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An Investigation into the Health Risks Associated with the Noise and Vibrations on Board of a Boat—A Case Study on the Danube River

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Abstract: This paper studies the noise and vibrations transmitted to the crew of a pusher with eight barges sailing upstream the Danube River, between Cernavoda and Drobeta, with a staff consisting of a captain, one coxswain, one mechanic and three sailors. The research was conducted over a one-week period in August 2018. The navigation time was 24/24 h and the seafarers' schedule was 4/8. Determinations were made on three different workers: Coxswain, mechanic and sailor. The meteorological parameters and the Danube river levels, the sound level and the transmitted vibrations, as well as the body temperature and blood pressure of the subjects were measured. The periods of activity and sleep were analyzed by means of an actigraph. Our research findings indicate that people worked overtime, slept less than necessary and, generally, did not observe the official program. The noise ($L_{EP,d}$ = 92 dB) and vibration levels (a total exposure A(8) = 4.1 m/s^2) also contributed to the sleep disorder. Such effects were accompanied by increased body temperature and blood pressure. Synthesizing, it can be concluded that: The peak (acrophase) of the work capacity was from 9:00 to 11:00 and from 17:00 to 19:00, which represent the maximum efficiency periods. More specifically, the highest mental performances were recorded in the morning, while the maximum physical ones were to be seen in the afternoon. The minimum efficiency period was from 13:00 to 15:00. Decreases in the work capacity were identified at 23:00 (reasonably low level) and 3:00 (extremely low level).

Keywords: noise; vibrations; shift work; river ships; Danube

1. Introduction

Diseases induced by noise and vibrations from the occupational environment are extremely dangerous, they appear after many years of exposure [1,2]. Occupational noise is a significant cause of hearing loss after many work years [3]. There is also evidence of ischemic heart diseases [4]. Van Kempen et al. (2002) [5] found that exists an association between noise exposure blood pressure and heart diseases. Sulkowski et al. (2004) [6] analyzed that there are over 35 million people in Europe who work in environments with sound levels higher than 85 dB. In this way, the deafness of these workers will appear in 10–20 years.

As well, diseases induced by the occupational environment vibrations are very harmful and frequent. These are vascular, such as: Primary Raynaud's phenomenon, secondary Raynaud's phenomenon. Such diseases are caused by: Connective tissue diseases, occlusive vascular disease, compression of proximal vessels, trauma, neurogenic disorders and blood abnormalities. Other diseases are peripheral vascular disorders (arteriosclerosis obliterans, thromboangiitis obliterans, acquired arteriovenous fistulas and erythromelalgia); at the same time, vascular disorders secondary to malformations that can be observed are: Injuries, fractures or surgery in the hand, arm or neck. Neurological diseases can also occur, such as: Peripheral nerve entrapment, peripheral neuropathy, disorders of the central nervous system, neurological disorders secondary to malformations, injuries, fractures or surgery in the hand, arm or neck and musculoskeletal diseases. Among these, the most frequent are: Severe tendinitis or tenosynovitis in the hand–wrist, elbow or shoulder, severe unspecific cervicobrachial disorders, severe Dupuytren's contracture, severe degenerative bone and joints disorders in the upper limbs and the neck, severe deformities of the bone and joints of the upper limbs secondary to malformations, injuries, fractures or surgery, severe myopathies [7,8].

In terms of people's work at sea or ocean, sailors face higher health risks than individuals on land [9–11]. Besides the stressors that have been remembered so far (noise and vibrations), the shift work also takes place. In other words, the sailors' sleep is deeply disturbed, so their physical and mental health.

The biological rhythm of living organisms is the way these organisms adapt to solar and lunar rhythms [12]. The repetition of a phenomenon in the biological system over a more or less regular time frame can be called a biological rhythm. These rhythms reflect any reaction to a periodical action occurring outside the system (exogenous rhythm), or within the system (endogenous rhythm). The number of cycles in a unit of time represents the frequency of the rhythms. By amplitude, we mean the magnitude of oscillations between two limit values of a rhythmically changing value. The notion "phase" can be assigned to any highlighted part of the cycle. The maximum point is the maximum size of the index under review.

In each cycle, the time period when the process is more active is called acrophase [13]. When the process is less active, the cycle is in the bathyphase or in the minimum phase. The special moment of highest activity is the peak or the maximum; the lowest point is the nadir. The first people who studied the human rhythm were the Chinese (about 1200 BC) in "Chinese medical texts": Noon and Midnight Manual and the Mnemonic Rhyme to Aid in the Selection of Acu-points According to the Diurnal Cycle, the Day of the Month and the Season of the Year [14,15].

During a day (24 h), the human rhythm can be divided into three cycles:

- Diurnal (describing bodies active during the day),
- Nocturnal (describing bodies active at night),
- Twilight (describing active organisms at dusk) [16].

Many researchers [17–25] have studied the assessment and treatment of shift work disorder (SWD) and jet lag disorder (JLD). The physiological assessment was undertaken by measuring the body temperature and determining the moment of melatonin secretion. For behavioral assessment, sleep logs, actigraphy and questionnaires were used. The treatment involved planning the sleep program and prescription of hypnotic drugs and stimulants (symptomatic treatment) [26].

The method that monitors activity and rest cycles in humans is called actigraphy. This is used more and more in sleep research and in the clinical care of patients with sleep disorders [27].

However, only a few have analyzed the negative effects of these disturbances in the case of vessels sailing on rivers. We note in this regard the works of Picu and Rusu in recent years that have studied the working conditions of the Romanian sailors on the Danube [28–34]. We have highlighted the need to develop prescriptions on the limits of vibrations and noise levels applicable to inland waterway vessels (like those for seagoing navigation).

From this perspective, in the present paper we analyze the environmental noise and the vibrations transmitted by the ship equipment on the crew members and how these factors, as well as shift work, affect the sleep of the subjects.

2. Materials and Methods

The study was done on a pusher with eight barges sailing upstream the Danube River, between Cernavodă and Drobeta, with a staff made up of a captain, one coxswain, one mechanic and three sailors. The towns crossed by the ship on each day of travel are: Cernavoda, Calarasi, Giurgiu, Turnu Magurele, Calafat and Drobeta (Figure 1). The research was carried out in August 2018 and lasted one week. The navigation time was 24/24 h and the seafarers' schedule was 4/8. Determinations were made on three people: The coxswain, the mechanic and one sailor. This is because the crew members were asked if they agreed to the experiment and of the six people, only three agreed.

Figure 1. The towns crossed by the ship on each day of travel.

During the navigation time, the weather was warm, without any spells of wind or rain.

(a) The Danube water levels. The information concerning the Danube water levels was taken from the website https://www.edelta.ro/cote-dunare-365-de-zile? start = 10 [35] (see Figure 2). The Danube water levels are measured against a specific reference level for each locality. Level 0 is considered to be at Sulina (compared to The Black Sea level) while Drobeta is at 6.5 m. Figure 2 shows that during the first four days of the trip (Cernavoda-Turnu Magurele), the water levels are very low due to the drought along the Danube, so sailing is more dangerous because it is possible for the ship to reach the bottom of the Danube and to get stuck. In the last two days, the levels are elevated, surpassing the attention threshold and reaching at Drobeta the level of 736 mm.

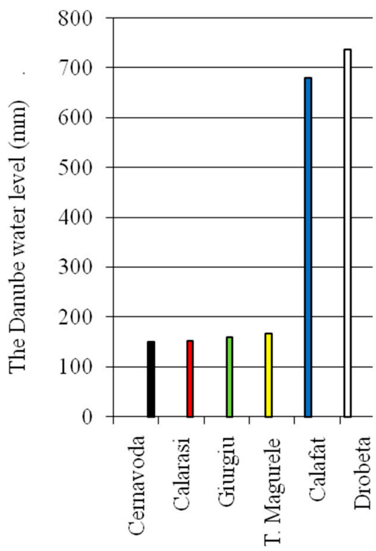

Figure 2. The Danube water levels in the cities that have been crossed during the period under discussion.

(b) Meteorological parameters. The meteorological parameters that can alter the working conditions are: The air temperature (Figure 3), wind speed and direction, amount of rainfall, cloud cover (affecting brightness) and atmospheric pressure. Figure 3 presents the air temperature, because in August this meteorological parameter is the most important. For the rest of the year, other parameters that may reduce the visibility and/or lead to unbalance the ship are also important. It can be seen that during the journey the temperature was high (by day the averages reached 36–37–38 °C, which are extremely disturbing for the sailors).

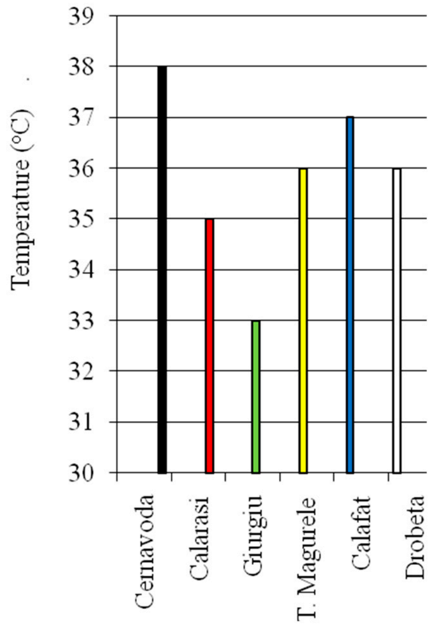

Figure 3. Air temperature in the cities that have been crossed during the period under discussion.

The official work schedule of the three workers is shown in Figure 4.

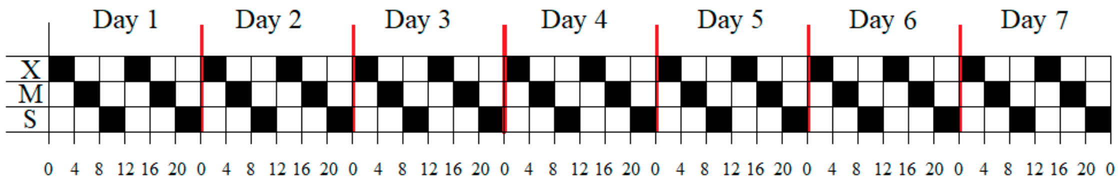

Figure 4. Official working hours X—Coxswain, M—Mechanic, S—Sailor, (■)—Work and (□)—Rest/Sleep.

(c) The characteristics of the three subjects (coxswain, mechanic, and sailor) are shown in Table 1.

Table 1. Characteristics of the subjects.

Subject	Age (Years)	Weight (kg)	Height (m)	BMI		Smoker	Drinker *	Work Experience (Years)	Cardiovascular Diseases in the Family	Declared Personal Problems
Coxswain (X)	57	95	1.80	29.3	Ov	yes	yes	36	yes	yes
Mechanic (M)	48	103	1.78	32.5	Ob	no	no	22	yes	no
Sailor (S)	52	92	1.84	27.2	Ov	yes	yes	35	no	yes

Ov—overweight; Ob—obesity; * more than one glass of wine per day (when not on the ship).

It can be seen that all the subjects were of fairly advanced age and, therefore, very experienced in the seaman's profession. Two of the three subjects were smokers and drinkers. Two also have cardiovascular diseases in the family and two have reported personal problems. All subjects were overweight, which leads to various health problems.

All three subjects declared that they were in good health and agreed to the measurements. These subjects were measured for their body temperatures three times/day: At 4:00, at 12:00 and at 23:00. Their blood pressure was also measured twice/day, in the morning and in the evening, as follows: Three consecutive measurements before breakfast, at intervals of several minutes between them and three measurements in the evening, between dinner and bedtime, also separated by a few minutes' intervals.

(d) The level of noise in different parts of the ship was measured with a BlueSolo 01 dB sonometer (Figure 5) and the transmitted vibrations to the humans were measured with a 01 dB Maestro vibrometer (Figure 6). The data was processed with the software dBTrait 32° and dBBati. dBTrait is a high-performance software program for post-processing acoustic, vibrations and meteorological data gathered using the 01 dB data collection systems.

Figure 5. The sonometer BlueSolo 01 dB.

Figure 6. The Vibrometer Maestro 01 dB.

Dose is a measure of noise exposure and it is directly related to $L_{EP,d}$ (or L_{ex}). In the UK Dose is also described as the HSE 'Points' system. $L_{EP,d}$ (formerly L_{EX}) is one of the most widely used measures of noise exposure, and it depends not only on the sound pressure level but also on the duration of the noise exposure. It is the measure of noise exposure used in the 'Noise at Work Regulations 2005' (https://www.castlegroup.co.uk/guidance/noise-at-work-assessments/dose/). It is best described with the following statement: 100% Dose (or 100 points) = 85 dBA for 8 h. This is known as the 'Criterion' level. Figure 7 gives examples of how DOSE (or points) is related to the exposure time and L_{ex} ($L_{ep,d}$; assuming 100% Dose (or 100 points) = 85 dBA for 8 h.) The equation dose (D) versus time (t) is given by: D = 12 t + 4.

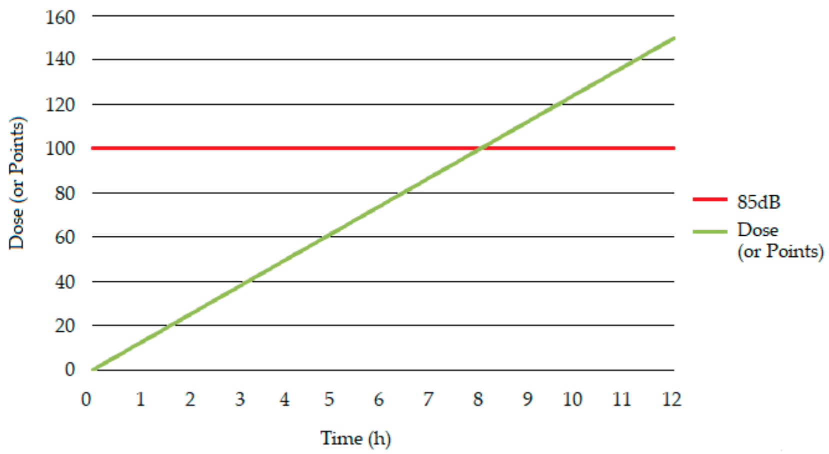

Figure 7. Relationship between %Dose (or points) and Time (Leq of 85 dBA).

For WBV (whole body vibration), we have:

(a) Partial vibration dose value (VDV): if a person is exposed to more than one source of vibrations (perhaps because they use two or more different machines or perform different activities during the day) then a partial VDV is calculated from the magnitude and duration for each axis and for each exposure. The partial VDVs are combined to give the overall daily VDV for that person, for each axis:

$$VDV_{exp,x,y} = 1.4 \cdot VDV_{x,y} \left(\frac{T_{exp}}{T_{meas}}\right)^{1/4} \text{ and } VDV_{exp,z} = VDV_{z} \left(\frac{T_{exp}}{T_{meas}}\right)^{1/4}, \quad (1)$$

where T_{meas} is the measurement period and T_{exp} is the daily duration of exposure to the vibration.

(b) Partial exposure A(8): If a person is exposed to more than one source of vibration (perhaps because they use two or more different machines or perform different activities during the day) then a partial vibration exposure is calculated from the magnitude and duration for each axis and for each exposure:

$$A_{x,y}(8) = 1.4 \cdot a_{x,y} \sqrt{\frac{T_{exp}}{T_0}} \text{ and } A_z(8) = a_z \sqrt{\frac{T_{exp}}{T_0}}, \quad (2)$$

where T_0 is the reference duration of 8 h.

(c) The time period needed to reach the value of the exposure, which triggers the action EAV (exposure action value) and the exposure limit value (ELV):

$$T_{EAV,A(8)} = 8 \left(\frac{0.5}{A_w}\right)^2 \text{ and } T_{ELV,A(8)} = 8 \left(\frac{1.15}{A_w}\right)^2, \quad (3)$$

where A_w is root mean square average vibration.

(d) Estimated vibration dose value (eVDV):

$$eVDV = k \cdot A_w(rms) \cdot t^{0.25}, \quad (4)$$

where k is nominally 1.4 for crest factors below 6 and t is the total cumulative time (in seconds) of the vibration events(s) or period(s) of vibration [36].

(e) Analysis of periods of activity and sleep. This analysis was undertaken through a non-invasive method of monitoring work and rest periods for at least one week, called actigraphy. The clock-shaped actigraph (Figure 8) is worn on the wrist of one of the hands. The motion to which the actigraph is exposed during hand movements, as well as the exposure to light, are constantly recorded. The actigraph information is downloaded using software, in the form of graphical representations. This device is removed from the wrist only when showering, and the interval is clearly noted down. The actigraph used is the Bluetooth® Smart ActiGraph GT9X. It includes a gyroscope, a magnetometer and a secondary accelerometer to provide valuable information about motion, rotation and body position [37].

Figure 8. Actigraph GT9X.

3. Results and Discussions

This study examined the noise and vibration exposure of each subject: One coxswain, one mechanic and one sailor. It also analyzed the sleep of the three subjects. Each of the three subjects is no longer young and has great work experience (see Table 1). This has led to chronic fatigue, as well as to various health problems, amplified by shift work, under noise and vibrations.

These people reported on the 3rd day of the trip that they had sleeping disorders in qualitative and quantitative terms and complained about drowsiness, nervousness, poor concentration, headaches and digestive disorders, which seemed to be related to, or worsen pre-existing chronic diseases: Cardiovascular, gastrointestinal, psychic, etc. The established work schedule of the three workers has been presented in Figure 4. In reality, things are different; people work overtime and do not observe the required number of sleeping hours (Figure 9).

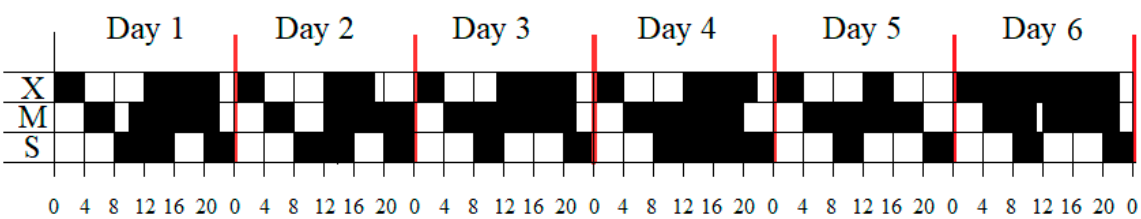

Figure 9. The real program of the subjects during the studied period, X—Coxswain, M—Mechanic, S—Sailor, ■—Work and □—Rest/Sleep.

When drawing a parallel between theoretical and realistic schedules (Figure 4 versus Figure 9), a large discrepancy was found. For example, the coxswain worked, on average, 14 h/day, the mechanic 16 h/day and the sailor 12 h/day. These people disregard the established work schedule for many reasons: Insufficient staff, poor rest conditions (noise and vibrations). In order to study these factors, the following determinations were made:

(1) Measuring body temperatures of the subjects

Normal body temperature is one of the main indicators of normal body functioning and a sign of general health. Internally, all body functions require maintaining an appropriate temperature value. The body temperature is changing throughout the day. It has the smallest values between 4:00 and 6:00 in the morning and the highest values between 18:00 and 20:00. The normal body temperature is 37 °C. However, a 36.1 °C temperature recorded in the morning, or 37.2 °C recorded in the evening, is also normal. That is why the body temperature of our subjects was measured three times a day, as shown in Figure 10.

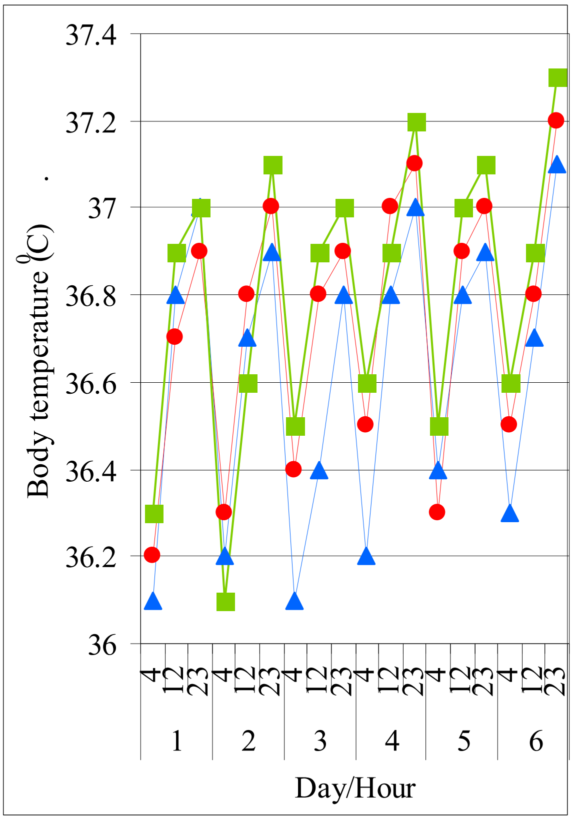

Figure 10. Body temperature variation at different times of the day (hour 4:00, 12:00 and 23:00) (▲)—Coxswain; (●)—Mechanic and (■)—Sailor.

(2) Measuring the blood pressure of the subjects

In today's society, blood pressure is and will remain an important health problem while being at the same time a cardiovascular disease and a risk factor for other cardiovascular diseases (aggravating and complicating their development when present). Normal blood pressure levels depend on several factors (age, gender, metabolic parameters of the body, kidney function, liver function, etc.), but modern protocols of the American Heart Association and the European Society of Cardiology formally establish the following algorithm:

- Normal values are those that do not exceed 120 systolic BP and 75 diastolic BP;
- Any patient with values between 120–140 systolic BP and 75–90 diastolic BP is considered pre-hypertensive (it is statistically proven that in this group of patients the vast majority will be declared hypertensive, in a shorter or longer time frame);
- Values over 140 BP systolic and 90 diastolic BP are considered to belong in the hypertensive area, with its stages.

All these protocols stipulate that the presence of hypertension (HTN) is an additional risk factor for other cardiovascular diseases. Figure 11 shows the blood pressure values in the morning and evening (systolic and diastolic) for the three subjects.

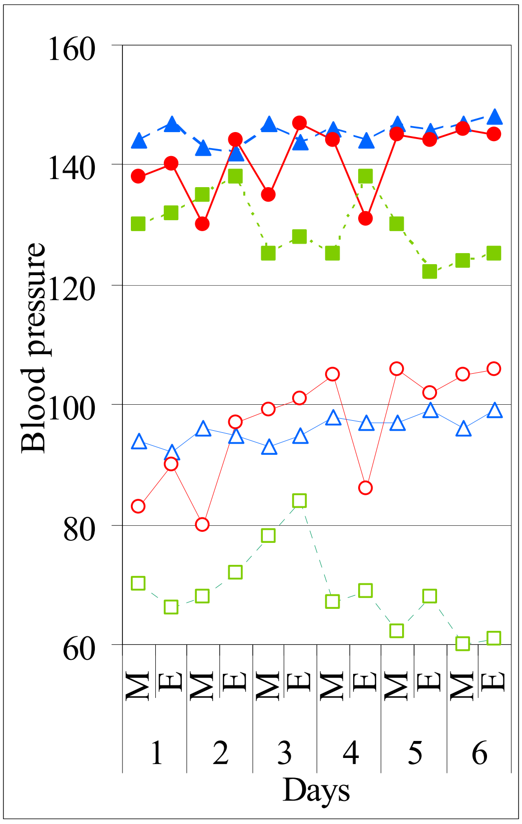

Figure 11. Blood pressure variation in the morning (M) and evening (E). (▲)—Coxswain systolic; (∆)—Coxswain diastolic; (●)—Mechanic systolic; (o)—Mechanic diastolic; (■)—Sailor systolic and (□)—Sailor diastolic.

Figure 10 shows that there were no large temperature differences between the three subjects. However, the highest temperature was found in the sailor, followed by mechanic and coxswain. The situation was the inverse in the case of blood pressure (Figure 11). An explanation could be given by the fact that the sailor had more physical labor than coxswain.

(3) Sound level measurement in the relaxation room

The calculation was made using the Exposure calculator and ready-reckoners calculator: http://www.hse.gov.uk/noise/calculator.htm [38] (Table 2).

Table 2. Calculation of noise-specific parameters.

HSE Health & Safety Executive	Noise Level (L_{Aeq} dB)	Exposure Duration (Hours)	Exposure Points (Job/Task)	Exposure Points Per Hour
Idling with generator engine	92	6	376	70
Ship starts from the shore	87	0.25	5	7
Running	78	17.25	43	More work shifts
Mooring maneuver	94	0.5	50	10
Total duration	24			
Daily noise exposure ($L_{EP,d}$)	92 dB		474 points	100 points/8h

The lower exposure action value (an $L_{EP,d}$ of 80 dB) was represented by 32 exposure points, the upper exposure action value ($L_{EP,d}$ of 85 dB) by 100 points.

L_{Aeq} (in dB) was entered and the daily exposure duration (in hours) was selected for four tasks performed by a person:

- Idling with generator engine—6 h,
- The ship starts from the shore—15 min,
- The ship is running—17 h 15 min,
- Mooring maneuver—30 min.

Calculations show results in accordance with the Control of Noise at Work Regulations 2005, Schedule 1 Part 1, a document issued following the adoption by the UK of Directive 2003/10/EC of the European Parliament and of the Council. 100 points correspond to the maximum limit, where $L_{EP,\,d}$ = 85 dB and 32 points represent the minimum limit, where $L_{EP,\,d}$ = 80 dB [39]. Table 2 shows that the rule given by Directive 2003/10/EC (80 dB/100 points for 8 h work) was far exceeded.

(4) Measuring the vibrations transmitted to human beings in the relaxation rooms

The measurement of vibrations transmitted to humans in three directions (O_x, O_y and O_z) was followed by the calculation of the total r.m.s. (root mean square) weighted acceleration:

$$A = \sqrt{\left(k_x^2 \cdot a_{wx}^2\right) + \left(k_y^2 \cdot a_{wy}^2\right) + \left(k_z^2 \cdot a_{wz}^2\right)}, \tag{5}$$

where $a_{wx/y/z}$ are accelerations r.m.s. weighted on x/y/z axes, and k, the multiplication factor is k_x = k_y = 1.4 and k_z = 1.

The vibration-specific parameters transmitted to the subjects were calculated online (see Table 3) with the program of the Health and Safety Executive (a UK government agency; http://www.hse.gov.uk/vibration/wbv/calculator.htm) [40].

Table 3. Calculation of the average vibration-specific parameters transmitted to the three subjects during the period under discussion.

HSE Health & Safety Executive	Vibration Magnitude	Exposure Duration		Partial VDV	Partial Exposure
	m/s^2 r.m.s.	Hours	Minutes	m/s$^{1.75}$	m/s^2 A(8)
Idling with generator engine	2.1	6	-	35.641894	1.8186533
The ship starts from the shore	3.2	-	15	24.537971	0.5656854
The ship is running	2.4	17	15	53.041058	3.524202
Mooring maneuver	3.8	-	30	34.652116	0.95

Time to Reach EAV (VDV Option)		Time to Reach EAV (A(8) Option)		Time to Reach ELV (A(8) Option Only)		eVDV	eVDV Version Time to EAV
9.1 m/s$^{1.75}$ VDV		0.5 m/s^2 A(8)		1.15 m/s^2 A(8)			
hours	minutes	hours	minutes	hours	minutes		hours
0	1.529766	0	27.210884	2	23.945578	35.641894	0.0254961
0	0.283728	0	11.71875	1	1.9921875	24.537971	0.0047288
0	0.8967207	0	20.833333	1	50.208333	53.041058	0.0149453
0	0.1426815	0	8.3102493	0	43.961219	34.652116	0.002378
Total VDV = 58.021289 m/s$^{1.75}$				Total exposure A(8) = 4.117 m/s^2			

(5) Changing the periods of activity and sleep

Alternate work schedule (AWS) is a way of organizing the workers' or teams' professional activities, over time. In alternating work shifts, biological overloads occur, linked to the desynchronization of professional activity and inconsistency between some body functions. Overloading the body takes place when switching from one shift to another because efforts are made to change biological rhythms. The professional rhythms correspond to the temporal organization of the professional activity and are represented by normal working day, night shift, alternating shifts (two, three or four teams working 8 h each, or with irregular periodicity). In addition, extra-professional rhythms are imposed by family responsibilities and/or social obligations. Strain and work overload that affect alternate shift workers result from the offset and inversion of the basic sleep-wake rhythm of the body. The physiological mechanism of the variations in different physiological functions during the day is based on the conditioned reflex connections that have formed during the person's life while adapting to the external environmental conditions. According to the "Crew endurance handbook—A Guide to Applying Circadian-Based Watchbills" [41], "crew endurance is the ability to maintain optimal warfighting performance while sustaining physical, psychological, and environmental challenges. If crew members are overly fatigued, mission accomplishment, performance, and safety are in jeopardy. Morale suffers. Chronic sleep debt has long-term physical and mental health consequences and degrades human performance".

International rules mention several types of patterns that are in use:

1. 3/9 Program Rotation and Daily Routine,
2. 6/18 Program Rotation and Daily Routine,
3. 4/8 Program Rotation and Daily Routine (Figure 12).

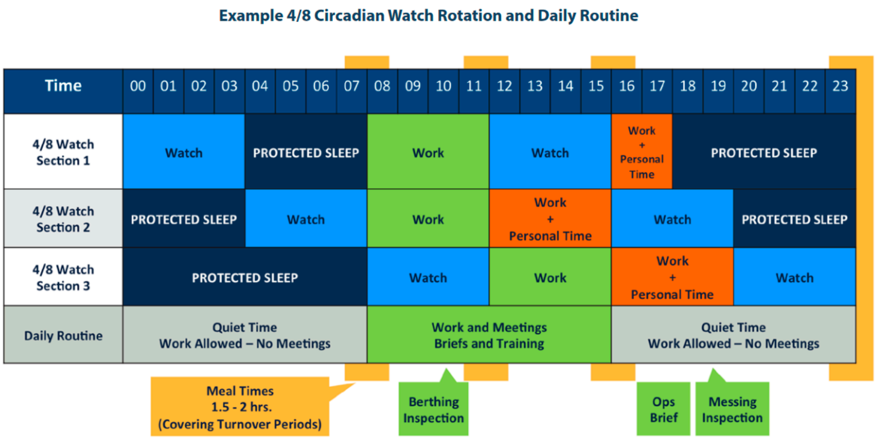

Figure 12. 4/8 Program Watch Rotation and Daily Routine [41].

Figure 13 illustrates a normal work and rest schedule, and Figure 14 shows the real work and sleep schedule (determined by the actigraph) of the three subjects. It can be seen that there were significant differences between the normal and real work schedule of the ship's staff.

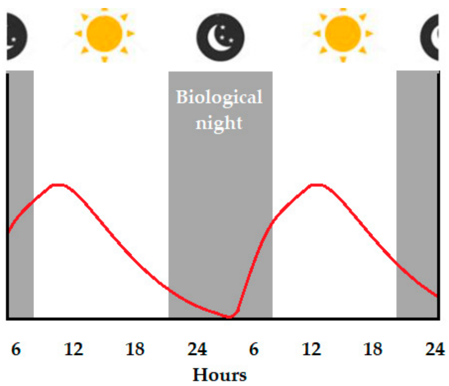

Figure 13. Normal work and rest schedule, (—) = work [42].

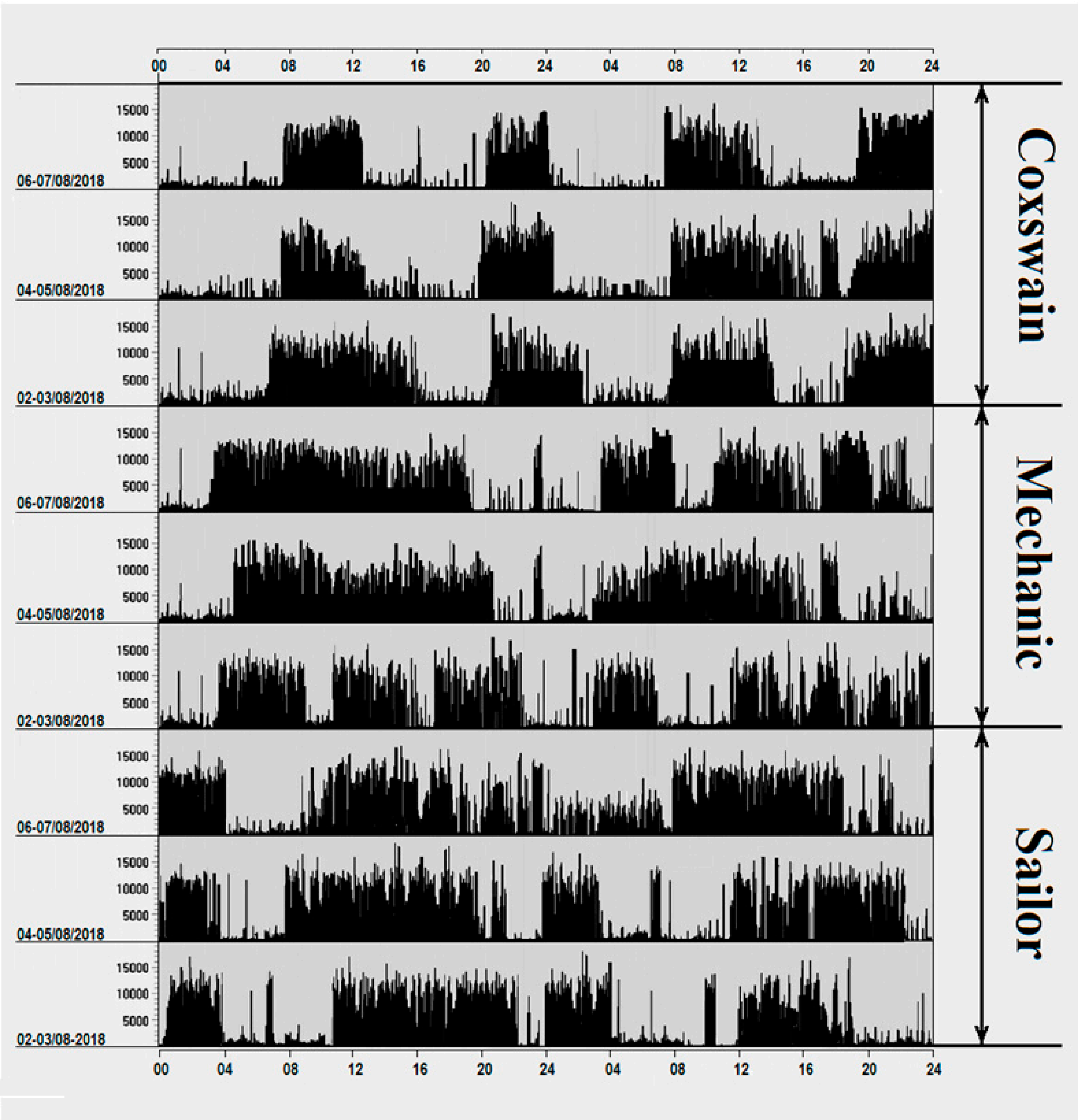

Figure 14. Real work and sleep schedule (determined by the actigraph) of the three subjects for a two-day time interval.

Take the coxswain, for example: In the first two days he worked between 07:00–15:00, and then rested for about 3 h. Afterwards, he worked from 18.00 to 24:30 and rested for the ensuing 5 h during the night. On the 3rd day, he worked all day, and then during the third night, he rested for almost 2 h. On the 4th day, he worked roughly from 08:00–24:00. A 6 h period of rest followed. In the remaining few days, the working period decreased to 8 h and even though he did not actually sleep, the period of rest was longer. Given that this subject was 57 years old and was overweight, he smokes, drinks and had cardiovascular diseases in the family, this work system was extremely demanding.

Regarding the work and sleep schedule of the mechanic, he was totally confused in the first four days when he worked, on average, 20 h/day. In the remaining two days, the mechanic worked for 6 h with a 2 h break. This is extremely demanding and, naturally, a longer period of rest will be needed at some point. The mechanic was obese and also had cardiovascular diseases in the family. This subject was also at risk and needed regular rest periods.

As for the sailor, this subject worked up to 16 h/day; he had short periods of rest and not always during the night when his sleep was often interrupted. He was 52 years old, overweight, a smoker and a drinker, afflicted by personal problems, which, all, greatly influence the quality of work and rest. The sailor needed much more rest in order to carry out his tasks without any work accidents. The impact of this imbalance between work and rest was also visible in high body temperature and blood pressure.

4. Conclusions

From the sound level analysis, it was concluded that the daily noise exposure was 92 dB/474 points, compared to 80 dB (lower exposure action value)—85 dB (upper exposure action value)/or 100 points, as indicated by the Directive 2003/10/EC.

From the analysis of the vibrations transmitted to the subjects, it can be seen that the total exposure A(8) was 4.117 m/s^2, compared to 1.15 m/s^2 (or total VDV = 58.021289 $m/s^{1.75}$ compared to 21 $m/s^{1.75}$), as indicated by the Directive 2002/44/EC.

The noise and vibrations transmitted to the sailing crew were two more major issues affecting the normal schedule for shift work.

As a result of the measurements made, it was found that shift work seriously disrupted the regular rhythm of the sailors, as evidenced by variations in body temperature—that were seen to widen after several sleepless nights—and by increased blood pressure of the subjects. Admittedly, these figures were also influenced by other factors, such as: Stress, physical effort, smoking and caffeine consumption, as well as the weather conditions or the type of environment in which subjects work (on the deck or below deck).

Finally, the choice made for the sailing staff program (Figure 4) did not correspond to the 4/8 Program Watch Rotation and Daily Routine (Figure 14).

Work in alternate shifts often had harmful effects, among which: Sleep disturbances, chronic fatigue and drowsiness, neuropsychiatric disorders, digestive disorders, increased cardiovascular risk, effects on reproductive capacity and trigger/exacerbation of pre-existing chronic diseases: Cardiovascular, psychiatric, gastrointestinal, renal, etc.

Work accidents can also happen due to a lack of correspondence between biological and professional rhythms. They are caused either by technical problems or by diminished attention and/or impairment of other superior nerve function, due to sleep disturbances and chronic fatigue. Studies and statistics show that most work accidents occur between 7:00 and 13:00, but those that occur at night, even though rare, are more severe.

Summarizing, it can be concluded that the peak (acrophase) of the work capacity was between 9:00–11:00 and 17:00–19:00, representing the maximum efficiency periods. The minimum efficiency period was from 13:00 to 15:00, while the work capacity gradually declined up to 23:00 (reasonably lower) and further on, up to 3:00 (extremely lower). The mental performances reached a peak in the morning, while physical ones do so in the afternoon.

The conclusion of this study should serve to enhance awareness of the negative impact of noise and vibration on sleep and work and rest programs. In order to improve this situation, it is necessary to acquire modern, high-performance ships that do not produce so much noise and vibration. It is also desirable to increase the number of people in the crew in order to make easier shifts and to avoid any danger of work accidents.

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