Exposition of working and natural environment to noise during timber transport by helicopter MIL MI-8 in Carpathian region of Slovakia

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Abstract: This paper includes the results of noise measurements during timber transport by helicopter MI-8 in The High Tatras conditions in 2005. Using this highly efficient timber skidding technology with multiple positive environmental properties causes an unwanted effect – air-traffic noise. The objective of this paper is to quantify the level of noise effect for two correlated groups; noise effecting workers and noise effecting environment. The highest values measured in the worst conditions reached 90–100 dB (A).

Keywords: helicopter; timber skidding; noise; environment; analysis

In forest management one of the most important and the most expensive factors of the production process is timber transport solution. Presently forestry timber transport technologies are mostly oriented on railways (in Slovakia it is as much as 98% of the overall volume of transported wood).

Some of the reasons why there is a continuous increase in the use of aerial timber transport are: increasing demands on preserving ecosystems stability, their biodiversity, the overall forest health state and sustained usage of its functions. One of the possibilities is to utilize helicopters during the skidding phase, mainly from mountainsides and steep terrains.

Timber skidding by helicopters is routinely used in many silviculturally and economically advanced European countries; in Canada and the USA the amount of skidded timber is even greater.

Within the European countries the greatest volume of skidded timber is in Switzerland, France (Alps region), Germany, Austria and Russia. The work is secured by private companies. In Switzerland 6.5% of timber is skidded by helicopters and in the Swiss Alps region it is as much as 20.1%.

Using this highly efficient timber skidding technology with multiple positive environmental properties causes an unwanted effect – air-traffic noise. The objective of this paper is to quantify the level of noise effect for two correlated groups; noise effecting workers and noise effecting environment.

Helicopter skidding and noise issue

Many authors have dealt with the issues of helicopter skidding and loading the environment with noise. Because of this papers extent we present only the most significant authors from this region: Jackson & Morris (1986), Smetana (1987), Kaluckij *et al.* (1988), Stehle (1990), Abel & Sauloquin (1991), Konrád & Messingerová (1993), Messingerová (1994), Lambert (1995).

From the point of evaluating the noise effect on the environment it is important to quantify some substantial parameters. Furthermore we present a survey of noise categorization according to its individual types and the basic terms or parameters of its characteristics.

According to its properties, noise is categorized as follows:

(a) Steady noise – overall level of acoustic pressure does not change over time for a given point by more than 5 dB (A) and its frequency composition stays almost the same.

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(b) Intermittent noise – depending on time, overall level of acoustic pressure changes by more than 5 dB (A).

(c) Interrupted noise – change of level takes place rapidly during which the time duration of silent and loud periods is longer than 30 s, and within each period noise changes only a little.

(d) Impulse noise – is created by individual impulses or by a series of impulses varying in length from 1 ms to 200 ms, and intervals between impulses longer than 10 ms.

Intermittent noise is categorized as follows:

(1) Fluctuating noise – its changes take place gradually and they are roughly periodical. The louder part of the period lasts only for a specific time.

(2) Irregular noise – changes take place completely irregularly, unexpectedly, and at random (e.g. street noise).

According to the character of frequency spectrum the noise is categorized as follows:

(1) low-frequency noise (up to around 500 Hz),

(2) medium-frequency noise (from around 500 to 800 Hz),

(3) high-frequency noise (over 800 Hz).

Basic parameters for noise description are used in the working environment more accurate characteristics of noise. We further introduce some of the most important characteristics (according to Government direction of Slovak republic No. 40/2002).

Sound – is the mechanical oscillation of flexible setting particles. Audible sound is a sound which able to cause acoustic perception (its frequency range with medium frequencies is from 20 Hz to 20 kHz).

Noise – every unwanted, disturbing, uncomfortable or harmful sound.

Frequency wave-length – range of frequencies limited by the lower frequency bound f_d, and the upper frequency bound f_h; characterized by center frequency f_s, for which the following is valid:

$$f_s = (f_d \times f_h)^{1/2} \tag{1}$$

Intermittent acoustic pressure $p(t_i)$ – is the difference between overall pressure and static pressure in a certain moment t_i, for a given point.

Acoustic pressure level; L, L_s (dB) – continuous level of acoustic pressure is determined by the equation:

$$L = 10 \times \log \left[\frac{p}{p_0}\right]^2 \tag{2}$$

where:

p – acoustic pressure (Pa); its level is determined,

p_0 – reference acoustic pressure, $p_0 = 2 \times 10^{-5}$ (Pa).

Equivalent sound A level , sound C or infrasound G – time-average sound A level, sound C, or infrasound G $L_{Aeq.T}$ (dB):

$$L_{Aeq.T} = 10 \times \log \frac{1}{T} \int_{t_1}^{t_2} \left[\frac{P_A(t)}{p_0}\right]^2 dt \tag{3}$$

where:

$p_{A(T)}$ – acoustic pressure time function esteemed by frequency impulse function A, C or G

T – duration of integration and averaging, $T = t_2 - t_1$

p_0 – reference acoustic pressure, $p_0 = 2 \times 10^{-5}$ (Pa).

Sound exposition $E_{A,T}$ (Pa^2 × s):

$$E_{A,T} = \int_{t_1}^{t_2} \left[P_A(t)\right]^2 dt \tag{4}$$

where:

$p_{A(T)}$ – acoustic pressure time function esteemed by frequency impulse function A,

T – time interval during which sound exposition is determined, $T = t_2 - t_1$

Note: connection of sound exposition with equivalent sound A level is defined by the equation:

$$E_{A.T} = p_0^2 \times T \times 10^{0.1 L_{aeq,T}}$$

Normalized level of noise exposition $L_{EX.8h}$ (dB):

$$L_{EX.8h} = 10 \times \log (E_{A,T}/E_0) \tag{5}$$

where:

$E_{A,T}$ – sound exposition defined in Eq. (4),

E_0 – reference sound exposition.

$$E_0 = {p_0}^2 \times T_0 = (2 \times 10^{-5}\ \text{Pa})^2 \times 28\,800\ \text{s} = 1.15 \times 10^{-5}\ \text{Pa}^2\text{s}$$

where:

T_0 – normalized duration of working shift,

T_0 = 8 h = 28 800 s.

Note: there is an equation between normalized noise exposition level and equivalent sound A level:

$$L_{EX,8h} = L_{Aeq,T} + 10 \times \log (T/T_0)$$

where:

T – duration of equivalent level measurement.

On the basis of this equation it is possible to calculate any equivalent level – esteemed, non-esteemed, or one in frequency range to normalized level.

Maximum sound A level L_{Amax} (dB) – is the highest sound A level determined during the selected time interval using the time impulse function *F*. When using the other time impulse function it must be highlighted by a marking, e.g.: L_{Amax}

Peak sound C level $L_{CPk,T}$ (dB) – sound level with frequency estimation C defined by the equation:

$$L_{CPk,T} = 20 \times \log\left[\max\left(\frac{p_c(t)}{p_0}\right)\right] \quad (6)$$

Background noise – is noise or other influences registered by the measuring device even when the noise source, which is supposed to be evaluated, is not active. It is measured before or after the measurement of the evaluated source under the same conditions, e.g. placement of the microphone, measurement time, weather conditions. Background noise can be caused not only by noise but also by non-acoustic influences, e.g. magnetic fields or air flow.

Table 1. Technical parameters of helicopter MIL MI-8

Dimensions	load-bearing rotor diameter (m)	21.29
	balancing rotor diameter (m)	3.91
	length with spinning rotors (m)	25.35
	body length (m)	18.22
	height (m)	4.75
Weight	empty weight (kg)	7 150
	maximum take-off weight (kg)	12 000
	effective weight (kg)	4 000
Output	maximum speed (km/h)	250
	traveling speed (km/h)	230
	service ceiling (m)	4 400
	static ceiling under the ground influence (m)	2 000
	static ceiling without the ground influence (m)	950
	flying range (km)	510

MATERIAL AND METHODS

Measurements of efficiency and noisiness of helicopter MIL MI-8 skidding technology (Table 1, Figure 1) were conducted in 2005 in High Tatras – Tatranská Lomnica – State Forests of Tatras National Park on function area number 640 where effects of wind calamity from November 2004 were being removed on surrounding stands, numbers 1000–1011.

Figure 1. MIL MI-8

In Table 2 the basic mensuration characteristics of stands where the measurements took place are presented.

Helicopter timber skidding technology or working cycle can be divided into these working operations:

ascending to the storage area,
flying to the stand,
descending to the stand,
connecting the load,
ascending from the stand with the load,
flying with the load from stand to storage area,

Table 2. Basic mensuration characteristics of stands

Forest stand	Area (ha)	Age (years)	Crop density	Overall supply (m^3)	Supply (m^3/ha)	Wood composition (%)	Calamity area (ha)	Skidding distance (m)	Slope (%)
1000a	1.87	110	0.6	550	294	spruce 90 pine 5 larch 5	1.87	1 885	80
1003	17.35	115	0.7	5 569	321	spruce 100	9.55	3 460	75
1004	64.44	130	0.8	29 127	452	spruce 90 larch 10	0.94	4 125	90
1008	39.56	115	0.6	9 494	240	spruce 100	8.64	4 085	80
1010	12.63	100	0.4	2 009	159	spruce 45 pine 55	8.88	3 220	70
1011	30.17	115	0.4	5 431	180	pine 30 larch 70	25.21	2 630	80

ascending to the storage area,
disconnecting the load,
connecting the bonds for load transport.

Direct noise measurements were conducted by the real-time noise analyzer – Nor 118 during several cycles. Minimum and maximum noise values in one second intervals and the equivalent noise level were noted.

Before terrain measurements, various sources were studied (web pages, literature concerning noise topic, its measurements, evaluation and actual legislative, effective in Slovakia and the European Union).

During measurements and noise exposition evaluations in a working environment of MIL MI-8 helicopter we used standard STN ISO 9612: Acoustics, instructions for measurements and evaluation of noise exposition in a working environment. This international standard offers general instructions about which type of measurements and which type of conditions are required for noise measurements; with the respect to its influence on the worker in order to be in accordance with established regulations and to indicate the need of lowering the noise by the noise control actions.

Maximum (L_{Amax}) and equivalent (L_{Aeq}) noise levels were measured and the values were used to calculate $L_{EX,8h}$. Besides these values sound-level meter also measured: sound level in frequency ranges (L_{feq}, L_{fmax}, L_{fmin}), sound A equivalent level in frequency range (L_{Afeq}), sound A peak level L_{Cpk} and sound A percentage levels, which were exceeded in *n* percents out of the overall measurement time ($L_{0,1}$,L_1,L_5,L_{10},L_{50}, L_{90}, L_{95}, L_{99}). Values were analyzed within the Norreview program equipment from the company Norsonic Slovensko, and by standard mathematic-statistical methods.

Equivalent and maximum noise level were measured by using filter A, frequency characteristic of which are close to human auditory organ. Impulse noises and background noise were measured. In the case that it is not impulse noise, it is described by noise level A under the dynamic characteristic level F.

In the course of the research noise was measured besides common operation distances in the worst conditions, a minimal distance from the helicopter (under the helicopter or abreast the helicopter in slope). During the usual air traffic, the noise levels at the ground are low. Noise was measured perpendicularly to the flight path and along with the flight path of the helicopter.

RESULTS

Helicopter timber skidding technology is 8 to 10 times more effective than tractor technologies and even 20 times more efficient than cable systems. It shows that the noise during helicopter operation effects the forest environment and the workers substantially less, which is an important factor in conservation areas.

Working environment – helicopter pilot

The microphone was placed inside the pilots cockpit 0.20 m from the outer auditory passage of the pilot. Measurements were conducted by dosimetry technique. The course of the measurements are depicted in Figure 2. In the first 90 seconds, acoustic

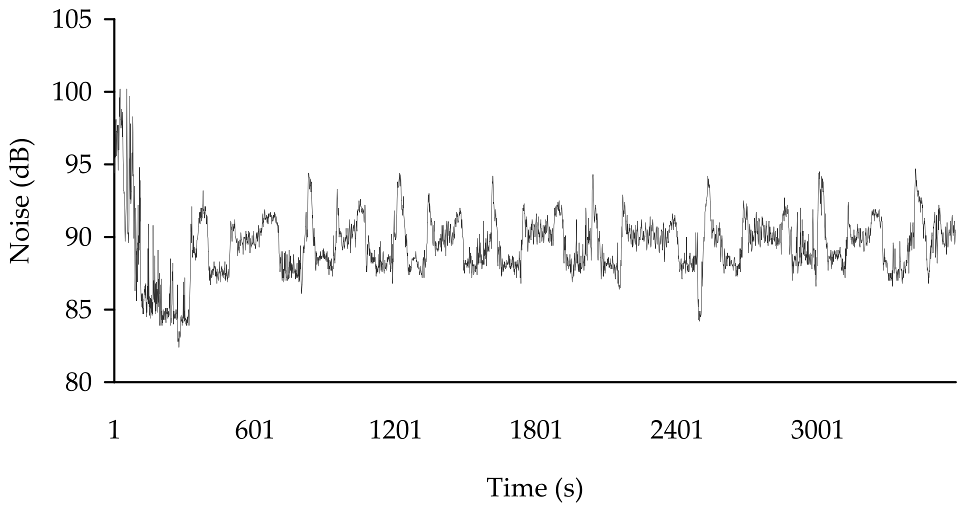

Figure 2. Behavior of the acoustic pressure L_{Aeq} in the cockpit

pressure is increased to 100 dB during the helicopter take-off.

Peak sound C level L_{Cpk} (6) reached the value of 118.3 dB. The highest acceptable level is 140 dB according to the standard. Equivalent sound A level was 89.5 dB, out of which noise exposition level $L_{EX,8h}$ (5) counted is 85.5 dB. The highest acceptable level is $L_{EX,8h}$ – 75 dB. It shows that it is necessary to use ear protectors with the absorption minimum of 10 dB.

Working environment – loading of isolator at the storage area

Measured helicopter noise values are presented in Figures 3 and 4. Figure 3 depicts the course of L_{Aeq} during 16 working cycles of helicopter skidding. The measurements took 7200 s. These measurements were conducted approximately 100 m away from the place where the load was being disconnected along with the flight path of the helicopter.

Peak sound C level L_{CPk} reached 121.7 dB and maximum acceptable level is 140 dB. Equivalent sound A level was 79.2 dB, out of which normalized noise exposition level $L_{EX,8h}$ calculated is 73.3 dB. The highest acceptable level is $L_{EX,8h}$ – 75 dB. It is necessary to use the ear protectors when the helicopter is near the storage area.

Figure 4 shows the course of L_{Aeq} (3) during 3 working cycles of helicopter timber skidding. The measurements took 1200 s. This measurement was conducted approximately 100 m from the place where the load was being disconnected perpendicularly to the flight path. During the measurement the value L_{Aeq} 70.0 dB and peak sound C level L_{CPk} reached 103.6 dB. These values are lower compared to the previous measurement L_{Aeq} 70.0–79.2 dB, L_{CPk} 103.6–121.7 dB. The cause of such high variance is that during measurement against the helicopter flight path acoustic pressure is directed in front of the helicopter (Doppler phenomenon).

Loading of natural environment by helicopter MIL MI-8

Figure 5 shows the course of L_{Aeq} in detail during one working cycle. It depicts the increasing equivalent noise level when the helicopter is coming closer to the measuring point. Highest values L_{Aeq} were reached during the loaded helicopter descending to the storage area. The picture shows that after approximately 1/5 of the flight time, L_{Aeq} decreases under 50 dB, which represents approx. 800 m from microphone placement. According to the standards, the highest acceptable value of traffic noise for an outdoor environment is 60 dB. At the same time L_{Aeq} variations at the end of the third cycle (helicopter take-off) are reaching 65 dB. They are background noises (songbirds). The result is that the noise in a distance of approx. 800 m from the helicopter does not influence environmental loading.

For comparison we present measurement results from the eastern locality of the High Tatras from 2001. Noise was measured by a device from Brüel a Kjaer company with integrated impulse filter A. Values were processed by the analysis of variance method (Table 3).

Processing of data by analysis of variance

The significance of the influence of distance, helicopter flight height and terrain configuration were analyzed. Terrain was classified as follows:

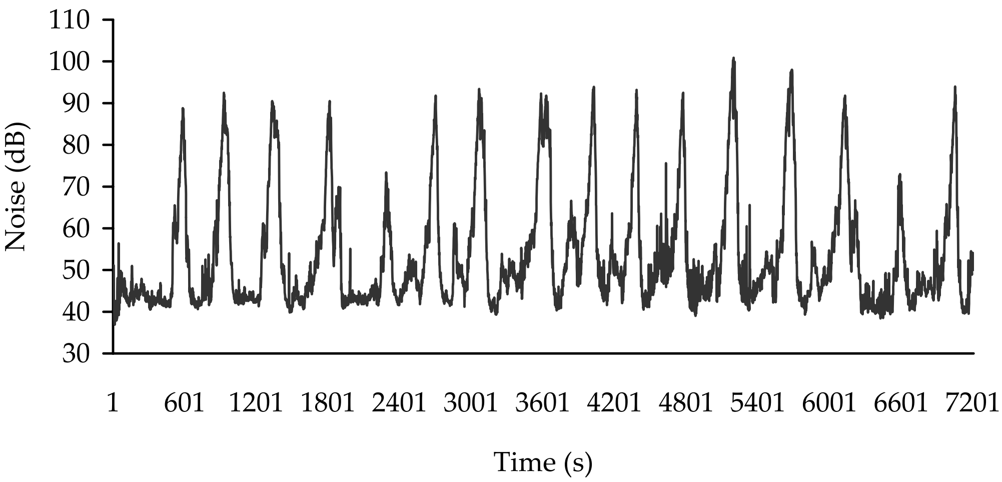

Figure 3. Behavior of acoustic pressure L_{Aeq} during helicopter operation; measurements conducted along with the flight path of the helicopter

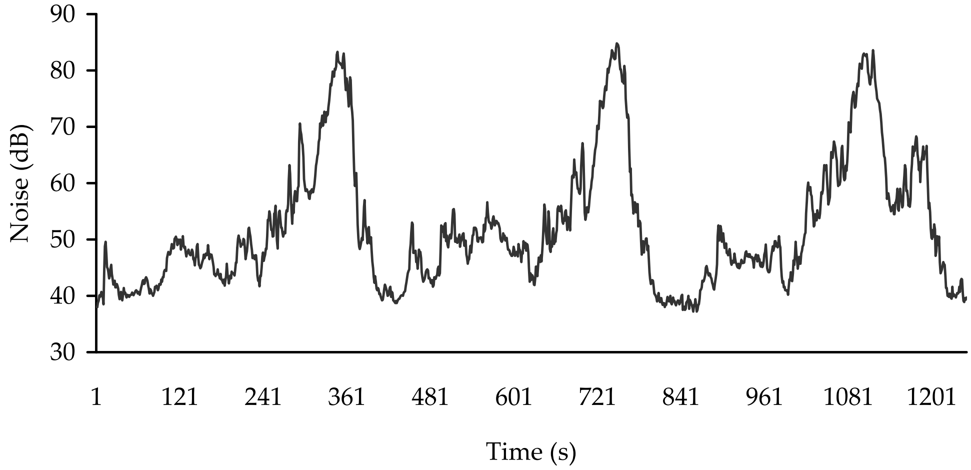

Figure 4. Behavior of acoustic pressure L_{Aeq} during helicopter operation; measurements conducted perpendicularly to the flight path of the helicopter

Table 3. Significance of factors

Factor	F	α	$P_{1-α}$	β
Distance	66.812	0.000 00	1.000 00	–0.64
Flight height	11.866	0.000 00	1.000 00	–0.41
Terrain	5.9585	0.003 38	0.996 62	–0.12
Together	20.581	0.000 00	1.000 00	R = 0.87

F – calculated value F-distribution; α – significance level; $P_{1-α}$ – reliability index; β – partial correlation coefficients (calculated by method of multiple regression), (number of measurements $n = 122$ is $F_{tab,\,0.05} \approx 3.08$.)

(1) – open terrain, plain,
(2) – broken terrain in a slope,
(3) – valley outside the flight path.

Table 3 shows that the influence of distance and flight height are significant with 100% probability. The influence of terrain is significant with 99.62% probability.

Coefficient values β could be interpreted as an intensity of effecting individual factors within their synergetic influence. Table 4 presents average values of noise intensity in various factor levels. Average noise intensity was 77 dB. Results correspond with the results conducted by Norsonic sound meter.

For sound perception in general (in outdoor as well as in a working environment), some of the principles resulting from the physiology of perceptive organs as well as from others are valid. Different subjective sound perceptions in dependence on sound oscillation are processed into normalized curves with equal volume level - Fletcher-Munson curves (Smetana 1987).

According to the presented authors we perceive sounds with low frequency more intensely by 40 to 60 dB than common sounds with frequency of 1–8 kHz because they are transmitted by the skull bones. Helicopter noise caused mainly by the rotation of the main rotor has indeed low frequency of 500 Hz, but it is in the range where human organisms

Table 4. Average values of intensity noise in different factor levels

Distance		Flight height		Terrain configuration	
(m)	(dB)	(m)	(dB)	classification	(dB)
0	95	0	112	1	80
100	81	35	83	2	74
200	74	40	80	3	70
300	69	45	78		
400	65	50	77		
1200	50	60	71		

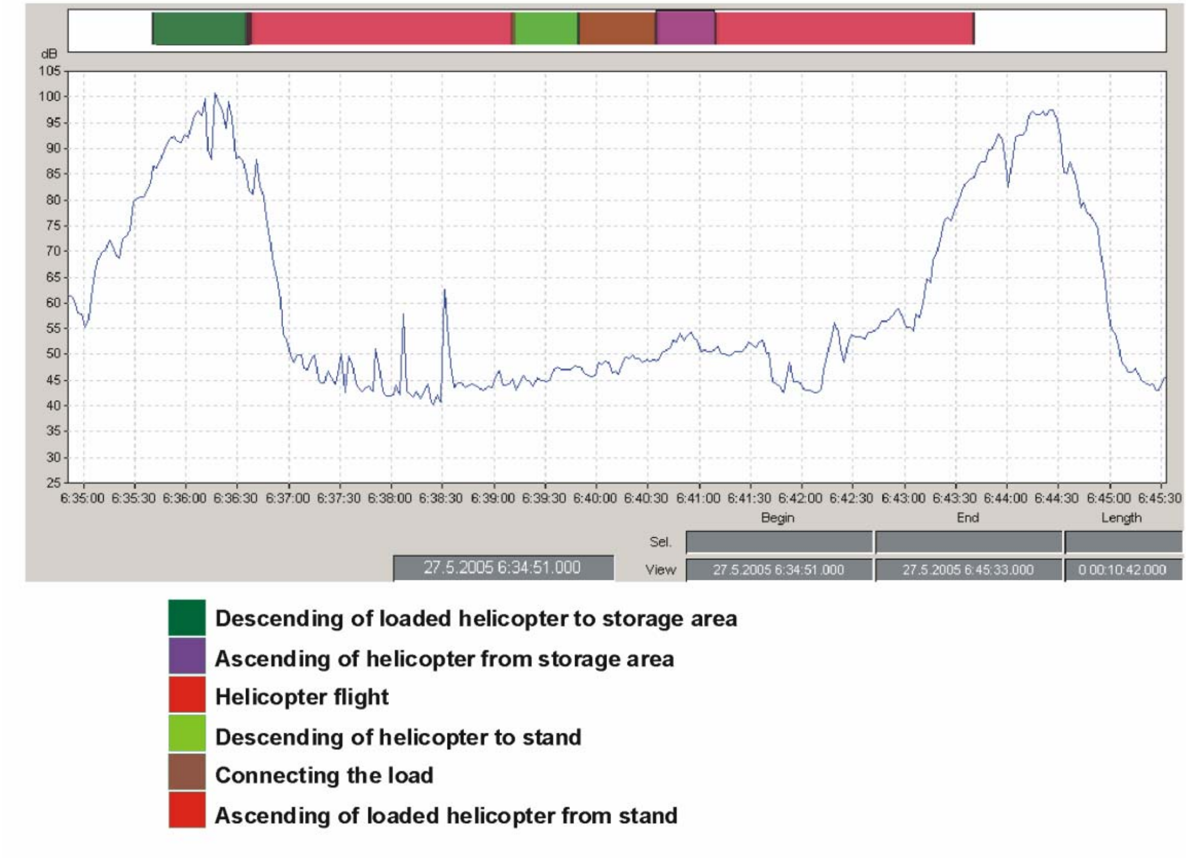

Figure 5. Graphic course of helicopter acoustic pressure L_{Aeq} during one working cycle

are loaded only with such intensity as frequencies 1–4 kHz. Helicopter engine noise (turbines) has a frequency of about 10 kHz and is perceived less intensely by 30 dB (against 1–4 kHz). Sounds in the frequency spectrum 1–4 kHz (from body shell vibrations etc.) have a lower intensity.

RESULTS AND DISCUSSION

In conclusion, we can state that the helicopter MIL MI-8 has a higher acoustic pressure than ergonomic criteria allow. Forest environment loading is minimal from a distance of approx. 800 m and further. The highest acceptable normalized noise exposition level values are exceeded and that results in an obligation to wear ear protectors. The load of storage area workers is lower than the pilots because of the short exposition time. Exceeding the highest acceptable normalized noise exposition level value is minimal (0.1 dB). Optimal duration of one cycle is 240–480 s; skidding distance is 800–2000 m.

In general, the analysis of the timber skidding problem abroad, substantiated by our own measurements, confirms that the technology is highly efficient and at the same time it is considerate to the forest environment. Some very important positive features of aerial transport are undemanding road construction, lowering the forest land production area on the road construction, timber skidding without damaging the timber when skidded from poorly accessible terrains or from actual technologically inaccessible terrains which are not exploited and their production efficiency is decreasing as a result of neglecting.

Helicopter technology further eliminates land erosion and enables the fast skidding of large volumes of timber during calamities and its utilization without quality loss.

By observing good planning and work management for preventing noise attack on the environment, it is possible to reach acceptable results even when the classic timber skidding technologies is the most risky in these areas.

Despite the financial demands of the mentioned technology, we can assume that this technology will not be the “ultimate” technology, everywhere where environmental stability preservation demands prevail.

A further question is the influence of redundant noise on fauna disturbance, mostly in protected areas. It is necessary to avoid nesting and mating seasons and the choice of the schedule should be discussed with state nature protection service.

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Abstrakt

Messingerová V., Tajboš J. (2007): **Hluk v pracovnom a prírodnom prostredí pri doprave dreva vrtuľníkom MI-8.** Res. Agr. Eng., **53**: 103–110.

Príspevok obsahuje výsledky meraní hluku pri doprave dreva vrtuľníkom MI-8 v podmienkach Vysokých Tatier v roku 2005. Používanie tejto vysoko výkonnej technológie sústreďovania dreva s viacerými pozitívnymi enviromentálnymi vlastnosťami vyvoláva nežiadúci jav – hluk z leteckej prevádzky. Cieľom práce je kvantifikovanie miery pôsobenia hluku v dvoch vzájomne úzko súvisiacich rovinách, ako hluk pôsobiaci na pracovníkov a hluk pôsobiaci na okolité prírodné prostredie. Najvyššie namerané hodnoty hluku v najnepriaznivejších podmienkach dosiahli hodnotu 90–100 dB (A).

Kľúčové slová: vrtuľník; sústreďovanie dreva; hluk; prostredie; analýza

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