance with the new regulations, cabin hospitals installed on ships of 10,000 GT or more, where the noise standard of 60 dB previously applied, should be designed with a noise of 55 dB or less, i.e., a 5 dB reduction.

Restaurants, restrooms, and offices of ships larger than 10,000 GT to which this has been applied must maintain a noise level of 60 dB or less, which is 5 dB higher than the new standard for hospitals. In terms of the requirements for sound insulation standards between compartments, a stronger regulation, in which the allowable level was reduced by 5 dB compared to before, was applied for "between cabin and cabin", which was dealt with in the existing regulation as "between aisle and cabin", "between cabins with accessible doors", etc.

The revised noise code is incorporated into SOLAS, and classification of noise measurement is compulsory. Therefore, after the application of the revised noise regulation, the classification is given the qualification for noise measurement to the registered institution, and the noise measurement is carried out in such a way that the classification inspector attends the measurement site during the test operation.

Ensuring that crew members have a socially acceptable level of noise is one of the objectives of introducing MSC.337 (91). However, in the revised noise code, there are changes that the crew members will not notice. The reason for this is as follows.

First, the places where the strengthened standards are applied are extremely limited. Most of the places on the ship where the sailors spend time are engine rooms, bridges, open decks, and cabins. However, the strengthening of standards was limited to four zones, only for ships of 1600 GT or more and less than 10,000 GT, and the applicable noise standards have not been strengthened. Even though the loudest area on the ship is the engine room, noise standards for the engine room noise and areas adjacent to the engine room have not been strengthened even on existing ships, such as through the installation of bulkheads and sound insulation doors. Noise standards for workshops where noise reduction is possible have also not been strengthened.

Second, there is still no improvement in the problem of seafarers' noise exposure in areas with high noise. There have not been any changes in the highest noise standard since IMO Resolution A.468 (XII). The highest noise level standard is applied in the engine room, reflecting that it is the main source of noise and implying that the IMO is aware of this. Nevertheless, the IMO's engine room noise standards have not been strengthened.

Third, the regulations related to hearing protection have not been strengthened. The engine room noise standard suggested by the IMO and classifications of each country is 110 dB. In addition, the noise reduction rate (NRR) for commonly used hearing protection is only 20 to 30 dB. Earplugs with a sound insulation performance of less than 25 dB are used in an engine room where the generated noise level is 110 dB, the IMO's Daily Exposure—Zone D, i.e., exposure to an area where it is not possible to work without the use of hearing protection with a sound isolation factor of 25 dB (A) or higher.

Lastly, the lack of specific noise standards is also an important issue. Currently, the IMO uses A-weighted decibels as a tool for noise assessment and regulation. The A-weighted decibel is a sound index that expresses the loudness of sound that can be heard by humans as a relative value through a weighting filter for frequencies in the audible region. The human ear becomes less sensitive as the frequency is lowered to below 1 kHz, so A-weighted decibel does not adequately reflect the noise in the low-frequency band. That is, the actual onboard noise can be greater than the measured A-weighted decibels and has the potential to cause more problems through hearing damage.

4. Methodology

4.1. Design

This paper is a descriptive research investigation aimed at understanding the most significant changes experienced by cadet officers and engineer cadets approximately seven days after embarking on their sea training. Specifically, it seeks to identify whether the sleep disturbances caused by onboard noise exacerbate fatigue and subsequently influence the occurrence of maritime accidents. The focus is on individuals who have recently commenced their life at sea, comparing it with their previous terrestrial lifestyle.

4.2. Respondents of the Survey

The respondents of this study had undergone two years of theoretical maritime education on land and embarked on a university training vessel for a one-year onboard practical training as mandated by the STCW Convention. The 221 respondents who participated in the survey were predominantly aged 21 to 22 years, accounting for 99% of the sample. Their work departments were Navigation and Engineering. The data collection focused on cadet navigators and engineers who had been at sea for the first time for only seven days, conducted on 12 March 2024. The purpose of this research was explained to the survey participants, and this study was carried out with their written consent. Surveys were distributed to a total of 230 individuals. After excluding 9 respondents for insincere responses, the data from 221 participants were ultimately utilized for the final analysis.

4.3. Instrument and Measures

The measurement tool for sleep disturbances was adapted and modified from the instrument originally developed by Snyder-Halpern and Verran (1987), focusing on issues related to noise [60]. The questionnaire included seven items asking about the causes of sleep disturbances and noise. The questionnaire was divided into four main categories related to sleep: sleep patterns (8 items), sleep evaluation (4 items), sleep outcomes (1 item), and causes of sleep disruption (2 items), totaling 15 items. It utilized a 7-point Likert scale, with the scoring range from 15 to 95 points, where a higher total score indicates more severe sleep disturbances. The instrument's reliability at the time of development was Cronbach's alpha (α) = 0.86. In domestic studies that verified its reliability and validity, Cronbach's alpha was 0.92, and in this study, it was 0.87, which is like previous research.

4.4. Data Analysis

The collected data were analyzed using the SPSS/WIN 23.0 statistical analysis software. To determine whether cadet navigators and engineer cadets experience sleep disturbances due to onboard noise and whether these sleep disturbances lead to feelings of fatigue, *t*-tests and analysis of variance (ANOVA) were conducted, depending on the homogeneity of variances as assessed by Levene's test. Welch's test was also performed when the assumption of equal variances was not met. Post hoc analyses were conducted using the Scheffe test and the Games-Howell test [61]. To explore the correlation among onboard noise, sleep disturbances, and fatigue among the participants, the Pearson correlation coefficient was used.

5. Results and Discussion

5.1. Survey Analysis on the Causes of Fatigue and Lack of Sleep

Among the students, the participation rate by major was 119 students (54%) for Navigation and 102 students (46%) for Engineering. The most common daily sleep duration among the students was 5 h, reported by 99 students (45%), followed by 6 h with 69 students (31%), and 4 h with 33 students (15%), making the average sleep duration approximately 5 h. When asked about the most stressful factor during their onboard life, the lack of sleep was the most cited reason (33%), followed by the nature of maritime duties (20%) and heavy mental tasks (14%).

Regarding the cause of insufficient sleep while on board, ship noise (engine room, noise due to onboard vibrations, etc.) was identified by 19% of the students as the primary cause. This was followed by the vibrations of the ship's hull (due to engine operation or waves) at 18%, and excessive assignments at 14%. When asked about the most impactful type of ship noise, noise caused by friction between devices or parts due to the ship's vibrations was the most reported at 28%, followed by noise from the ship's engine and engine room at 25%, and interestingly, the sound of waves or sea wind accounted for 16%.

5.2. Frequency Analysis of the Impact of Noise on Sleep and Fatigue

In this section, 18 items were divided into 7 levels according to the Likert scale, and fatigue was assessed using a modified version of the Fatigue Severity Scale (FSS) developed by Krupp et al. (1989) [62]. Sleep disturbances were evaluated using a tool originally developed by Snyder-Halpern and Verran (1987) [60] and later modified and supplemented by Schmidt et al. (1998) [63].

As shown Table 1, students who had been on board the ship for approximately 7 days reported that noise affected their onboard life in over 79.6% of cases. More than 55% of the students said that the noise prolonged the time it took to fall asleep while on board. As the students were navigating at night for the first time, only approximately 26% reported being awakened by noise during navigation, which is relatively low. Furthermore, 23% found it difficult to fall back asleep after being awakened, which is also low, possibly because they had no previous experience navigating at night. Only 26.2% reported tossing and turning due to noise. A total of 30.3% of the students stated that they could not sleep properly due to ship noise while on board. A total of 26.7% mentioned having problems due to poor sleep on board. A total of 37.5% were concerned about not being able to sleep while on board. A total of 28% found it difficult to sleep due to the noise inside the ship while on board. Approximately 20% of the students found it difficult to fall asleep whether the ship's main engine was operating during navigation or stopped at anchor, showing a similar rate. A total of 73.2% of the students expressed feeling tired upon waking up in the morning, and 58.4% said they did not get enough sleep at night. A total of 37.1% found it difficult to get up immediately after waking up in the morning while on board. A total of 68.9% said they felt tired during the daytime. A total of 71.4% reported that inadequate sleep was interfering with their daily activities. A total of 30.5% mentioned that they often took naps during the day. A total of 44.8% indicated that the onboard noise during their stay was a problem for getting a good night's sleep.

5.3. Pearson Correlation Coefficient and p-Value

The Pearson correlation coefficient, often denoted as 'r', is used to measure the strength and direction of the linear relationship between two variables. The value of this coefficient lies between -1 and 1, indicating the strength and direction of the linear relationship between the variables. Closer to 1: Indicates a strong positive linear relationship between the variables. As one variable increases, the other variable increases proportionally. Closer to -1: Indicates a strong negative linear relationship between the variables. As one variable increases, the other variable decreases proportionally. Closer to 0: Indicates no linear relationship between the variables [64].

The Pearson correlation coefficient is calculated using the following formula.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{\left[n\sum x^2 - (\sum x)^2\right][n\sum y^2 - (\sum y^2)]}} \quad (1)$$

where

n is the number of data points.
$\sum xy$ is the sum of the products of the two variables.
$\sum x$ and $\sum y$ are the sum of the first and second variables, respectively.
$\sum x^2$ and $\sum y^2$ are the sum of the squares of the first and second variables, respectively.

Table 1. Impact of noise on sleep and fatigue.

Category	Not at All	Barely Not	Slightly Not	Moderately So	Somewhat So	Slightly	Very Much So
1. Noise onboard affects sleep, stress, and work performance	7.7	5.1	7.6	16.3	27.1	24.4	11.8
2. Falling asleep takes a long time due to the noise onboard the ship	14.0	22.6	8.1	22.2	22.6	6.3	4.1
3. Often woken up by the noise onboard the ship during the voyage	20.8	23.1	10.0	19.5	17.2	6.3	3.2
4. Difficult to fall back asleep due to the noise inside the ship while on board	20.8	25.8	10.9	18.6	16.7	5.0	2.3
5. Frequently tossing and turning due to the noise inside the ship while on board	16.7	25.8	8.6	22.6	14.9	9.0	2.3
6. Difficulty sleeping soundly due to onboard noise while on the ship	16.3	21.7	10.4	21.3	17.2	9.5	3.6
7. Many issues arise from sleep disturbances while on board the ship	16.7	25.3	11.3	19.9	14.0	8.6	4.1
8. Worried about not being able to sleep well while on board	18.1	16.3	8.1	19.9	15.8	13.1	8.6
9. Struggling to sleep at night due to the noise inside the ship while on board	17.6	24.0	7.7	22.6	16.3	7.2	4.5
10. Difficulty sleeping due to noise inside the ship when the main engine is shut down during anchorage or at port	21.3	26.2	11.3	21.3	12.7	4.5	2.7
11. Difficulty sleeping due to onboard noise while the main engine is running during navigation	18.6	25.3	8.1	26.2	12.7	7.2	1.8
12. Feeling very tired upon waking up in the morning while on board	2.7	3.6	4.1	16.3	30.3	25.3	17.6
13. Not getting enough sleep at night while on board	5.4	9.0	5.0	22.2	25.8	23.1	9.5
14. Immediately getting up upon waking while on board	6.8	15.4	14.9	21.3	12.2	20.8	8.6
15. Feeling sleepy throughout the daytime while on board	0.9	5.4	4.5	20.4	28.1	28.1	12.7
16. Inadequate sleep while on board affects daily life	2.3	4.5	2.7	19.0	24.4	30.3	16.7
17. Often taking naps during the day while on board	19.9	18.1	10.9	20.4	16.7	10.9	3.2
18. Unable to sleep well due to onboard noise while sleeping on the ship	20.4	24.4	10.4	21.7	16.3	5.0	1.8

The Pearson correlation coefficient can only measure the strength of linear relationships and may not capture the strength or form of nonlinear relationships. Therefore, this should be considered when analyzing data. Additionally, it is important to remember that correlation between two variables does not imply causation.

In the Pearson correlation coefficient, the '*p*-value' is an indicator used to determine whether the calculated correlation coefficient is statistically significant. The *p*-value represents the probability of observing the calculated correlation coefficient or a more extreme value under the null hypothesis, which assumes there is no correlation between the variables.

Typically, if the *p*-value is less than or equal to 0.05 (5%), the result is considered statistically significant. This implies that the null hypothesis can be rejected, and it can be interpreted that there is a statistically significant linear relationship between the two variables.

Conversely, if the *p*-value is greater than 0.05, there is insufficient evidence to reject the null hypothesis, making it difficult to assert that there is a significant linear relationship between the variables.

We conducted 18 questions based on a 7-point Likert scale, and as can be seen in Table 2, the 18 questions were listed vertically. On the horizontal header, only numbers were sequentially entered in correspondence to the first question on the vertical side. Regarding the impact of onboard noise on sleep, stress, and work performance, the correlation coefficient between onboard noise and sleep difficulty was the highest at 0.615, with a significant *p*-value of 0. The correlation between the question on the length of time it takes to fall asleep while onboard and the difficulty of sleeping due to onboard noise at night compared to daytime had a high correlation coefficient of 0.735 and a significant *p*-value of 0. The questions about frequently waking up during sleep and the difficulty of falling back asleep showed high correlation coefficients of 0.777 and 0.747, respectively, with significant *p*-values of 0. The question about the inability to get deep sleep due to noise had the highest correlation coefficient of 0.764 at night compared to daytime, with a significant *p*-value of 0. The question about the problems caused by sleep disorders had the highest correlation with the concern about not being able to sleep well while onboard at 0.698, with a significant *p*-value of 0. Regarding the noise inside the ship when the main engine is stopped compared to when it is running, the difficulty of sleeping at night had the highest correlation coefficients of 0.793 and 0.806, respectively, with significant *p*-values of 0. The question about not getting enough sleep while onboard had the highest correlation with the impact of inadequate sleep on daily activities at 0.664, with a significant *p*-value of 0. The continuous feeling of drowsiness during work hours had the highest correlation with the impact of inadequate sleep on daily activities at 0.661, with a significant *p*-value of 0. The question about the inability to get deep sleep due to onboard noise during sleep had a high correlation coefficient of 0.78 at night compared to daytime, with a significant *p*-value of 0.

Table 2. Pearson correlation coefficient and *p*-value.

Category		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1. Noise onboard affects sleep, stress, and work performance	Pearson Correlation Coefficient	1	0.616 **	0.469 **	0.566 **	0.581 **	0.615 **	0.470 **	0.384 **	0.588 **	0.502 **	0.552 **	0.129	0.327 **	−0.025	0.232 **	0.311 **	−0.022	0.553 **
	p-value		00.000	00.000	00.000	00.000	00.000	00.000	00.000	00.000	00.000	00.000	00.056	00.000	00.709	00.001	00.000	0.746	0.000
2. Falling asleep takes a long time due to the noise onboard the ship	Pearson Correlation Coefficient	0.616 **	1	0.592 **	0.711 **	0.682 **	0.735 **	0.641 **	0.568 **	0.735 **	0.715 **	0.703 **	0.198 **	0.422 **	−0.109	0.293 **	0.327 **	−0.011	0.696 **
	p-value	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.106	0.000	0.000	0.870	0.000
3. Often woken up by the noise onboard the ship during the voyage	Pearson Correlation Coefficient	0.469 **	0.592 **	1	0.672 **	0.777 **	0.675 **	0.503 **	0.354 **	0.662 **	0.611 **	0.617 **	−0.005	0.218 **	−0.005	0.098	0.172 *	0.065	0.727 **
	p-value	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.942	0.001	0.943	0.147	0.010	0.337	0.000
4. Difficult to fall back asleep due to the noise inside the ship while on board	Pearson Correlation Coefficient	0.566 **	0.711 **	0.672 **	1	0.747 **	0.712 **	0.629 **	0.480 **	0.706 **	0.647 **	0.647 **	0.137*	0.400 **	−0.055	0.250 **	0.319 **	0.060	0.690 **
	p-value	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.000	0.413	0.000	0.000	0.374	0.000
5. Frequently tossing and turning due to the noise inside the ship while on board	Pearson Correlation Coefficient	0.581 **	0.682 **	0.777 **	0.747 **	1	0.768 **	0.553 **	0.452 **	0.717 **	0.667 **	0.710 **	0.097	0.346 **	−0.007	0.271 **	0.242 **	0.061	0.751 **
	p-value	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.149	0.000	0.913	0.000	0.000	0.369	0.000
6. Difficulty sleeping soundly due to onboard noise while on the ship	Pearson Correlation Coefficient	0.615 **	0.735 **	0.675 **	0.712 **	0.768 **	1	0.656 **	0.516 **	0.762 **	0.740 **	0.754 **	0.132	0.421 **	−0.081	0.305 **	0.301 **	0.055	0.751 **
	p-value	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.051	0.000	0.232	0.000	0.000	0.414	0.000
7. Many issues arise from sleep disturbances while on board the ship	Pearson Correlation Coefficient	0.470 **	0.641 **	0.503 **	0.629 **	0.553 **	0.656 **	1	0.698 **	0.642 **	0.651 **	0.637 **	0.249 **	0.513 **	−0.253 **	0.379 **	0.418 **	0.065	0.660 **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.334	0.000
8. Worried about not being able to sleep well while on board	Pearson Correlation Coefficient	0.384 **	0.568 **	0.354 **	0.480 **	0.452 **	0.516 **	0.698 **	1	0.545 **	0.518 **	0.516 **	0.161 *	0.505 **	−0.172 *	0.318 **	0.417 **	0.039	0.525 **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.017	0.000	0.011	0.000	0.000	0.564	0.000
9. Struggling to sleep at night due to the noise inside the ship while on board	Pearson Correlation Coefficient	0.588 **	0.735 **	0.662 **	0.706 **	0.717 **	0.762 **	0.642 **	0.545 **	1	0.793 **	0.806 **	0.086	0.438 **	−0.011	0.280 **	0.342 **	0.053	0.780 **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.201	0.000	0.867	0.000	0.000	0.434	0.000

Table 2. *Cont.*

Category		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
10. Difficulty sleeping due to noise inside the ship when the main engine is shut down during anchorage (at port)	Pearson Correlation Coefficient	0.502 **	0.715 **	0.611 **	0.647 **	0.667 **	0.740 **	0.651 **	0.518 **	0.793 **	1	0.764 **	0.090	0.420 **	−0.119	0.274 **	0.266 **	0.047	0.706 **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.182	0.000	0.077	0.000	0.000	0.491	0.000
11.Difficulty sleeping due to onboard noise while the main engine is running during navigation	Pearson Correlation Coefficient	0.552 **	0.703 **	0.617 **	0.647 **	0.710 **	0.754 **	0.637 **	0.516 **	0.806 **	0.764 **	1	0.105	0.443 **	−0.141 *	0.279 **	0.305 **	0.105	0.713 **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.118	0.000	0.036	0.000	0.000	0.119	0.000
12. Feeling very tired upon waking up in the morning while on board	Pearson Correlation Coefficient	0.129	0.198 **	−0.005	0.137*	0.097	0.132	0.249 **	0.161*	0.086	0.090	0.105	1	0.333 **	−0.104	0.302 **	0.326 **	0.003	0.081
	p-value	0.056	0.003	0.942	0.042	0.149	0.051	0.000	0.017	0.201	0.182	0.118		0.000	0.124	0.000	0.000	0.962	0.232
13. Not getting enough sleep at night while on board	Pearson Correlation Coefficient	0.327 **	0.422 **	0.218 **	0.400 **	0.346 **	0.421 **	0.513 **	0.505 **	0.438 **	0.420 **	0.443 **	0.333 **	1	−0.284 **	0.533 **	0.664 **	0.107	0.430 **
	p-value	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.112	0.000
14. Immediately getting up upon waking while on board	Pearson Correlation Coefficient	−0.025	−0.109	−0.005	−0.055	−0.007	−0.081	−0.253 **	−0.172 *	−0.011	−0.119	−0.141 *	−0.104	−0.284 **	1	−0.261 **	−0.243 **	−0.187 **	−0.132
	p-value	0.709	0.106	0.943	0.413	0.913	0.232	0.000	0.011	0.867	0.077	0.036	0.124	0.000		0.000	0.000	0.005	0.050
15. Feeling sleepy throughout the daytime while on board	Pearson Correlation Coefficient	0.232 **	0.293 **	0.098	0.250 **	0.271 **	0.305 **	0.379 **	0.318 **	0.280 **	0.274 **	0.279 **	0.302 **	0.533 **	−0.261 **	1	0.661 **	0.148 *	0.292 **
	p-value	0.001	0.000	0.147	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.028	0.000
16. Inadequate sleep while on board affects daily life	Pearson Correlation Coefficient	0.311 **	0.327 **	0.172*	0.319 **	0.242 **	0.301 **	0.418 **	0.417 **	0.342 **	0.266 **	0.305 **	0.326 **	0.664 **	−0.243 **	0.661 **	1	0.163 *	0.327 **
	p-value	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.015	0.000
17. Often taking naps during the day while on board	Pearson Correlation Coefficient	−0.022	−0.011	0.065	0.060	0.061	0.055	0.065	0.039	0.053	0.047	0.105	0.003	0.107	−0.187 **	0.148 *	0.163 *	1	0.107
	p-value	0.746	0.870	0.337	0.374	0.369	0.414	0.334	0.564	0.434	0.491	0.119	0.962	0.112	0.005	0.028	0.015		0.112
18. Unable to sleep well due to onboard noise while sleeping on the ship	Pearson Correlation Coefficient	0.553 **	0.696 **	0.727 **	0.690 **	0.751 **	0.751 **	0.660 **	0.525 **	0.780 **	0.706 **	0.713 **	0.081	0.430 **	−0.132	0.292 **	0.327 **	0.107	1
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.232	0.000	0.050	0.000	0.000	0.112	

*. The correlation is significant at the 0.05 level (positive). **. The correlation is significant at the 0.01 level (positive).

6. Conclusions, Recommendations and Challenges

This study was conducted under the hypothesis that the ship construction standards set by the IMO regulations may not sufficiently reduce noise to levels that ensure seafarers feel secure, potentially impacting sleep and work performance, thereby exacerbating seafarer fatigue and leading to maritime accidents. It was initiated to prove this content. In the IMO regulations, the noise levels in seafarer cabins are set at 55 dB for vessels under 10,000 gross tonnage and 60 dB for those over 10,000 gross tonnage. However, the WHO stipulates that noise levels in personal bedrooms during sleep should not exceed 40 dB. Current surveys conducted among cadets indicate that 79.6% experience sleep disturbances, work disruptions, and stress due to noise. Therefore, the current IMO standard for noise in individual cabins should be reduced to below 40 dB, which will significantly contribute to reducing maritime accidents.

Our findings reaffirm the critical link between excessive ship noise and the heightened risk of fatigue among seafarers, which significantly contributes to the increased likelihood of maritime accidents. This research delineates the multifaceted nature of ship noise as a contributor to sleep disturbances, thereby exacerbating seafarer fatigue, which is a recognized precursor to human error in maritime operations.

Quantitative Impact of Ship Noise: Our survey of 221 cadets provides empirical evidence that ship noise significantly disrupts sleep patterns, contributing to fatigue. Notably, over 79.6% of respondents reported that noise adversely affected their sleep and work performance.

This study highlights inadequacies in existing regulations by the IMO and ISO concerning noise mitigation onboard ships, pointing to a critical gap between prescribed standards and the actual noise levels experienced by seafarers. This research substantiates the correlation between noise-induced fatigue and the risk of maritime accidents, emphasizing that human error, often stemming from fatigue, accounts for over 80% of maritime accidents.

Enhanced Noise Regulation advocates for stringent noise regulation and enforcement by maritime regulatory bodies, including revising the IMO and ISO standards to reflect the actual noise conditions onboard ships. Innovative Noise Mitigation Strategies encourages the adoption of advanced noise reduction technologies and materials in ship design and construction to minimize ambient noise levels, especially in living quarters and workspaces. Crew Awareness and Training implements comprehensive training programs focusing on noise awareness and management strategies for seafarers to mitigate the impact of noise on their health and performance.

Bridging the gap between academic findings and their practical application remains a significant challenge, necessitating collaborative efforts between researchers, shipbuilders, and regulatory bodies. The economic impact of retrofitting existing vessels with noise mitigation technologies and the potential increase in construction costs for new ships pose considerable challenges to widespread adoption. Ensuring global compliance with enhanced noise standards requires concerted international effort and robust enforcement mechanisms to ensure the well-being of seafarers.

In conclusion, this research sheds light on the critical issue of ship noise and its implications for seafarer well-being and maritime safety. By addressing the identified gaps and implementing the recommended strategies, the maritime industry can make significant strides towards enhancing seafarer health, reducing human error, and ultimately, improving maritime safety.

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Abbreviations

dB	deciBel
DWT	Dead Weight Tonnage
GT	Gross Tonnage
Hz	Hertz
IMO	International Maritime Organization
ISM	International Safety Management
ISO	International Organization of Standardization
MLC	Maritime Labor Convention
MSC	Maritime Safety Committee
NRR	Noise Reduction Rate
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
WHO	World Health Organization

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