International Journal of Occupational Safety and Ergonomics

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tose20

An application study for the determination of ship-borne noise pollution

Ünal Özdemir

To cite this article: Ünal Özdemir (2024) An application study for the determination of ship-borne noise pollution, International Journal of Occupational Safety and Ergonomics, 30:1, 153-160, DOI: 10.1080/10803548.2023.2282874

To link to this article: https://doi.org/10.1080/10803548.2023.2282874

INTERNATIONAL JOURNAL OF OCCUPATIONAL SAFETY AND ERGONOMICS (JOSE)
2024, VOL. 30, NO. 1, 153–160
https://doi.org/10.1080/10803548.2023.2282874

Taylor & Francis
Taylor & Francis Group

An application study for the determination of ship-borne noise pollution

Ünal Özdemir

Department of Maritime Transportation and Management Engineering, Mersin University, Turkey

ABSTRACT
Noise pollution includes undesired sounds that lead to negative physiological and psychological outcomes in individuals. Areas with a unique ergonomic design when compared to other work environments, such as ships, are risky. Identification and limitation or minimization of the impact of noise pollution in ships would directly affect crew health and maximum efficiency of the operation of the systems. Thus, the exposure of the ship crew to noise pollution was measured in the current study. Furthermore, the measurements conducted on the ships were compared to the International Maritime Organization (IMO) A.468 (XII) international standards. In the study, noise measurements were conducted with 72 crew members who met certain criteria in nine ships with different properties to determine noise pollution in these ship environments and the exposure of the crew. The current study analyzed the effects of ship-borne noise pollution on the crew and certain solutions were proposed.

KEYWORDS
Noise pollution; ship crew; measurement; International Maritime Organization

1. Introduction

Safe and sustainable global maritime transportation should be conducted based on certain rules and standards. Thus, several international conventions, agreements and practices have been introduced by the International Maritime Organization (IMO). Technological advances and novel requirements lead to the introduction of new applications. One of these applications is the Maritime Labour Convention (MLC) [1]. In general, the MLC determines the living and working condition standards for seafarers. The MLC determined the living standards on the ships, including the safety, nutrition, health, work hours, environmental requirements and basic needs of the seafarers, based on general International Labour Organization (ILO) regulations [1,2]. In recent years, interest in noise pollution in the maritime transportation industry has increased due to these and similar conventions [3]. In addition to the MLC, the IMO A.468 circular has also been used as a criterion for noise levels in ship living spaces, and certain flag states and classification institutions started to demand compliance with noise levels far below these criteria [4–8]. Although the noise pollution regulations are quite new in the maritime industry, noise measurements have been conducted in numerous industries to reduce the impact of noise on employees and provide rest environments [9–16].

Noise pollution entails all types of natural or mechanical noise that negatively affects human life [17,18]. Noise pollution was also described as undesired noises with negative physiological and psychological effects on individuals [19–29]. In general, noise could be described as an acoustic phenomenon created by undesired sounds [12,14,16,17]. This phenomenon could induce serious temporary or permanent damage to human health [23,30,31]. The most common source of noise is the equipment in mechanical vehicles [27,32–34]. The work environment of ships is consistent with [29] this definition. An analysis of the structural properties and work environments of ships would reveal that they include several pieces of equipment with high noise levels [4,29,35]. Especially, the main and auxiliary engines are among this equipment. Due to the location and ergonomic design requirements of these engines, they are adjacent to or very close to the crew's living quarters, which makes it very difficult to protect the crew from exposure to noise. Furthermore, safety alarms that ring during rest hours, tests, announcements, emergency sirens, construction and repair work, chimneys with poor or damaged insulation and defective or poorly insulated fans are other sources of noise pollution on ships [36–38]. Independent of the source, noise levels that exceed a certain limit would adversely affect the health of the crew.

Due to its nature, the work environment in a ship is quite different when compared to other work environments. This is mainly due to the fact that the crew's work and living domains are the same [39–41]. Even when they finish their shift, the crew are still exposed to noise exposure on the ship. They work, rest, sleep and fulfill their basic needs in the same environment [1,41–43]. In other words, they are exposed to the adverse effects of noise pollution 24/7 during the time they spend on the ship.

Protective equipment for noise reduction is used during work hours but not used during rest and sleep periods. This situation further increases the negative effects that seafarers suffer. Personnel in the engine room are required to wear ear protection while working in the engine room at all times. It is simply forbidden to work in the engine room without wearing ear protection. Deck personnel, on the other hand, are not required to wear ear protection throughout their shift but only when conducting certain jobs such as scraping [10,44–46]. This significantly increases the exposure of the crew to noise pollution when compared to employees in other industries [1,7,37]. Living quarters are built right above the engine room in ships to distribute the load efficiently. This leads to constant engine noise exposure in living quarters and physical and mental pressure for the crew [4,38]. In particular, the crew who stays in the ship for months on long contracts are directly exposed to noise pollution for long periods. The

CONTACT Ünal Özdemir ✉ unalozdemir@mersin.edu.tr

noise pollution has negative effects on the crew. Identification and limitation or minimization of these adverse effects would directly affect the health of the crew and the operation of systems with maximum efficiency [4–7,29,35,38]. Thus, the current study aimed to determine the noise pollution in ship environments and the level of exposure to noise pollution based on on-board measurements to determine the compliance of the findings with the IMO A.468 (XII) code, which was developed based on international human health standards. The fact that there were a limited number of studies on noise pollution in ships was another reason why the current study was conducted.

In this study, to determine the noise exposure in ships, noise measurements were conducted with the crew who met certain criteria in predetermined ships. Thus, the exposure of the ship crew to noise pollution was determined and the associated risks were assessed. The measurements were conducted daily based on the Turkish Standards Institute (TSE) technical specification (TS) European Standards (EN) International Organization for Standardization (ISO) Standard No. 9612 'Acoustics – Determination of Occupational Noise Exposure – Engineering Method' standard. The measurements were conducted with the SV88 102+ Noise Dosimeter that was calibrated using the SV 30A Acoustic Calibrator (Svantek, Poland) [47]. Furthermore, the measurement findings were compared to the noise standards specified in the IMO A.468 (XII) code [4], the gold standard in world maritime transportation, and then the possible negative effects of ship-borne noise pollution on the crew were analyzed.

2. Materials and methods

In the study, noise exposure measurements were conducted on the crew employed in nine ships with different properties to determine the noise pollution levels and their impact on the crew. In the study, the measurements were conducted with an SV 25D Microphone (Svantek, Poland) and the SV 30A Acoustic Calibrator, which were integrated with the SV 102+ Noise Dosimeter (Svantek, Poland) [47]. In this device, *A*-weight, audible sound frequency type-A filter, sound pressure level mode and 30–140 dB sound range were employed. The device was calibrated before each measurement. The SV 30A Acoustic Calibrator was used to calibrate the sound level. Furthermore, the measurement results were compared to the noise standards specified in the IMO A.468 (XII) code, the gold standard in world maritime transportation.

Figure 1. SV 102+ Noise Dosimeter (Svantek, Poland).

Figure 2. SV 30A Acoustic Calibrator (Svantek, Poland).

2.1. Measurement devices

The SV 25D Microphone integrated into the SV 102+ Noise Dosimeter device (Figure 1) and the SV 30A Acoustic Calibrator (Figure 2) were used for the noise exposure measurements. This method was preferred as it was necessary to conduct long-term measurements while the employees performed complex, unpredictable or several tasks [47,48]. The measurements were carried out suing a precision sound-level meter (SV 102+ Noise Dosimeter), which complies with the characteristics imposed by the standards. The instrument calibration was performed before and after each measurement cycle by means of a calibrator compliant with the standard. The sound-level meter was connected to a G.R.A.S. 46 AC LEMO free-field microphone (GRAS Sound & Vibration, Denmark), having frequency in the range of 3.15 Hz–40kHz (±2 dB) and sensitivity of 12.5 mV/Pa at 250 Hz (±1 dB).

2.2. Study stages and procedures

After it was decided to conduct the study on ship environments, where the noise exposure values were higher than the limits specified in international legislations and standards, the study was conducted based on the stages shown in Figure 3.

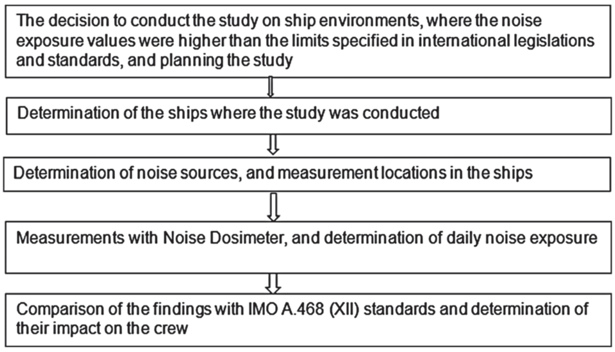

Figure 3. Study flow chart. Note: IMO, International Maritime Organization.

Table 1. TS EN ISO Standard No. 9612:2009 procedures [48].

Stage	Process	Detail
Step 1	Task analysis	Collection of adequate data on the task and related employees, and determination of the measurement strategy and planning
Step 2	Selection of the measurement strategy	A task-oriented, job-oriented or whole-day measurement strategy should be determined. Multiple strategies could be employed when necessary
Step 3	Measurements	The basic measurement should entail $L_{p,A,\mathrm{eq}T}$. Also, $L_{p,\mathrm{Cpeak}}$ should be measured when necessary
Step 4	Errors and ambiguities	The sources of errors and ambiguities that could affect the findings should be analyzed
Step 5	Measurement and presentation of the results and ambiguities	$L_{\mathrm{ex,8h}}$ should be calculated as indicated by the selected strategy, and ambiguities should be calculated with the method identified in the standard appendix. These could be calculated with the table provided in ISO Standard No. 9612

Note: EN, European Standards; ISO, International Organization for Standardization; $L_{\mathrm{ex,8h}}$, A-weighted noise exposure level; $L_{p,A,\mathrm{eq}T}$, A-weighted equivalent continuous sound pressure level; $L_{p,\mathrm{Cpeak}}$, C-weighted peak sound pressure level; TS, technical specification.

The TS EN ISO Standard No. 9612:2009 ‘Determination of Occupational Noise Exposure – Engineering Method’ [48] was employed for the noise exposure measurements in the current study. The standard procedures are as follows, as presented in Table 1:

- Step 1. Based on the processes summarized in Table 1, the first step was determination of the ships where the measurements would be conducted and the crew members in these ships. Work environments in the ships are categorized as the engine and the deck department. Similarly, ship personnel were categorized into engine crew and deck crew [49]. Measurements were conducted on these two groups to determine the ship-borne noise levels. The first group included the engine crew who are exposed to the highest noise levels in the ships. The second group included the deck crew who are exposed to noise on the deck emitted by scrapers, hammers, welding, opening/closing of the hatch cover, loading/unloading, anchor and capstan equipment, etc. To determine homogeneous noise exposure groups in each ship, the crew with similar qualifications, duties and jobs were grouped. The engine crew included the second engineer, the third engineer and the chief engineer in each ship. The deck personnel included the ocean-going first officer, the boatswain and an able seaman in each ship. The second and third engineers work at least 8-h shifts daily (engine watch) in the engine room, a completely secluded area during navigation. During this time, they are directly exposed to the noise of the main engine. Similarly, the selected deck crew work mostly in open spaces for at least 8 h a day under quite different noise levels. A measurement group of six individuals per ship was determined, and since the measurements were conducted separately on nine ships with different properties as presented in Table 2, the total number of participants was 72. Measurements were conducted on all crew members concurrently and are presented in Section 3. The ships were selected based on similarities in equipment/hardware, work conditions, design features, etc. Also, the engine capacities of the selected vessels (indoor space, engine size, engine operation, etc.) were similar. Measurements were conducted between November 2021 and January 2022 over a period of 3 months.
- Step 2. The TS EN ISO Standard No. 9612:2009 ‘Determination of Occupational Noise Exposure – Engineering Method’ suggests three measurement strategies to determine noise exposure in the workplace: task-based measurement, job-based measurement and full-day measurement. It was decided to adopt the task-based measurement strategy based on the work environment in the ship and the shifts of the selected personnel.

Task-based measurement refers to the analysis of the tasks conducted during the workday and the measurement of the sound levels separately for each task.

The daily tasks of the employees designated for task-based measurements were categorized in nominal tasks. A value such as $L_{p,A,\mathrm{eq}T}$ that could be repeated in each task was set. The A-weighted equivalent continuous sound pressure level $L_{p,A,\mathrm{eq}T}$ was calculated using Equation (1) for the mth task:

$$L_{p,\,A,\mathrm{eq}T} = 10\log_{10}/g\left[\frac{\frac{1}{T}\int_{t_1}^{t_2} p_A^2(t)\mathrm{d}t}{p_0^2}\right]\mathrm{d}B, \tag{1}$$

where p_A = A-weighted sound pressure during the stated time interval T, starting at t_1 and ending at t_2; p_0 = reference pressure value (20 µPa).

After ensuring that all sources that contribute to the noise level were included, the tasks with the peak noise level were identified and $L_{p,A,\mathrm{eq}T}$ and $L_{p,\mathrm{Cpeak}}$ were determined. The

Table 2. Ship details.

Ship number	Ship type	Overall length (m)	Beam (m)	Gross tonnage (GRT)	Year built	Engine type and details
1	General cargo	131.32	18	5619 GRT	2007	STX MAN-B&W (6S50MC-C7) 6 CY X 1 SET – 6,480 kW
2	General cargo	139.81	16.56	6211 GRT	1989	DEUTZ SBV 8M 628 2600 kW
3	General cargo	110	17	4897 GRT	1979	Caterpillar Motoren GmbH & Co. / Mak 9 M 25 /4970 kW
4	Container	180.42	25.27	17,068 GRT	2009	MAN-11200 KW
5	Chemical/oil	183.12	32.2	54,646.5 GRT	2014	Hyundai B&W 6G50ME-B9.3, 90.7 rpm. 8090 kW
6	General cargo	79.65	10.90	1574 GRT	1990	DEUTZ SBV 6M 628: 600 kW
7	General cargo	89.80	13.60	2769 GRT	1991	STORK WARTSILA 6sw280: 900 rpm / 1750 kW
8	General cargo	90.40	13.20	2846 GRT	1991	DEUTZ MwM SBV 9M 628: 900 rpm / 1800 kW
9	General cargo	68.28	11.2	1445 GRT	1983	B & W-ALPHA 750 kW

C-weighted peak sound pressure level $L_{p,\text{Cpeak}}$ was calculated by the following equation:

$$L_{p,\,\text{Cpeak}} = 10/g\frac{p_{\text{Cpeak}}^2}{p_0^2}\text{dB}, \tag{2}$$

where p_0 = reference pressure value (20 μPa).

Initially, the time required to complete the task (T_m) was determined. For this purpose, 18 participating crew members were interviewed. Previously, the deck and engine sections of the ships were observed to determine various noise sources other than the work environment. It was determined that the daily engine shifts of the participating employees were 8 h long.

- Step 3. Crew members with the same job description were determined to ensure homogeneous noise exposure in the nine ships where the measurements were conducted. Measurements were conducted with 72 crew members: four deck crew members and four engine crew members in each ship. The measurements were conducted when the ship's main engines were continuously operational and the deck shifts were active in all three ships. The SV 104 noise exposure meter and the SV 25D Microphone integrated with the device were placed on the crew member's overalls. This was attached to the shoulder of the individual on the side with higher exposure at a distance of 0.15 m from the outer ear canal and 0.04 m above the shoulder [48]. The microphone and cable were connected to prevent mechanical or clothing interference and resulting false data. The microphone placement is shown in Figure 4. The SV 102+ Noise Dosimeter was calibrated before and after each measurement with the SV 30A Acoustic Calibrator shown in Figure 2 for sensitive and accurate measurements. The measurements were saved on the device with a particular file name for each ship, and the data were transferred to the computer.

2.3. *Risk assessment method*

In the study, the 5 × 5 matrix risk assessment method, which has been frequently used in the literature, was employed [50–56]. In the study, the risk assessment was limited to the engine rooms of the ships where the measurements were conducted. The probability and risk components of the matrix are presented in Table 3.

The 5 × 5 matrix was employed to analyze causality. As this is a simple method, it can be used when the risk assessment personnel are limited. The risk is calculated by the multiplication of probability by severity [52,53,55,56]. The probability of an event was calculated based on the ranges presented in Table 4.

The ranges presented in Table 5 were employed to determine the degree of severity of a future event.

Figure 4. Microphone placement.

After the risk score was calculated with the probability and severity multipliers, the procedures presented in Table 6 were implemented [55,57,58].

3. Findings

Various measurements were conducted to determine the exposure of engine room crew to noise and daily exposure values were calculated with the procedures described in Section 2. The task-based measurement strategy was adopted as the crew of the engine room where the measurements were conducted were exposed to similar noise levels, no other workstation contributed to the noise and the job descriptions of the employees were the same. The task-based measurement strategy was adopted as the job descriptions and the tenure of the

Table 4. Probability of an event.

Probability	Degree of occurrence
Very low	Scarcely ever
Low	Once a year or at longer intervals
Average	Several times a year
High	Once a month
Very high	Once a week or more

Table 5. Event severity.

Intensity	Degree of intensity
Very insignificant	No loss of working hours, requiring first aid
Insignificant	No lost work days, requiring outpatient treatment
Average	Minor injury, requiring inpatient treatment
Significant	Serious injury, prolonged treatment, occupational disease
Very significant	Death, permanent incapacity

Table 3. The 5 × 5 matrix risk assessment scale.

	Intensity				
Probability	1 (very insignificant)	2 (insignificant)	3 (average)	4 (significant)	5 (very significant)
1 (very low)	Very low (1)	Low (2)	Low (3)	Low (4)	Low (5)
2 (low)	Low (2)	Low (4)	Low (6)	Average (8)	Average (10)
3 (average)	Low (3)	Low (6)	Average (9)	Average (12)	High (15)
4 (high)	Low (4)	Average (8)	Average (12)	High (16)	High (20)
5 (very high)	Low (5)	Average (10)	High (15)	High (20)	Intolerable (25)

Table 6. Risk levels and details [48].

Level	Detail
Intolerable risks (25)	The task should not be initiated until the identified risk is reduced to an acceptable level; if the activity is ongoing, it should be stopped immediately. If it is not possible to reduce the risk after the measures, the activity should be prevented
Significant risks (15, 16, 20)	The task should not be initiated until the identified risk is reduced to an acceptable level; if the activity is ongoing, it should be stopped immediately. If the risk is associated with the maintenance of the task, urgent action should be taken, and the maintenance of the task should be decided based on the outcome of these measures
Moderate risks (8, 9, 10, 12)	Measures should be adopted to reduce the identified risks. Risk reduction measures could take time
Acceptable risks (2, 3, 4, 5, 6)	Additional control processes may not be needed to eliminate identified risks. However, existing controls should be maintained and supervised

deck crew were clearly defined and they were also exposed to stable noise levels. The tasks with the peak noise level were identified and $L_{p,A,\mathrm{eq}T}$ and $L_{p,\mathrm{Cpeak}}$ were determined. Initially, the time required to complete the task T_m was determined, where m is the task number. Finally, the evaluation of the A-weighted noise exposure level $L_{\mathrm{ex,8h}}$ from the noise contribution of each of the tasks was executed using Equation (3):

$$L_{\mathrm{EX,\,8h}} = 10/g\left(\sum_{m=1}^{M=8} 10^{0.1XL_{\mathrm{EX,8h},m}}\right)\mathrm{d}B, \qquad (3)$$

where m = task number; M = total considered number of tasks contributing to the daily noise exposure level. For this purpose, 18 participating crew members were interviewed. Measurements details are presented in Table 7.

Exposure was calculated with CadnaA Version 2021 MR2 (Computer Aided Noise Abatement) [59]. The data collected in each ship were compared. During the ship operations, different noises are continuously emitted both in the engine room and on the deck; however, since noise sources emit lower noise levels when compared to the noise generated by the tasks, it was observed that they did not affect noise exposure levels. The task-based measurement strategy measurements are presented in Table 8.

The comparison of the task-based measurement strategy exposure measurements revealed that the highest daily noise exposure was in Ship 7 and the lowest exposure was in Ship 1. The main regulation for noise pollution on ships is IMO A.468 (XII) according to the IMO [4]. Based on this regulation, the exposure limit for engine rooms (with continuous human control) is 90 dB. In all measurements, it was determined that the limit specified in the regulation was exceeded. Similarly, in the IMO A.468 (XII) code, the mean exposure limit for ship work environments except the engine room should be between 70 and 85 dB. The exposure of the deck personnel to noise was measured with the task-based measurement strategy, as presented in Table 9, and exceeded the code in all measurements. The highest exposures were observed for the first officer, boatswain and able seaman in Ship 7. The highest daily noise level in decibels is in Ships 7, 8 and 9. The highest job-based exposure value is for the able seaman in Ship 7.

Table 7. Measurements, measurement durations and number of personnel.

Characteristic	Value
Number of noise exposure measurements with the job-based strategy (n)	98
Duration of the noise exposure measurements with the job-based strategy (min)	6146
Number of employees on whom the exposure measurements with the job-based strategy were conducted (n)	36
Noise exposure measurements with the task-based strategy (n)	95
Duration of the noise exposure measurements with the task-based strategy (min)	1583
Number of employees on whom the exposure measurements with the task-based strategy were conducted (n)	36

3.1. *Risk assessment*

A risk assessment was conducted as outlined in Section 2.3 for Ship 7, where the highest values were determined with both task-based and job-based noise exposure measurements. The risk assessment conducted on the deck and the engine room revealed certain high risks, which are presented in Table 10.

4. Results

It is known that the job conditions of seafarers are quite difficult, and the profession requires serious efforts. In these difficult job conditions and demanding tempo, ship crews could be exposed to certain elements that could induce certain health problems. Noise pollution is one of these factors. It was demonstrated that noise pollution could lead to hearing loss, and various studies evidenced that noise pollution could be associated with a high heart rate, leading to chronic and acute medical conditions such as high blood pressure and heart attack [12,18,60,61]. The decision-making skills of an individual could

Table 8. Task-based measurement of strategy noise exposure (engine room crew).

Ship number	Daily noise level (dB)
1	108.3
2	109.2
3	111.3
4	115.2
5	113.4
6	116.4
7	118.2
8	117.5
9	118.1

Table 9. Task-based measurement of daily noise exposure (deck crew).

	Exposure value			
Ship number	First officer	Boatswain	Able seaman	Daily noise level (dB)
1	87.2	94.5	96.4	80.2
2	89.5	93.3	95.3	81
3	89.8	95.2	97.2	81.5
4	90.4	96.7	98.2	82
5	88.8	93.5	95.4	81.5
6	90	97.2	106.3	81
7	92	106.5	117.2	83
8	91	105.5	112.2	83
9	89	104	115.5	83

Table 10. High-risk noise exposure.

Activity	Hazard	Risk	Risk level Probability	Severity	Outcome	Required measures
Ship operations	Exposure to high noise levels	Loss of hearing	4	4	16	Periodic general health examinations should be conducted for those employed in noisy jobs. Those with low hearing and any hearing impairment, those with ear and nerve diseases, and those with hypertension should quit their jobs, and should be monitored and treated When noise exposure exceeds the minimum exposure action limits, the employer should prepare ear protectors for the employees Ear protectors should be employed when noise exposure reaches or exceeds the highest exposure action limits Ear protectors should be selected to eliminate or minimize hearing risks The employer should spend every effort to ensure the use of ear protectors and will be responsible to monitor the effectiveness of the measures

be impaired for 30 s after exposure to 110 dB noise for 1 s. It is also known that exposure to noise could reduce occupational safety by preventing auditory stimuli [62]. Ship environments are ideal workplaces for excessive noise pollution [29]. Both the degree and the duration of exposure are significant factors [30,31]. Thus, since ships are both a work environment and environments where the crew fulfill their needs, they are exposed to noise pollution during every moment they spend on the ship. An especially long period of exposure could lead to an elevation of health risks.

During ship operations, different noises are continuously emitted both in the engine room and on the deck; however, as noise sources emit lower noise levels when compared to the noise generated by the jobs, it was observed that they did not affect noise exposure levels in the study. The comparison of the job-based noise exposure measurements revealed that the highest daily noise exposure was in Ship 7 and the lowest exposure was in Ship 1. In all measurements, it was determined that the limit specified in the regulation was exceeded.

The main noise pollution regulation for ships is IMO A.468 (XII), as recommended by the IMO. In the current study, it was determined that the upper noise pollution limit specified by the IMO was exceeded. The study findings demonstrated that the upper limit specified by the IMO was not adequate for ships. Certain flag states set further noise pollution criteria for ships that fly their flags. Also, some classification institutions adapted the passenger ship comfort criteria for freight ships [5–8]. These practices were consistent with the current study findings. It could be suggested that the aforementioned flag states and classification institutions considered the IMO limits inadequate. Furthermore, although there are almost no studies on the topic in the literature, the ship noise pollution findings reported by İnsel and Helvacıoğlu [35] were quite similar to the present study. Thus, it could be suggested that strict implementation of the IMO-recommended A.468 (XII) code and improvement of MLC practices would contribute to the jobs and occupational health of the ship crew.

A significant limitation of the study was the differences in the ages of the ships. Thus, it could be suggested that the condition of the ship could also have affected the measurements. Although each ship in the sample was of the same ship type, their equipment and conditions were different. Thus, technological differences, design limits and equipment employed by engine manufacturers and the shipyards could have led to variations in the findings. The subject of future quantitative studies could be to determine the causes of these differences.

The general approach in the literature on the reduction of noise pollution entails the elimination of noise before it is emitted, similar to the reduction of all risks [12,25,32,60,63]. When practices such as isolation of hazards that could not be eliminated, replacement of hazardous equipment with non-hazardous equipment, collective protection measures and engineering solutions would not lead to the desired outcomes, personal protective equipment (PPE) should be used as a last resort. Thus, although it is obligatory to wear protective earplugs, especially in engine rooms, further proactive occupational safety and health measures should be adopted, especially to limit the main engine noise. It could be suggested that approaching the problem from an engineering perspective could lead to more precise solutions by improving the design criteria and better engine selection.

5. Conclusion

Currently, it could be argued that the job conditions of seafarers are quite difficult and they face several occupational health risks. One of these risks is noise pollution. Thus, the current study aimed to determine the risks posed by noise pollution in ships. The study findings demonstrated that exposure to noise pollution exceeded the IMO-recommended limits in ships. This raised the possibility of adverse effects to the health of the crew in the case of long-term exposure. Hearing loss is among these health problems; however, it was also observed that exposure could also lead to chronic and acute medical conditions such as high blood pressure and heart attack. Future studies analyze the problem from this perspective, especially from the perspective of healthcare professionals. The current study contributes to the literature, as previous studies on exposure to noise pollution in ships were quite limited.

The study findings could provide a foundation for future IMO regulations, maritime industry policy makers, the World Health Organization (WHO) and related institutions. The compulsory MLC practices should be revised based on the current and future study findings on noise pollution. It was estimated that the interest of the maritime transport industry in the issue will increase in the future with an increase in the number of studies on noise pollution in ships, as the number of current studies is quite limited.

Disclosure statement

No potential conflict of interest was reported by the author.

Ethics committee approval

The author declares that, according to the laws of the country where the study was conducted, there was no ethical approval requirement/obligation as of the commencement of the work process.

Supplemental data

Supplemental data for this article can be accessed online at https://doi.org/10.1080/10803548.2023.2282874.

ORCID

Ünal Özdemir http://orcid.org/0000-0001-9682-4239

References

[1] MLC. Maritime Labour Convention [Internet]; 2006 [cited 2022 Feb 2]. Available from: https://www.ilo.org/wcmsp5/groups/public/—ed_norm/—normes/documents/normativeinstrument/wcms_763684.pdf

[2] ILO. International Labour Organization [Internet]; 2022 [cited 2022 Feb 2]. Available from: https://www.ilo.org/dyn/normlex/en/f?p = NORMLEXPUB:91:0::NO::P91_ILO_CODE:C186

[3] Zhang P, Zhao M. Maritime Labour Convention, 2006 and the Chinese seafarers: how far is China to ratification? Mar Policy. 2015;61:54–65. doi:10.1016/j.marpol.2015.07.016

[4] IMO. International Maritime Organization code on noise levels on board ships; London, IMO Press,1981 Nov 19. IMO resolution A. 468(XII).

[5] BV. Bureau Veritas rules for the classification of steel ships: additional class notations, part F, comfort on board (COMF),Paris, 8 cours du Triangle Press; 2001 Apr.

[6] ABS. American Bureau of Shipping (ABS),: guide for crew habitability on ships; Houston, American Bureau of Shipping Press, 2001 Dec.

[7] GL. Germanischer Lloyd, rules for classification and construction. Chapter 16 harmony class – rules on rating noise and vibration control, cruise ships ($V < 25$ kn); Hovik (Norway), Group Communications Press, 2003.

[8] LR. Lloyd's Register, provisional rules for passenger and crew accommodation comfort; London (U.K), The Midas Press, 2004 Jan.

[9] Nardo M. Noise pollution: an overview of management strategies. Int J Environ Technol Manage. 2004;4(4):300–322. doi:10.1504/IJETM.2004.005719

[10] Badino A, Borelli D, Gaggero T, et al. Normative framework for ship noise: present situation and future trends. Noise Control Eng J. 2012;60(6):740–762. doi:10.3397/1.3701045

[11] Gozalo GR, Morillas JMB, Escobar VG. Urban streets functionality as a tool for urban pollution management. Sci Total Environ. 2013;461–462:453–461. doi:10.1016/j.scitotenv.2013.05.017

[12] Basner M, Babisch W, Davis A, et al. Auditory and non-auditory effects of noise on health. Lancet. 2014;383:1325–1332. doi:10.1016/S0140-6736(13)61613-X

[13] Demian H. Environmental noise and sleep disturbances: a threat to health? Sleep Sci. 2014;7:209–212. doi:10.1016/j.slsci.2014.11.003

[14] Murphy E, King EA. Environmental noise pollution: noise mapping, public health, and policy. Amsterdam (Netherlands), Elsevier; 2014.

[15] Wothge J, Belke C, Möhler U, et al. The combined effects of aircraft and road traffic noise and aircraft and railway noise on noise annoyance – an analysis in the context of the joint research initiative NORAH. Int J Environ Res Public Health. 2017;14(8):871. doi:10.3390/ijerph14080871

[16] Slabbekoorn H, Dooling R, Popper AN, et al. Effects of anthropogenic noise on animals. In: Richard R.Fay, editor. Springer handbook of auditory research. New York (NY): SpringerVerlag; 2018. p. 309.

[17] Kraus U, Schneider A, Breitner S, et al. Individual daytime noise exposure during routine activities and heart rate variability in adults: a repeated measures study. Environ Health Perspect. 2013;121:607–612. doi:10.1289/ehp.1205606

[18] Sim S, Sung H, Cheon H, et al. The effects of different noise types on heart rate variability in men. Yonsei Med J. 2015;56:235–243. doi:10.3349/ymj.2015.56.1.235

[19] Shuanggui Y, Chenchen D, Qi Z. Noise pollution in the re-use of the electric vehicles. Procedia Eng. 2011;21:239–242. doi:10.1016/j.proeng.2011.11.2010

[20] Altıparmak Z. Determination of noise exposure of workers in iron foundries and precautions to be taken [thesis]. Ankara: Ministry of Labour and Social Security, Directorate General of Occupational Health and Safety, Occupational Health and Safety Specialization Thesis; 2014.

[21] Almomani H, Almutairi N. Vehicles maintenance workshops layout and its management to reduce noise pollution and improve maintenance quality. J Environ Treat Tech. 2020;8(4):1352–1356. doi:10.47277/JETT/8(4)1356

[22] Klaeboe R, Amundsen A, Fyhri A, et al. Road traffic noise – the relationship between noise exposure and noise annoyance in Norway. Appl Acoust. 2004;65(9):893–912. doi:10.1016/j.apacoust.2004.04.001

[23] Ingle S, Pachpande B, Wagh N, et al. Noise exposure and hearing loss among the traffic policemen working at busy streets of Jalgaon urban center. Transp Res Part D Transp Environ. 2005;10(1):69–75. doi:10.1016/j.trd.2004.09.004

[24] Andersson H, Ogren M. Noise charges in railway infrastructure: a pricing schedule based on the marginal cost principle. Transp Policy. 2007;14:204–213. doi:10.1016/j.tranpol.2007.01.002

[25] Malcolm JC. Handbook of noise and vibration control. Wiley, Hoboken, New Jersey; 2007.

[26] Blokland G, Peeters B.. Modeling the noise emission of road vehicles and results of recent experiments. Inter-Noise 2009, Ottawa, Canada, 2009

[27] Sarıdemir S, Tekin M. Influence of canola oil methyl ester and diesel fuel blends on a single cylinder diesel engine performance and noise emissions. J Polytech. 2016;19(1):53–59.

[28] Şabikoğlu İ, Şabikoğlu D. Comparison of environment noise intensity using iOS and android based sound measurement applications and commercial sound measurement devices and obtaining the measurement uncertainty. Yüzüncü Yıl Univ J Nat Appl Sci. 2021;26(2):69–79.

[29] Vukíc L, Mihanovíc V, Fredianelli L, et al. Seafarers' perception and attitudes towards noise emission on board ships. Int J Environ Res Public Health. 2021;18:6671. doi:10.3390/ijerph18126671

[30] Krug E, Cieza MA, Chadha S, et al. Noise induced hearing loss. hearing loss due to recreational exposure to loud sound. 1st edn. Geneva: WHO; 2014.

[31] Gupta A, Gupta A, Jain K, et al. Noise pollution and impact on children health. Indian J Pediatr. 2018;85(4):300–306. doi:10.1007/s12098-017-2579-7

[32] Torregrosa AJ, Broatch A, Novella R, et al. Suitability analysis of advanced diesel combustion concepts for emissions and noise control. Energy. 2011;36:825–838. doi:10.1016/j.energy.2010.12.032

[33] Redel-Macias MD, Pinzi S, Leiva D, et al. Air and noise pollution of a diesel engine fueled with olive pomace oil methyl ester and

petrodiesel blends. Fuel. 2012;95:615–621. doi:10.1016/j.fuel.2011.11.003

[34] Sheppard A, Ralli M, Gilardi A, et al. Occupational noise: auditory and non-auditory consequences. Int J Environ Res Public Health. 2020;17(23):8963, doi:10.3390/ijerph17238963

[35] İnsel M, Helvacıoğlu H. Gemi Yaşam Mahallerinde Gürültü Hesapları ve Ölçümleri. Gemi İnşaatı ve Deniz Teknolojisi Teknik Kongresi, Bildiriler Kitabı. 2008;1:304–315. Turkish.

[36] Holland CG, Wong SF. Noise prediction and correlation with full scale measurements in ships. Trans Inst Mar Eng. 1995;107(3):195–207.

[37] DMA. Danish Maritime Authority Technical Regulation no. 4 of 3 May 2002. Kopenhag.

[38] MSC. Proposal for protection against noise on board ships. IMO Maritime Safety Committee; 2007 Jul 3. MSC 83/25/13. London

[39] Joode BW, Burdorf A, Verspuy C. Physical load in ship maintenance: hazard evaluation by means of a workplace survey. Appl Ergon. 1997;28(3):213–219. doi:10.1016/S0003-6870(96)00051-8

[40] Andy S. From the brain to the workplace: studies of cognitive fatigue in the laboratory and aboard ship. In: PL Ackerman, editor. Cognitive fatigue: multidisciplinary perspectives on current research and future applications. CC: American Psychological Association,Washington; 2011. p. 291–305..

[41] Baumler R, Singh Bhatia BS, Kitada M. Ship first: seafarers' adjustment of records on work and rest hours. Mar Policy. 2021;130:104186, doi:10.1016/j.marpol.2020.104186

[42] Bhattacharya S. The impact of the ISM code on the management of occupational health and safety in the maritime industry [dissertation]. Ph.D. Thesis, School of Social Sciences, Cardiff University; 2009.

[43] IMO. International Maritime Organization guidelines on fatigue. London: IMO; 2019. MSC.1/Circ1598.

[44] Spence J, Fischer R, Boroditskyet L, et al. Case study: application of SEA to predicting shipboard noise. In: JS Carlton, D Vlasic, editor. Lloyds Ship Noise and Vibration Conference; London; 20-21 June. 2005.

[45] Insel M, Helvacioğlu IH, Unsan Y, et al. Noise predictions for shipboardaccommodations. In: Proceedings of the 13th Congress of International Maritime Association of Mediterranean; Istanbul, Turkey; ITU Fac. of Naval Architecture and Ocean Engineering Press; Oct. 12–15,; 2009, p. 203–208.

[46] Turan O, Helvacioglu IH, Insel M, et al. Crew noise exposure on board ships and comparative study of applicable standards. Ships Offshore Struct. 2011;6(4):323–338. doi:10.1080/17445302.2010.514716

[47] Svantek. SV 104 Noise Dosimeter [Internet]; cited 2022 Feb 2. Available from: http://www.econorm.com.tr/site/assets/files/1129/2015_sv104_sv104is.pdf

[48] TS EN ISO 9612:2009. Determination of occupational noise exposure – engineering method. Ankara/Turkey: ISO; 2009. Standard No. 9612:2009.

[49] STCW. International Convention on Standards of Training, Certification and Watchkeeping 1978, as amended IMO; IMO press, London, 1978.

[50] Özkılıç Ö. İş Sağlığı ve Güvenliği Yönetim Sistemleri ve Risk Değerlendirme Metodolojileri (Birinci Baskı). In: Ajans-Türk Basım Ve Basım A.Ş. Sayfa. Ankara: Çalışma ve Sosyal Güvenlik Bakanlığı İş Teftiş Kurulu İstanbul Grup Başkanlığı (in Turkish); 2005. p. 130–132.

[51] Katsumata P, Hemenway J, Gavins W. Cybersecurity risk management. In: MILCOM 2010 Military Communications Conference.San Jose, CA, USA; 2010, p. 890–895. doi:10.1109/MILCOM.2010.5680181

[52] Jairus H, Debarati C, Robert S. Risk identification and visualization in a concurrent engineering team environment. In: 2010 Jun 8–11; ISPA/SCEA Conference and Training Workshop 2010; San Diego (CA); American Institute of Aeronautics and Astronautics; 2010.

[53] Ristić D. A tool for risk assessment. Saf Eng. 2013;64:614. doi:10.7562/SE2013.3.03.03

[54] Konior J. Enterprise's risk assessment of complex construction projects. Arch Civ Eng. 2015;61(3):63–74. doi:10.1515/ace-2015-0025

[55] Fehring A. Risk management: putting the appetite into risk management: is it time to delete your risk matrix? Governance Directions. 2018;70(7):390–402.

[56] Lindsey NJ, Alimardani M, Gallo LD. Reliability analysis of complex NASA systems with model-based engineering. In: 2020 Annual Reliability and Maintainability Symposium (RAMS). Palm Springs; 2020, p. 1´8. doi:10.1109/RAMS48030.2020.9153633

[57] James R. Space systems engineering and risk management – joined at the hip. In: Space Systems Engineering & Risk Management Symposium; Manhattan Beach (CA); 2003 Feb 17–20. https://dataverse.jpl.nasa.gov/dataset.xhtml?persistentId = hdl:2014/39148&version = 1.1.

[58] Shakya S, Mishra AK. Risk assessment in construction of Gautam Buddha international airport. J Adv Res Constr Urban Archit. 2019;4(1):17–34.

[59] DataKustik. CadnA [Internet]; [cited 2022 Jan 11]. Available from: https://www.datakustik.com/products/cadnaa/cadnaa

[60] Singhal S, Yadav B, Hashmi SF, et al. Effects of workplace noise on blood pressure and heart rate. Biomed. 2009;20:122–126.

[61] Hohmann C, Grabenhenrich L, de Kluizenaar Y. Health effects of chronic noise exposure in pregnancy and childhood: a systematic review initiated by ENRIECO. Int J Hyg Environ Health. 2013;216:217–229. doi:10.1016/j.ijheh.2012.06.001

[62] Özdemir S. Gürültü ile oluşan işitme kayıpları ve alınacak önlemler [Internet]; [cited 2021 Jan 12]. Turkish. Available from: http://www.bilgin.net/GurultuSelcukOzdmr.htm

[63] Tang UW, Wang ZS. Influences of urban form on traffic-induced noise and air pollution: results from a modelling system. Environ Model Softw. 2007;22:1750–1764. doi:10.1016/j.envsoft.2007.02.003