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EFFECTS OF LOW-FREQUENCY NOISE ON CREWS OF RIVER VESSELS ON THE DANUBE

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Laurentiu PICU, Eugen RUSU

"Dunarea de Jos" University, Galati, ROMANIA

constantin.picu@ugal.ro; eugen.rusu@ugal.ro

ABSTRACT

This paper has analyzed in which way the navigating personnel of some river ships on the Danube react under the action of low frequency noise (LNF) emitted by the equipment on the vessels. The subjects were 11 sailors with extensive experience in sailing on the Danube. After irradiation with LFN in the third octave band 6.3-200 Hz, for 30 min for each subject, with a 10 min break, each subject solved 2 tests (The Stroop Color and Word Test and Comparing of Names Test) and evaluated the degree of discomfort on the Likert scale with 5 items. At the end of the work period, a classification could be made in: person high-sensitive to LFN (subjects 1-6) and person low-sensitive to LFN (subjects 7-11).

Keywords: Noise, Low-frequency, Sensitivity, Crew, Danube

1. INTRODUCTION

Infrasounds are vibrations with the frequency between 0.001 Hz and 20 Hz and cannot be heard by the human ear. They are characterized by their ability to propagate over long distances and bypass obstacles without much dissipation. Infrasounds have harmful effects on the human body; these effects depend on frequency, acceleration of the movement of environmental particles, time of action and intensity of the waves. For example, given that the average frequency of the α waves of the human brain is about 7 Hz, the infrasounds that have this frequency cause an extremely unpleasant sensation to the human body.

The effects of infrasounds are cumulative, generating a false state of euphoria, vomiting, irritability, fatigue and dizziness. The environment contains many sources of infrasound: engines, ventilation dryers, cars, trams, helicopters, blast furnaces, etc. [1].

Low-frequency noise (LFN) is defined as broadband noise, with low frequency dominant content (10-250 Hz), which can be annoying to exposed subjects [2-7].

The effects of infrasound on people are manifested on the cardiovascular and nervous systems, eyes structure, the auditory and vestibular function and on the endocrine system. The studied special effects of the central nervous system (CNS) included upset, sleep and awakening, perception, evoked potentials, electroencephalographic changes and cognition [8].

The people exposed to infrasound presented the following symptoms that attest to a worsening of their health: they stated that they have more frequent cardiovascular problems (increased risk of heart attack) and chronic insomnia.

Psychological tests have revealed the emergence of an essential reduction of mood, onset of depression or possible intensification of an already existing depression, but of which the person is not aware [9]-[12].

Other tests performed on people exposed to LFN showed a tendency to work less accurately, obtaining fewer correct answers, having more wrong reactions. These findings suggest that LFN at moderate levels could adversely affect visual functions, concentration, continuous and selective attention [13].

This paper presents an analysis of the reactions of subjects under the LFN action.

2. MATERIALS AND METHODS

In this study we analyzed the low frequency noise and the way in which the navigating personnel react to this type of stimuli.

„Energy generated by moving, at mooring ship or ship in a port can be divided into three basic ranges:

1. Infrasound, referred as low-frequency sound that is lower in frequency than 20 Hz (below audibility of the human ear),

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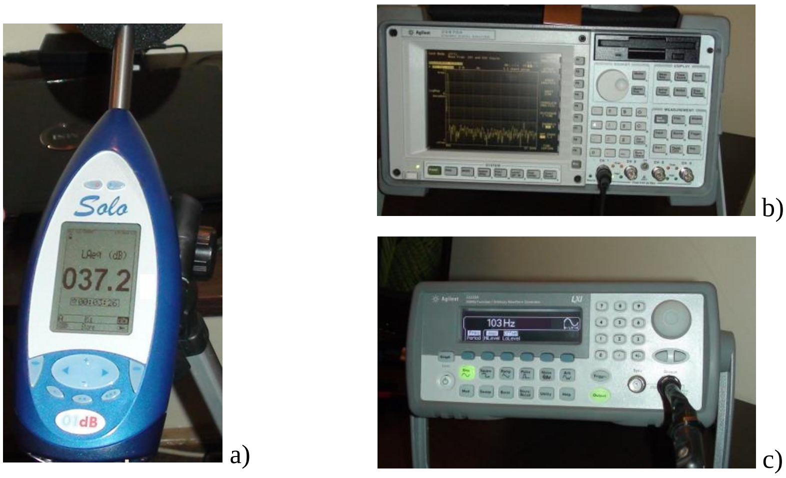

Fig. 1. Equipments: a) - sound level meter Blue Solo, b) - Dynamic Signal Analyzer 35670, c) - Arbitrary Waveform Generator 33220A

2. Sound defined as a mechanical wave that is an oscillation of acoustic pressure transmitted through a solid, liquid, or gas, composed of frequencies within the range of hearing. Most commonly accepted range is from 20 Hz to 20 kHz,

3. Ultrasound defined as an oscillating acoustic pressure wave with a frequency higher than the upper limit of the human hearing range – most often takes the range up to 100 kHz" [14].

The experiments were done in the "Interdisciplinary laboratory for vibro-acoustic measurements at occupational environment" laboratory at "Dunarea de Jos" University of Galati. The experiments were carried out in several stages. For start, the noise made by ships sailing on the Danube was recorded, in different modes of operation. This was done with a Blue Solo sound meter (01dB Metravib) (Fig. 1). The received signal was analyzed with DBTRAIT software, also from 01dB Metravib. Low-frequency signal was separated from these noises using Dynamic Signal Analyzer 35670 (Agilent). The obtained signal was transformed, again, into noise with the Arbitrary Waveform Generator 33220A (Agilent). To this noise were exposed some sailors from ships sailing on the Danube.

Calculation of daily exposure to noise

The daily noise exposure ($L_{EX,d}$) is found by summing all noise exposures in the day, like timeweighted average of the noise exposure levels for a nominal eight-hour working day as defined by international standards ISO 1999:2013 [15], point 3.6. This is not a simple addition, because levels in dB are logarithmic and not linear values.

$$L_{EX,d} = 10\lg\left[\frac{1}{T_0}\sum_{i=1}^{n} T_i \cdot 10^{0.1(L_{Aeq})i}\right] \quad (1)$$

where the working day comprises n discrete periods of time; T_0=8h; T_i - the duration of period i; $(L_{Aeq})i$ is the equivalent continuous A-weighted sound pressure level (or sound pressure level) to which the person is exposed during period i; and $\Sigma T_i = T_e$=the duration of the person's daily noise exposure to sound.

The equivalent continuous sound level L_{Aeq} can be evaluated using [16]:

$$L_{Aeq} = 10\log_{10}\left[\frac{1}{T_c}\int_0^T \left(\frac{p_A(t)}{p_0}\right)^2 dt\right] \quad (2)$$

where T_c is the criterion sound duration (usually 8h); T is the measurement duration [h]; $p_A(t)$ is time varying instantaneous A-weighted sound pressure [Pa]; p_0 = 20 μPa; t denotes time [h].

Subjects

11 sailors from the vessels on the Danube river were subjected to the determinations. All of them with long sailing experience (Table 1). After the experiment was presented, all subjects agreed to participate.

Exposure conditions

The experiments were carried out in the laboratory, which has a surface area of S = 18m^2 and a volume of V = 54m^3. The exposure at LFN lasted 30 minutes for each subject, with a break of 10 min. The frequency band used is shown in Fig. 2. The experiments and tests were repeated 3 times a day, for 2 weeks.

Performance tasks

Daily, at the end of each set of tests, subjects were asked to solve the following tests:

1) The Stroop Color and Word Test is a neuropsychological test extensively used to assess the ability to inhibit cognitive interference that occurs when the processing of a specific stimulus feature impedes the simultaneous processing of a second stimulus attribute, well-known as the Stroop Effect (An example is shown in Fig. 3) [17],

2) Comparing of Names Test (An example is given in Fig. 4). This test measures the speed at which a subject links words [18].

3) Also, subjects rated on the Likert scale the degree of discomfort:

- strongly disturbing = 5,
- disturbing = 4,
- neutral = 3,
- not disturbing = 2,
- strongly not disturbing = 1,

at different frequencies of noise (6.3 Hz, 12.5 Hz, 25 Hz, 50 Hz, 100 Hz and 200 Hz) [19].

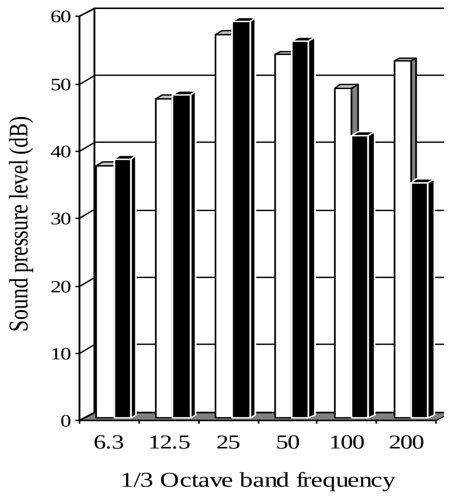

Fig. 2. 1/3-Octave band frequency spectrum of low frequency noise (□) and reference noise (■) used

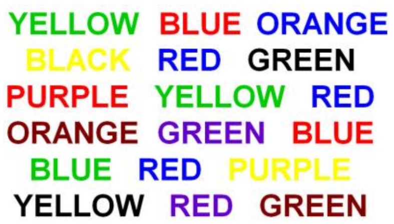

Fig. 3. Stroop Color and Word Test

sweet	wormwood
sour	pepper
bitter	lemon
salted	water
tasteless	cheese
spicy	cake
sweet	wormwood

sweet	cake
sour	lemon
bitter	wormwood
salted	cheese
tasteless	water
spicy	pepper
sweet	cake

Fig. 4. Comparing of Names Test

3. RESULTS AND DISCUSSIONS

Before starting the experiments, subjects were asked how they feel after a longer trip. More than half said they had chronic fatigue, chronic insomnia, headaches, irritation, anxiety. Then the exposures and tests began.

Following are the results obtained by the 11 subjects at Stroop Color (Figs. 5 & 6) and Comparing of Names Test (Figs. 7 & 8). All values in the figures below represent the average of the results obtained in the two weeks of experiments. Since the beginning of the tests, it was found that 6 of the subjects are more sensitive to high-sensitive LNF to LFN. For this reason, it is seen that they obtained poorer results in Stroop Color and Word Test (ref 100 points): none reached 80 correct answers (Fig. 5). Subjects 7-11 are low-sensitive to LFN; Fig. 8 shows that out of 30 responses, 10 are 100 points (Subjects 9-11), 1 is 98 points (Subject 8) and more than 90 points (Subject 7).

The same situation was observed in the Comparing of Names Test (ref 60 points): subjects 1-6 had below 50 points (the weakest results were obtained by subject 6) (Fig. 7). Subjects 7-11 had significantly higher results: the same people who obtained maximum score in the first test, now obtained maximum results, and the rest had over 55 points (Fig. 8).

Table 1. Anthropometric data of test subjects

Subject	Age (years)	Weight (kg)	Height (m)	Smoker	Drinker*	Experience (years)	Cardiovascular diseases in the family	Declared personal problems
S 1	59	91	1.78	-	-	18	-	X
S 2	48	114	1.82	X	X	22	X	X
S 3	55	98	1.86	X	X	34	-	X
S 4	49	72	1.66	-	-	30	X	-
S 5	45	80	1.72	-	-	26	-	-
S 6	56	85	1.70	X	X	36	X	X
S 7	58	88	1.75	-	X	38	X	X
S 8	52	108	1.98	X	-	23	-	X
S 9	52	102	1.80	X	X	32	-	-
S 10	50	71	1.78	-	-	22	-	-
S 11	47	68	1.70	X	-	26	X	X

* more than 200 ml alcohol/day (when not on the board of ship)

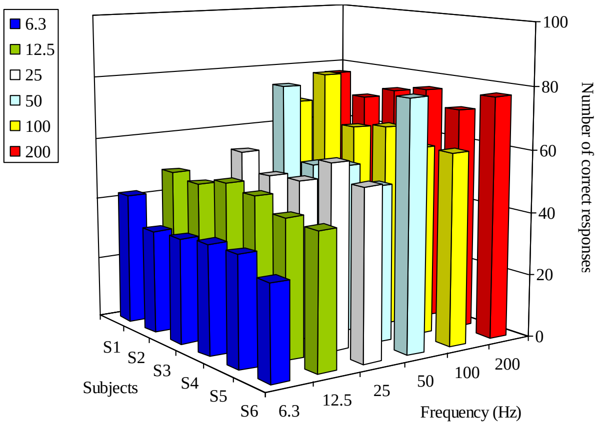

Fig. 5. Number of correct responses for Stroop Color and Word Test (ref. 100 points) for subjects 1-6

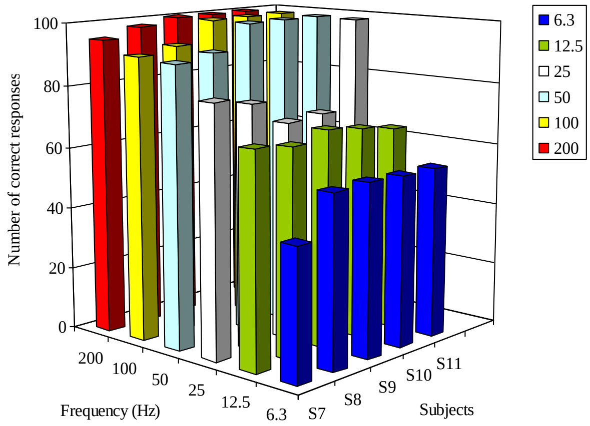

Fig. 6. Number of correct responses for Stroop Color and Word Test (ref. 100 points) for subjects 7-11

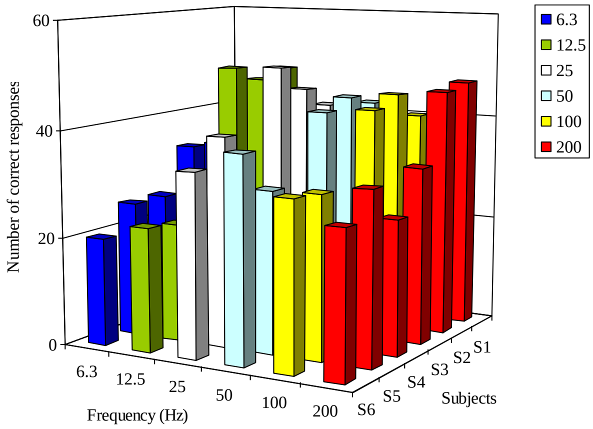

Fig. 7. Number of correct responses for Comparing of Names Test (ref. 60 points) for subjects 1-6

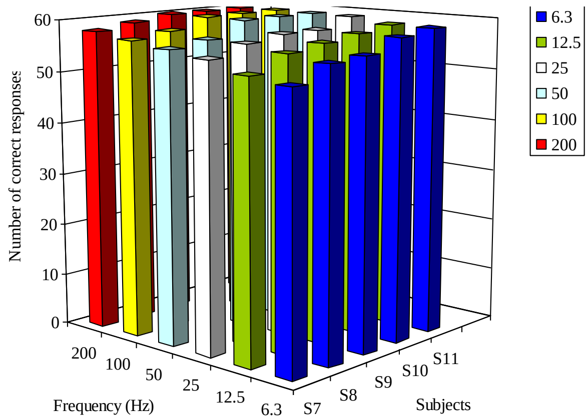

Fig. 8. Number of correct responses for Comparing of Names Test (ref. 60 points) for subjects 7-11

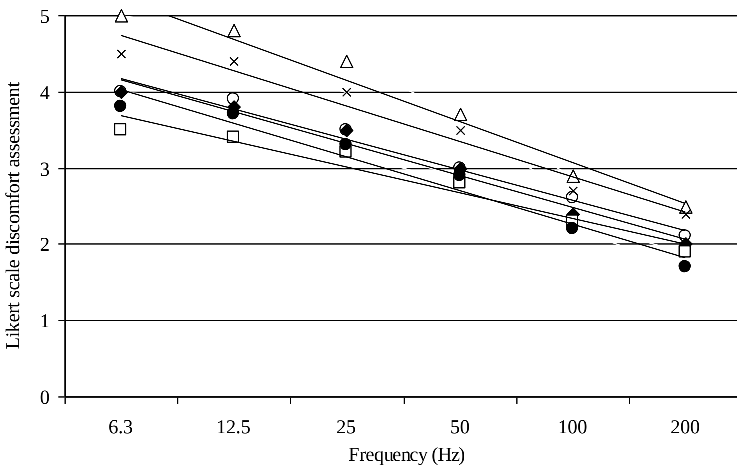

Fig. 9. 5 item Likert scale discomfort assessment for subjects 1-6
1(♦), 2 (□), 3 (Δ), 4 (X), 5 (o), 6 (•)

These objective results, obtained from direct measurements, were compared with the subjective results obtained when assessing the discomfort on the Likert scale (Fig. 9 & 11).

For the first 6 subjects, linear representations were obtained (Fig. 9), given by the equations (3) ÷ (9) (Table 2), from which it is observed that the discomfort decreases with increasing frequency.

Table 2.

Subject	Perception (P)	R^2	(3)
1(♦)	P = -0.42·ν + 4.5867	(0.9743)	(4)
2 (□)	P = -0.3343·ν + 4.02	(0.9516)	(5)
3 (Δ)	P = -0.54·ν + 5.7733	(0.9686)	(6)
4 (X)	P = -0.46·ν + 5.1933	(0.9573)	(7)
5 (o)	P = -0.3971·ν +4.5733	(0.9759)	(8)
6 (•)	P = -0.44·ν + 4.4733	(0.9589)	(9)

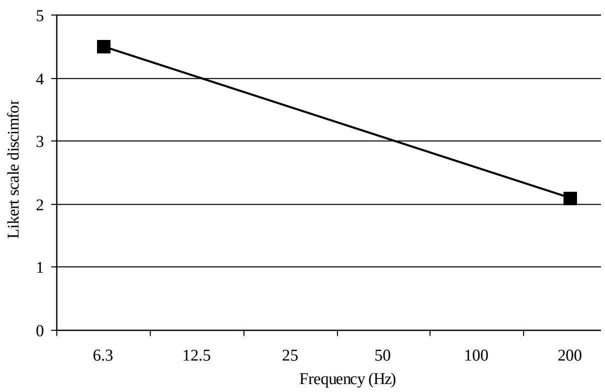

Fig. 10. Average perception

Table 3.

	Perception (P)	R^2	
Average	**P=-0.4319·ν+4.7699**	**1**	(10)

From Fig. 9, it is clear that these subjects are more sensitive to LNF; most of their ratings range from 3 to 5 on the Likert scale (strongly disturbing; disturbing and neutral). By fitting equations, an average of these evaluations is obtained (Fig. 10, Eq. 10 in Table 3).

As for subjects 7-11, things are different; the assessment of discomfort is between 1 (Strongly not disturbing) and 2 (Not disturbing) for the first 3 frequencies (6.3 Hz, 12.5 Hz and 25 Hz) for the first two subjects 7 and 8 (Fig. 11). In these 2 cases, the equations are also linear (Table 4).

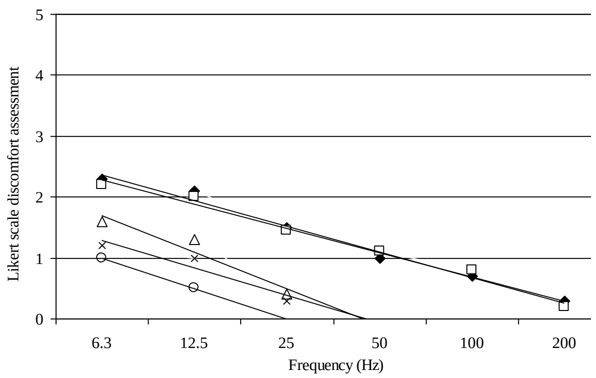

Fig. 11. 5 items on Likert scale discomfort assessment for subjects 7-11
7(♦), 8 (□), 9 (Δ), 10 (X), 11 (o)

Table 4.

Subject	**Perception (P)**	**R^2**	
7(♦)	P = -0.42·ν +2.7867	0.9868	(11)
8 (□)	P =-0.3986·ν+2.6867	0.9851	(12)

Table 5.

Subject	Perception (P)	R^2	Only for the frequencies ν [Hz]	
9 (Δ)	P=-0.6·ν+2.3	0.9231	6.3 12.5 25	(13)
10 (X)	P=-0.45·ν+1.733	0.9067	6.3 12.5 25	(14)
11 (o)	P=-0.5·ν +1.5	1	6.3 12.5	(15)

For the other subjects, linear representations are given by the equations (13) ÷ (15) (Table 5).

Subjects no. 9 and 10 felt no discomfort at frequencies of 50 Hz, 100 Hz and 200 Hz, and subject 11 stated that he would feel discomfort at frequencies of 6.3 Hz and 12.5 Hz, otherwise he felt nothing.

4. CONCLUSIONS

In this paper, the authors analyzed the way in which the navigating personnel of some river vessels on the Danube react under the action of low-frequency noise (LNF) emitted by the equipment on the vessels. The subjects were sailors with extensive experience in navigating the Danube.

The experiments, which lasted 2 weeks, took place in the laboratory, after each person had given their consent. After irradiation with LFN in the third octave band 6.3-200 Hz, for 30 minutes for each subject, with a 10-minute pause, each subject solved 2 tests (The Stroop Color and Word Test and Comparing of Names Test) and evaluated the degree of discomfort on the Likert scale with 5 items.

Following the analysis of the results from the tests of each subject, as well as the personal assessment of the degree of discomfort, it was confirmed that the LFN leads to a different state of discomfort, depending on the person. At the end of each day, subjects were asked how they feel; the same people who - at first - declared a state of discomfort, replied this time that they feel beating palpitation, ear pulsation, ear vibration, shortness of breath.

At the end of the work period, a classification could be made in: person high-sensitive to LFN (subjects 1-6) and person low-sensitive to LFN (subjects 7-11).

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