VPS VIBRATIONS IN PHYSICAL SYSTEMS

DOI: 10.21008/j.0860-6897.2025.2.04
Vibrations in Physical Systems, 2025, 36(2), 2025204

Occupational exposure to noise and infrasonic noise of crews of inland waterway vessels

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Abstract Ships, including inland waterway vessels, are special places to work for two main reasons: they operate in an unusual environment and they are characterised by limited space. Therefore, the working conditions on inland waterway vessels are specific. The safety of the crews of these vessels is influenced by, inter alia, hazards related to the operation of vessels and the movement of other vessels, as well as weather conditions. According to literature data, noise and mechanical vibrations dominate in the group of negative factors of the working environment on vessels. As part of the project, which aims to carry out a comprehensive assessment of environmental hazards and nuisances on selected vessels, research on working conditions on inland waterway vessels was carried out. These researches included measurements and evaluation of physical environmental factors, including noise and infrasonic noise, on the following types of inland waterway vessels: police boats, rescue boats, pushers and tourist vessels. The highest noise levels were recorded in the engine room on pushers. The measured equivalent A-weighted sound pressure levels in these rooms were in the range of 101.1 to 102.2 dB(A). On the other hand, the lowest noise levels were recorded at helmsman's workstations in control cabins on tourist vessels. The measured equivalent A-weighted sound pressure levels at these workplaces ranged from 59.2 to 61.1 dB(A). The article presents detailed results of measurements and assessment of noise and infrasonic noise on the tested inland waterway vessels.

Keywords: inland waterway vessel, noise, infrasonic noise, exposure, assessment, working conditions, risk assessment, workplace.

1. Introduction

Shipping and fishing are among those sectors of the economy that are characterised by particularly extreme environmental conditions. Vessel crews belong to this group of workers, whose health and life are particularly vulnerable. The data published in 2021 in [1] show that among fishermen, of which there are a total of approx. 28 million in the world, annually approx. 24000 of them lose their lives in the exercise of their profession. In turn, the results of research conducted by Baker and Seah [2] indicate that 85% of marine accidents on ships belonging to the USA, Australia, Canada and the United Kingdom are caused by crew errors due to excessive physical load, including inadequate working conditions. Similar data are cited in many publications, e.g. Wróbel [3] states that there is a strong belief among scientists that people contribute to about 80% of shipping accidents. This is confirmed by the latest data published by the Statistics Poland characterising maritime accidents and incidents that occurred on Polish vessels in the period 2020-2023 [4]. According to the Statistics Poland data, the number of maritime accidents (defined in [5] as an event, or several consecutive events, directly related to the operation of a ship, resulting in, inter alia, death or serious damage to human health or the disappearance of a person on board) and maritime incidents (defined in [5] as an event, or several consecutive events, other than a maritime accident, directly related to the operation of a ship, which had or could have an adverse impact, inter alia, on the safety of the ship, its occupants or the environment) is increasing and their main cause is the human factor. For example, in 2021, out of 63 marine accidents and incidents recorded by the State Commission for the Investigation of Marine Accidents, the human factor was the cause of as many as 45 of these accidents and incidents, while two years later, i.e. in 2023, out of 76 marine accidents and incidents, the human factor was the cause of 33 of these accidents and incidents.

Vessel crews are a specific professional group – for a significant part of the year, a craft is not only a working environment for them, but also a living environment for them. According to Slišković and Penezić [6], this is one of the two main sources of dissatisfaction with work for this professional group. The second source of this dissatisfaction is working conditions. In turn, working conditions, as defined by the Statistics Poland [7], are understood as a set of factors occurring in the work environment, resulting from the work process and factors related to the performance of work. On the other hand, the working environment consists of: physical (e.g. lighting, noise, microclimate), chemical (e.g. toxic substances) and biological (e.g. bacteria) factors occurring in the workplace area as well as in the area surrounding the workplace. In the group of negative factors of the working environment on vessels, according to literature data, noise and vibrations [8, 9] and extreme temperatures and relative humidity dominate, especially in engine rooms [10].

The above data also largely relate to inland waterway transport [11, 12]. Inland waterway vessels are special jobs. They operate in an unusual environment and are characterized by limited space. Therefore, according to Marczak [11], the functioning of ship crew members, including work and rest, is affected, inter alia, by working conditions, pitching of the ship, changing weather conditions and work organisation related to the performance of duties at different times of the day. A specific factor influencing the working conditions on Polish inland waterway vessels is the age of these vessels. The analysis carried out by Krystosik-Gromadzińska on the safety of work on inland waterway vessels shows that the majority of these vessels are over 50 years old, i.e. beyond their expected service life [12]. In [12] it is stated that the nuisance and harmful factors on inland waterway vessels are primarily noise, vibration, temperature and limited space. Moreover in [12] it is estimated that between 2000 and 4000 people work in inland navigation. On the other hand, the latest data published by the Central Statistical Office in 2024 show that in 2023 only 89 entities provide transport services in the field of inland navigation, and the number of employees there is 337 people, while it should be borne in mind that these data concern entities in which the number of employees exceeds 9 people [4].

It follows from the above that a meaningful assessment of the occupational exposure of workers employed on vessels requires a comprehensive analysis of the factors present in that specific working environment. It should cover both those physical factors whose impact is of common concern, such as noise, vibrations, lighting or non-ionising radiation, but also other factors such as electromagnetic fields, changing climatic conditions or psychosocial working conditions, which also significantly affect the well-being and ability to work and the safety and health of workers, including their quality of life. To this end, the authors adopted a research methodology comprising subjective research (survey) on working conditions [13] and objective research (environmental studies on working conditions).This methodology was positively assessed by the Bioethics Committee of the Witold Chodźko Institute of Rural Medicine in Lublin (Resolution No 20/2023).

In the group of the tested factors of the working environment on vessels there were infrasonic noise and noise which is recognized by the World Health Organization as one of the main risk factors for population health, with effects ranging from sleep disorders and concentration difficulties to damage of cardiovasscular system and irreversible hearing loss [14]. The aim of the paper is to present and analyze the results of noise and infrasonic noise measurements at workstations on inland waterway vessels and to present the results of the occupational risk assessment related to noise exposure.

2. Test method

2.1. General

The assessments of occupational risk related to noise exposure and infrasonic noise exposure are a complex process consisting of the following stages:

- estimation of noise exposure and infrasonic noise exposure,
- comparison of the obtained noise exposure and infrasonic noise exposure with the maximum allowable intensity values,
- assessment of the occupational risk related to noise and to noise exposure.

2.2. Methods for measuring noise and infrasonic noise

For noise and infrasonic noise measurements, the measurement methods specified in the following Polish Standards PN-EN ISO 9612:2011, PN-N-01307:1994 and PN-Z-01338:2010 [15-17] were used.

Due to the fact that the examined workstations on vessels are in principle stationary workstations with a limited range of activities performed, Strategy 1 (task-based measurements) was used in the tests [15]. This strategy is based on a detailed analysis of the work aimed at recognizing all activities. In addition, it requires continuous validation of measurements. This allows fewer measurements to be taken for activities that cause minor changes in noise levels. Task-based measurements provide information on the impact of noise from different activities on daily noise exposure.

Measurements were made using the Svantek sound level meter type SVAN 979, meeting the requirements of PN-EN 61672-1:2014-03 [18] for Class 1 measuring instruments. The measuring track was checked by means of an acoustic calibrator meeting the requirements of PN-EN IEC 60942:2018-06 [19] for Class 1 measuring instruments.

2.3. Maximum allowable intensity values for noise and infrasonic noise

Many organizations, both government and non-government, have developed some simple and some complex noise requirements for both crew and passengers on ships [20]. In this project the maximum allowable intensity (MAI) values for noise and infrasonic noise established in the current legislation (Regulation of the Minister of Family, Labour and Social Policy [21] and the Polish standard PN-Z-01338:2010 [17] respectively) were applied.

According to the regulation [21] occupational noise is characterized by:

- the A-weighted noise exposure level normalized to an 8 hour working day (daily noise exposure level), $L_{AEx,8h}$, (or normalized to a working week),
- the A-weighted maximum sound pressure level, L_{Amax},
- the C-weighted peak sound pressure level, L_{Cpeak}.

Table 1 specifies MAI values for noise.

Table 1. MAI values for noise according to [21].

Parameter	MAI value
The A-weighted noise exposure level normalized to an 8 hour working day (daily noise exposure level), $L_{AEx,8h}$	85.0 dB(A)
The A-weighted maximum sound pressure level, L_{Amax}	115.0 dB(A)
The C-weighted peak sound pressure level, L_{Cpeak}	135.0 dB(C)

According to the standard [17] infrasonic noise at workplaces is characterized by the following, two quantities:

- the equivalent continuous G-weighted sound pressure level normalized to a nominal 8-hour working day, $L_{Geq,8h}$, (or normalized to a working week),
- the equivalent continuous G-weighted sound pressure level during occupation of the workplace (T_e) by the employee, $L_{Geq,Te}$.

The facultative values that form the criterion of annoyance of infrasonic noise are defined in the Standard [17]. This criterion is given in Table 2.

Table 2. Criterion of annoyance of infrasonic noise – admissible values of the equivalent continuous G-weighted sound pressure level (SPL) according to [17].

Quantity	G-weighted SPL, dB(G)
The equivalent continuous G-weighted sound pressure level normalised to a nominal 8-hour working day, $L_{Geq,8h}$, (or normalized to a working week), for all employees	102.0
The equivalent continuous G-weighted sound pressure level during occupation of the workplace designated for conceptual work, $L_{Geq,Te}$	86.0

2.4. Assessment of occupational risk related to noise exposure

Occupational risk is defined as a combination of the likelihood of an occurrence of a hazardous event and the severity of injury or damage to the health of people caused by the event. According to [22] occupational risk assessment is the process by which work-related hazards are identified and the risks resulting from their presence are then estimated and evaluated. The Polish Standard PN-N-18002:2011 [23] recommends a three point risk-level estimator. In accordance with the principles given in the Standard [23], occupational risk related to noise exposure can be estimated on the value of multiplicity of MAI values for noise, k.

The maximum value of the calculated multiplicities k is the basis for the assessment of occupational risk related to noise exposure accordance with the principle given in Table 3.

Table 3. Principle of the assessment of occupational risk related to noise exposure.

Multiplicity of MAI value or of the criterion of annoyance of infrasonic noise, k	Risk estimation
$k < 0.5$	Low – acceptable
$0.5 \leq k \leq 1$	Medium – acceptable
$k > 1$	High – unacceptable

3. Test results

Environmental tests, i.e. noise and infrasonic noise measurements, were carried out on the following ten inland waterway vessels: three pushers, three tourist vessels, two police boats and two rescue boats of the Voluntary Water Rescue Service (WOPR).

As already stated, measurements on the tested vessels were carried out in terms of the impact of noise and infrasonic noise on the health of the workers staying on them. Therefore, the aim of the study was to determine occupational exposure to noise and infrasonic noise based on measurements of the following values:

- the equivalent A-weighted sound pressure level on the basis of which the A-weighted noise exposure level normalized to an 8 hour working day was determined,
- the A-weighted maximum sound pressure level,
- the C-weighted peak sound pressure level.

In addition, noise spectra ranging from 0.8 Hz to 20000 Hz and he equivalent continuous G-weighted sound pressure levels were recorded.

The measurements were made in real conditions, representing the typical operation of the tested inland waterway vessels. On each of the tested vessels, measurements were made at the helmsman's station (in the control cabin) and, depending on the type of vessel tested, at the workstations located at: engine rooms (in the case of pushers), social rooms (in the case of pushers), decks (in the case of pushers) and bars (in the case of tourist vessels). At each workstation, 3 noise measurements were made covering typical activities performed at these workstations. Each of the measurements lasted at least 5 minutes. The measuring microphone was placed at a distance of 0.1 m to 0.4 m from the entrance to the external ear canal, on the side of the ear more exposed to noise.

The results of noise and infrasonic noise measurements at workstations on pushers, tourist vessels and police and rescue boats are shown in Tables 4 - 6 respectively. The time given in the tables for each activity, $T_{e,m}$, was determined on the basis of an interview with employees.

Table 7 contains the determined values of parameters characterizing noise at workplaces at the tested objects in accordance with the Regulation [21], i.e. the A-weighted noise exposure level normalized to an 8 hour working day (daily noise exposure level), $L_{AEx,8h}$, the A-weighted maximum sound pressure level, L_{Amax}, and the C-weighted peak sound pressure level, L_{Cpeak}. In addition, Table 7 contains calculated multiples of MAI values, k.

Table 8, in turn, contains the determined values of infrasonic noise at workstations on the tested inland waterway vessels.

Table 4. Results of noise and infrasonic noise measurements at workplaces on pushers.

Workplace	Activity	$L_{Aeq,Te,m,i}$ dB(A)	$L_{Amax,m,i}$ dB(A)	$L_{Cpeak,m,i}$ dB(C)	$L_{Geq,Te,m,i}$ dB(G)	$L_{Aeq,Te,m}$ dB(A)	$L_{Geq,Te,m}$ dB(G)	$T_{e,m}$ min
Helmsman of large pusher No 1	Steering (control cabin)	68.5	69.4	98.4	87.4	68.5	88.8	300
		68.5	68.9	97.7	89.4			
		68.6	69.0	98.7	89.4			
	Work on board (open deck)	71.2	73.2	98.5	86.7	71.8	84.7	115
		71.8	72.5	97.7	82.3			
		72.2	74.4	95,1	84.1			
	Work in engine room (engine room)	101.4	102.8	121.1	87.7	101.2	88.0	5
		101.1	104.5	120.2	87.9			
		101.1	101.5	120.3	88.5			
	Rest (social room)	70.4	74.5	97.5	85.1	70.0	84.5	60
		69.7	70.6	97.0	84.6			
		69.8	70.5	98.1	83.7			
Helmsman of large pusher No 2	Steering (control cabin)	71.4	73.2	99.3	98.5	71.2	98.2	300
		71.1	72.0	100.5	98.0			
		71.1	74.5	100.5	98.0			
	Work on board (open deck)	66.2	70.4	97.1	82.9	66.3	82.3	115
		65.0	67.0	94.9	80.8			
		67.3	68.3	97.4	83.0			
	Work in engine room (engine room)	101.8	102.3	118.1	80.9	102.0	80.2	5
		101.9	103.8	117.4	80.0			
		102.2	102.5	118.8	79.7			
	Rest (social room)	77.1	77.8	102.1	96.4	77.3	95.8	60
		77.4	77.7	102.1	95.5			
		77.5	78.4	101.7	95.3			
Helmsman of small pusher	Steering (control cabin)	74.2	74.8	103.1	103.9	74.6	104.7	330
		75.0	80.1	104.9	105.4			
		74.6	75.5	104.8	104.6			
	Work on board (open deck)	82.3	82.9	101,8	77.3	81.9	84.7	150
		82.6	82.9	100.9	85.6			
		80.7	82.0	105.7	86.8			

The meaning of the symbols in the table:
$L_{Aeq,Te,m,i}$ - the A-weighted equivalent continuous sound pressure level of the i^{th} measurement during the m^{th} range of noise exposure,
$L_{Amax,m,i}$ - the A-weighted maximum sound pressure level of the i^{th} measurement during the m^{th} range of noise exposure,
$L_{Cpeak,m,i}$ - the C-weighted peak sound pressure level of the i^{th} measurement during the m^{th} range of noise exposure,
$L_{Geq,Te,m,i}$ - the equivalent continuous G-weighted sound pressure level of the i^{th} measurement during the m^{th} range of noise exposure,
$L_{Aeq,Te,m}$ - the A-weighted equivalent continuous sound pressure level during the m^{th} range of noise exposure,
$L_{Geq,Te,m}$ - the equivalent continuous G-weighted sound pressure level during the m^{th} range of noise exposure,
$T_{e,m}$ - duration of the m^{th} range of noise exposure.

Table 5. Results of noise and infrasonic noise measurements at workplaces on tourist vessels.

Workplace	Activity	$L_{Aeq,Te,m,i}$ dB(A)	$L_{Amax,m,i}$ dB(A)	$L_{Cpeak,m,i}$ dB(C)	$L_{Geq,Te,m,i}$ dB(G)	$L_{Aeq,Te,m}$ dB(A)	$L_{Geq,Te,m}$ dB(G)	$T_{e,m}$ min
Helmsman of tourist vessel No 1	Steering (control cabin)	60.6	65.9	94.7	83.3	60.6	81.8	465
		60.7	61.1	93.8	81.1			
		60.6	61.1	94.0	80.5			
Helmsman of tourist vessel No 2	Steering (control cabin)	60.5	61.3	94.2	90.2	60.5	90.0	465
		61.1	61.7	94.0	90.2			
		59.9	62.2	93.6	89.5			
Bartender of tourist vessel No 2	Bartending	64.4	65.6	96.7	92.5	64.7	92.5	465
		65.5	66.8	100.0	93.4			
		64.2	65.6	98.5	91.5			
Helmsman of tourist vessel No 3	Steering (control cabin)	59.9	61.0	91.3	96.1	59.6	96.1	360
		59.2	61.1	91.7	96.1			
		59,6	61.3	91.8	96.0			

Table 6. Results of noise and infrasonic noise measurements at workplaces on police boats and rescue boats.

Workplace	Activity	$L_{Aeq,Te,m,i}$ dB	$L_{Amax,m,i}$ dB	$L_{Cpeak,m,i}$ dB	$L_{Geq,Te,m,i}$ dB	$L_{Aeq,Te,m}$ dB	$L_{Geq,Te,m}$ dB	$T_{e,m}$ min
Helmsman of police boat No 1	Steering (control cabin with open door)	88.3 88.5 86.4	89.8 90.2 89.8	110.0 108.5 111.5	100.0 98.7 101.8	87.8	100.4	240
Helmsman of police boat No 1	Steering (control cabin with closed door)	77.3 78.7 76.3	78.4 79.5 77.1	110.9 112.7 99.6	105.7 106.1 106.5	77.5	106.1	240
Helmsman of police boat No 2	Steering (control cabin with open door)	86.4 85.6 86.6	88.3 86.5 89.2	108.1 106.5 107.2	97.9 97.5 97.4	86.2	97.6	240
Helmsman of police boat No 2	Steering (control cabin with closed door)	77.8 76.6 77.2	78.5 77.1 77.7	103.3 105.2 108.3	106.9 107.8 108.6	77.2	107.8	240
Helmsman of rescue boat No 1	Steering (control cabin)	68.2 67.6 68.1	72.5 71.7 73.1	90.9 90.5 91.0	99.9 99.1 98.6	68.0	99.2	240
Helmsman of rescue boat No 2	Steering (control cabin)	79.3 80.9 78.9	82.4 83.5 85.2	112.7 115.5 114.9	101.1 107.1 104.2	79.8	104.8	240

Table 7. Determined values of parameters characterizing noise at workplaces on tested inland waterway vessels.

Workplace	$L_{EX,8h}$ dB(A)	L_{Amax} dB(A)	L_{Cpeak} dB(C)	Multiplicity of MAI value
Helmsman of large pusher No 1	81.5	104.5	121.1	0.45
Helmsman of large pusher No 2	82.4	103.8	118.8	0.55
Helmsman of small pusher	78.4	82.9	105.7	0.22
Helmsman of tourist vessel No 1	60.5	65.9	94.7	0.0097
Helmsman of tourist vessel No 2	60.44	62.2	94.2	0.0091
Bartender of tourist vessel No 2	64.6	66.9	100.0	0.0178
Helmsman of tourist vessel No 3	58.3	61.3	91.8	0.01
Helmsman of police boat No 1 (control cabin with open door)	84.8	90.2	111.5	0.95
Helmsman of police boat No 1 (control cabin with closed door)	74.5	79.5	112.7	0.09
Helmsman of police boat No 2 (control cabin with open door)	83.2	89.2	108.1	0.66
Helmsman of police boat No 2 (control cabin with closed door)	74.2	78.5	108.3	0.08
Helmsman of rescue boat No 1	65.0	73.1	91.0	0.01
Helmsman of rescue boat No 2	76.8	85.2	115.5	0.15

Table 8. Determined values of the equivalent continuous G-weighted sound pressure level normalized to a nominal 8-hour working day, $L_{Geq,8h}$.

Workplace	$L_{Geq,8h}$ dB(G)
Helmsman of large pusher No 1	87.7
Helmsman of large pusher No 2	96.6
Helmsman of small pusher	103.1
Helmsman of tourist vessel No 1	81.7
Helmsman of tourist vessel No 2	89.9
Bartender of tourist vessel No 2	92.4
Helmsman of tourist vessel No 3	94.8
Helmsman of police boat No 1 (control cabin with open door)	97.3
Helmsman of police boat No 1 (control cabin with closed door)	103.1
Helmsman of police boat No 2 (control cabin with open door)	94.6
Helmsman of police boat No 2 (control cabin with closed door)	104.8
Helmsman of rescue boat No 1	96.2
Helmsman of rescue boat No 2	101.8

4. Discussion

According to literature data, noise and vibrations dominate in the group of negative factors of the working environment on vessels. There is little literature data on noise levels on inland waterway vessels. Picu et al. [8] find that noise levels on pushers and shoulders on the Danube river reach up to 92.0 dB. In turn, Krystosik-Gromadzińska [12] reports that the noise level in some places on pushers reaches 100.0 dB. Turan et al. [9] report that on tankers the A-weighted sound pressure levels, depending on the place on the tanker, range from 55.5 dB(A) (in cabins) to 96.8 dB(A) in engine rooms. As a result, daily noise exposure levels often exceed 90.0 dB(A) (e.g. 96.0 dB(A) in the case of a deck cadet). On the other hand, research carried out on military ships (Schaal et al. [14, 16]) indicates that the daily noise exposure levels are up to 102.0 dB(A).

The measured noise levels at workstations on the tested inland waterway vessels are close to the above quoted results. On the basis of the results obtained from the noise measurements carried out, it can be concluded that:

– the highest noise levels were recorded in the machinery spaces on pushers. The equivalent A-weighted sound pressure levels in these spaces were between 101.1 and 102.2 dB(A),
– the highest noise levels at the helmsman's workplaces in the control cabins were recorded on police boats. The equivalent A-weighted sound pressure levels at these workplaces were between 76.3 and 88.5 dB(A),
– the lowest noise levels at the helmsman's workplaces in the control cabins were recorded on inland waterway tourist vessels. The equivalent A-weighted sound pressure levels at these workplaces were between 59.2 and 61.1 dB(A),
– the measured equivalent A-weighted sound pressure levels at the helmsman's worksplaces in the pusher control cabins were between 68.5 and 75.0 dB(A),
– the measured equivalent A-weighted sound pressure levels on open decks on pushers were between 65.0 and 82.6 dB(A),
– the values of the equivalent A-weighted sound pressure levels in the pusher social rooms were in the range of 69.7 to 77.5 dB(A).

On the other hand, on the basis of the noise exposure assessments carried out on the tested inland waterway vessels, it can be concluded that:

– the determined values of the A-weighted noise exposure level normalized to an 8 hour working day ranged from 58.3 dB(A) (at the helmsman position of the tourist vessel) to 84.8 dB(A) (at the helmsman position of the police boat) and did not exceed MAI value specified in the Regulation of the Minister of Family, Labour and Social Policy [21], which is 85 dB(A),
– the measured values of the other noise-characterising values at the tested workplaces i.e. the A-weighted maximum sound pressure levels (ranged from 61.3 to 104.5 dB(A)) and the C-weighted peak sound pressure levels (ranged from 91.1 to 121.1 dB(C)), did not exceed MAI values laid specified in the Regulation [21], which are 115.0 dB(A) and 135.0 dB(C), respectively.

The assessment of occupational risks related to exposure to noise carried out in accordance with PN-N-18002:2011 [23] showed that in the case of 4 workplaces (helmsmen of large pushers and helmsmen of police boats), this risk was medium (acceptable). On the other hand, all other examined workplaces were characterised by low occupational risk due to exposure to noise.

The results of the infrasonic noise measurements (i.e. the measured equivalent continuous G-weighted sound pressure levels normalised to a nominal 8-hour working day) on the tested vessels showed that the limit value of 102.0 dB(G) (criterion of infrasonic noise nuisance) was exceeded at three workplaces (helmsman of small pushers and helmsmen of police boats). At these workplaces, the equivalent continuous G-weighted sound pressure levels normalised to a nominal 8-hour working day were in the range between 103.1 and 104.8 dB(G). At the other workplaces, the values of the equivalent continuous G-weighted sound pressure levels normalised to a nominal 8-hour working day ranged from 81.7 to 101.8 dB(G).

5. Conclusions

Working conditions on inland waterway vessels are an important issue for both an employer and employee. Correct identification of hazards and their impact on employed persons creates a basis for undertaking preventive actions and maintaining an adequate policy in order to improve occupational safety and health (OSH).

In the group of negative factors of the working environment on inland waterway vessels, noise predominates, however, the A-weighted noise exposure levels normalized to an 8 hour working day, the A-weighted maximum sound pressure levels and the C-weighted peak sound pressure levels at the tested workstations on vessels did not exceed the limit values set out in the Regulation [21].

The highest noise levels on the tested vessels occurred in engine rooms, where the equivalent A-weighted sound pressure levels measured in those spaces were greater than 100 dB(A). Therefore, in these parts of vessels, the crew should wear appropriately selected hearing protectors.

Acknowledgments

This task was completed on the basis of results of research carried out within the scope of the 6th stage of the National Programme “Governmental Programme for Improvement of Safety and Working Conditions” funded by the resources of the National Centre for Research and Development.
Task No.: III.PN.13
Entitled: “Research and assessment of environmental hazards and nuisances affecting work safety and quality of life on selected inland waterway, port and coastal vessels”
The Central Institute for Labour Protection – National Research Institute is the Programme’s main co-ordinator.

Additional information

The authors declare: no competing financial interests and that all material taken from other sources (including their own published works) is clearly cited and that appropriate permits are obtained.

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