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## Noise and hearing disorders

### Hałas a zaburzenia słuchu

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#### Conflict of interest

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None

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#### THE IMPORTANCE OF HEARING IN EVERYDAY LIFE

Hearing is developed before birth. It plays a significant role in shaping language and communication skills. Human being gains acoustic experiences using hearing organ. The perception of sound stimuli has a significant impact on the general psychomotor development (1).

Hearing is one of the basic senses desired in communication between people. Thanks to its efficient functioning, people may feel safe, because it often

#### Summary

Hearing is one of the most important human senses. It is highly sensitive to any acoustic stimuli – some of them may be harmful. Hearing damage caused by noise is becoming more common these days. It affects not only adults, but also adolescents and children. It is often irreversible and may arise as a result of a single exposure to noise or during long-term occupational exposure.

Noise has a strong impact on the hearing organ. It is a dangerous stimulus that damages external hair cells. Its effect may be caused by both long-term and short-term exposure.

To prevent noise-induced hearing impairment, it is necessary to avoid loud acoustic stimuli. Noise is ubiquitous and sometimes we do not realize how harmful it is to our hearing. People of all ages are exposed to hearing loss caused by noise. In order to avoid or reduce the effects of noise, one should follow preventive recommendations. Noise has a huge impact on the quality of our hearing.

#### Streszczenie

Słuch jest jednym z najważniejszych zmysłów ludzkich. Cechuje go wysoka wrażliwość na wszelkie bodźce akustyczne – niektóre z nich mogą być szkodliwe. Uszkodzenia słuchu spowodowane hałasem są coraz częściej spotykane. Dotykają one nie tylko ludzi dorosłych, ale również młodzież i dzieci. Często są nieodwracalne i mogą powstawać na skutek jednorazowej ekspozycji na hałas lub podczas wieloletniego narażenia zawodowego.

Hałas silnie oddziałuje na narząd słuchu. Jest niebezpiecznym bodźcem uszkadzającym zewnętrzne komórki słuchowe. Jego skutki mogą być wywołane zarówno długotrwałym, jak i krótkotrwałym narażeniem.

Aby zapobiec występowaniu zaburzeń słuchu wywołanych hałasem, należy unikać głośnych bodźców akustycznych. Hałas jest wszechobecny i czasem nie zdajemy sobie sprawy z tego, jak szkodliwie działa na słuch. Na ubytki słuchu powodowane hałasem narażeni są ludzie w każdym wieku. Chcąc uniknąć lub zmniejszyć skutki wywoływane przez hałas, należy postępować zgodnie z zaleceniami profilaktycznymi. Hałas ma ogromny wpływ na jakość naszego słyszenia.

warns us against danger signals. With proper hearing, we may communicate through auditory canal in various social situations without a difficulty. The proper functioning of hearing organ is very important aspect of everyday functioning (2). The activity of sense organs, mainly the hearing organ, is important when performing work in a way that is not only effective, but also safe for the worker and his environment (3). Professional life is an important element determining usefulness in society (4). First of all, proper hearing is one of the main aspects of a good quality of life for many people (3).

The sense of hearing enables: speech development, the ability to differentiate sounds, analyze and synthesize them, as well as the perception of speech from the environment and the improvement of speech constructed through auditory self-control (5). Being in the environment of speaking people helps to associate sounds with specific activities, objects and situations (2).

## DEFINITION OF SOUND AND NOISE

Sound is a wave disturbance in an compressible medium capable of producing an auditory sensation. The medium of sound propagation may be: liquids, gases and solids. Sound consists of mechanical vibrations and waves in an compressible medium, in the frequency range audible to the human ear, that is 16-20,000 Hz. Air is the main carrier of sound waves. At the sound source, it is alternately compressed (pressure increase) and diluted (pressure reduction). When it decreases or increases, the higher or lower pitch is heard (6).

The sounds are also vibrations inaudible to the human ear: ultrasounds (vibrations with a frequency above 20 kHz) and infrasound (vibrations with a frequency below 16 Hz) (7).

Taking into account the impact of sounds on the human body, we limit ourselves to those sounds that occur in the human environment. The sound that comes to us in the natural environment is defined as an auditory sensation defined by such features as: height, loudness, timbre. This proves that you can freely shift your attention from one feature of the auditory sensation to another feature, that is, for example, determine the loudness of a sound, and then its pitch or color (8).

We may distinguish three main parameters of sound: frequency, intensity and spectrum. The sound has a temporal dimension and therefore includes changes in the above-mentioned parameters during the duration of the sound. These objective sound parameters correspond to the sensation characteristics: vibration frequency – pitch, intensity – loudness of sound, spectrum of sound – timbre (9).

Human has always had contact with sound. Hearing serves as a basic cognitive instrument. Bothering sounds are often called noise. These are sounds caused by human activity. By shaping the environment, they are often factors that contribute to the devastation of the environment, tourism and reduce the quality of the living environment. Noise is part of the development of civilization. It degrades not only the natural environment, but also the environment created by human (6).

In Poland, the level of social awareness related to the dangers of noise is low. Warsaw is considered to be one of the loudest cities in Europe. It is on the black list of the most noisy European capitals. Nevertheless, new sources of noise that destroy people and the environment are still being created (7).

Noise has an impact on the human body. Audible noises may be divided according to their level into five groups:

1. below 35 dB – noise is not harmful to health, it may only interfere with work that requires concentration or may be annoying,
2. 35-70 dB – noise affects the fatigue of the human nervous system, greatly hinders the intelligibility of speech, rest and falling asleep,
3. 70-85 dB – noise reduces work efficiency, may damage hearing and be harmful to health,
4. 85-130 dB – noise makes it impossible to understand speech even from a distance of 0.5 m, causes numerous diseases of the human body,
5. above 130 dB – noise stimulates human internal organs to vibrate, causing their diseases and causes permanent hearing damage (7).

The acoustic phenomena that accompany us every day during sleep, work and rest, such as barking dogs, screaming children while playing, car alarms, but also completely different sounds coming from the street are defined as noise (10).

Noise is any sound of any acoustic character that may be annoying, bothersome or endanger your health (10). Noise is any unpleasant, undesirable or harmful mechanical vibrations of an elastic medium, acting through the air on the hearing organ and other human organs. This definition illustrates the harmfulness of noise, which has a destructive impact on the environment and surroundings, and above all causes nervous aggression, hinders work, prevents communication between people, destroys the environment, and thus the quality of life deteriorates (6). Noise is not only a public health problem, but also has a serious social and economic dimension (10).

The harmfulness or nuisance of noise depends on its frequency, intensity, nature of changes over time, duration of operation and the content of inaudible components, as well as the recipient's age, mental condition, health condition and individual sensitivity to sounds (11).

## NOISE CLASSIFICATION ACCORDING TO FREQUENCY

Infrasound is very low, bass sound to which the human ear does not react. The body may react to infrasound by perceiving their high intensity as vibrations. As a result of overcoming the resistance resulting from inertia and friction, almost all means of transport produce a type of infrasound that is characteristic of them. The body of a speeding car becomes a source of low tones, which can be caused by the so-called motion sickness. Infrasound propagates over very long distances and causes noise at the level of approx. 135 dB. Typical for infrasound is that it is impossible to precisely locate their source, they spread just above the

ground and cover long distances – practically without losing their power (7).

Ultrasound is elastic waves with frequencies above 16 kHz. These waves may propagate in different medias, and in the case of a working environment, it is most often air. The noise in the spectrum of which there are components in the range of audible high frequencies and components of low-frequency ultrasound, is referred to as ultrasonic noise (12). During the operation of some ultrasonic devices (e.g. during ultrasonic welding), the generated noise is close to impulse, which may have a significant impact on the extent of hearing damage. In terms of non-auditory effects, it has been revealed that occupational exposure to ultrasonic noise with levels above 80 dB in the range of audible frequencies and over 100 dB in the range of low ultrasound frequencies causes changes of a vegetative-vascular nature (13).

The use of ultrasound is common and may be described as active or passive depending on its environmental impact. Active applications include: coagulation, medical ultrasound therapy, soldering. Whereas, passive applications include, for example, medical ultrasound diagnostics (12).

### **CLASSIFICATION OF NOISE DUE TO VARIABILITY IN TIME**

Due to the time variability, noise may be divided into: steady noise – variability not greater than 5 dB; transient noise – variability above 5 dB; impulse noise – is the most dangerous noise, it consists of single or multiple sound events lasting less than 1 second (11).

Impulse noise is a significant hazard to hearing. Its mechanism of action on the auditory system differs from that of steady noise. Hearing loss may occur after even one event in which there is exposure to a strong acoustic pulse. This is an example of short-lived but very bothersome noise (14).

A specific type of impulse noise is impulse quasi-stationary noise – composed of a series of pulses with intervals between pulses shorter than 1 second, i.e. with a pulse repetition frequency greater than 1 Hz (15).

### **ENVIRONMENTAL NOISE CLASSIFICATION**

Among the physical factors in the work environment, noise occupies a special place. The concentration of the noise source occurs in urban agglomerations, where we meet the greatest concentration of people. The main sources of noise are:

- economic activity (renovation, construction, industrial noise),
- transport (traffic noise: road, rail, air),
- entertainment and recreation (sports events, loud music),
- natural phenomena (winds, earthquakes, waterfalls, storms) (7).

Industrial noise is local in nature and has a limited range to the immediate surroundings of the industrial plant. Traffic noise has a significant impact on the acoustic climate of the environment, it occurs in large areas along the streets. Due to the rapid development of urban infrastructure, the number of people living in cities is increasing, as well as the number of tram lines and cars. A man who lives in a city is constantly attacked by harmful sounds. Noise related to entertainment activities and music is a fairly recent phenomenon (7). Environmental noise is the most common factor as opposed to other pollutants presenting an unrecognized threat. The level of this noise in the environment is increasing. The reason for this is the development of urbanization, industry and transport (10).

### **NOISE EFFECTS**

Economic development has been observed for some time, which is related to the development of transport. Noise is an inseparable effect of transport activities (16). The impact of traffic noise affects more and more groups of people, causing difficulties in sleep, rest and work, and even causing disease. Noise has a detrimental effect on the human body and may cause:

1. permanent hearing loss or impaired hearing,
2. damage to the nervous system and psyche (drowsiness or irritability, decreased concentration, anxiety, aggression, insomnia, fatigue, prolonged reaction time, stress and its consequences for the whole body and psyche),
3. damage to internal organs (digestive, cardiovascular and musculoskeletal systems, weakening of the immune system, the so-called post-noise syndrome) (7).

The human being is negatively affected not only by audible sounds, but also by sounds inaccessible to the perception of the human ear (infrasound and vibrations). Infrasonic vibrations of the airplane fuselage completely penetrate the pilots' bodies, which may cause: extended reaction time, incorrect assessment of the situation and drawing illogical conclusions (7).

Many people do not even know that their malaise may be the result of being (often against their will) in the zone of infrasound emitted by sound devices, e.g. in clubs or in equipment used during various recreational events. Hearing damage may occur suddenly under the influence of a single impulse – e.g. a firecracker explosion, or it may progress gradually as a result of prolonged and repeated noise of up to 90 dB – e.g. during a concert. Long-term exposure to such noise may permanently damage hearing. In severe cases of noise above the pain limit, the eardrum may even burst. Young children and young people are most at risk of hearing loss or damage due to the impact of noise (7).

Excessive noise damages the hearing – it causes a permanent or temporary shift of the hearing threshold. A person may completely lose his hearing if he exceeds certain intensity thresholds or with prolonged exposure to noise. This factor equally affects the whole organism, causing systemic disorders and ailments (11).

### **PATHOGENESIS OF HEARING DAMAGE DUE TO NOISE**

Excessive noise always causes some degree of damage to hearing. When the ear is exposed to loud sounds for a long time, its blood vessels contract, reducing the supply of oxygen and nutrients to the inner ear. Depending on the degree of damage, the first symptoms of changes in hearing quality are periodic or continuous tinnitus or ringing, as well as loss of the ability to hear high tones and the ability to understand speech in noisy environments (7).

Excessive exposure to noise leads to the development of processes described as metabolic stress or oxidative stress, which result in toxic reactions leading to cell death. Long-lasting noise at industrial levels may lead to micro-damage to the cochlea by direct disruption of microscopic parts of the Corti organ structures. Impulse noise can lead not only to rupture of the eardrum, but also to rupture of the ossicular chain or disruption of the circular window membrane. Damage to the structures of the inner ear may also be associated with spasm of capillary vessels, ischemia of the inner ear and hypoxia of the hair cells (17).

In the initial stage of noise-induced hearing damage, selective destruction of the outer cells of the Corti organ, especially the first and third order, may be observed. The cilia of these cells are extremely susceptible to damage, they may become disorganized, deformed, broken, and even disappear. Chronic exposure to noise may cause secondary dendritic degeneration of the fibers of the auditory nerve, as well as of the spiral ganglion cells, which constitute the first neuron of the auditory pathway. Damage at the level of 30% and above the outer hair cells in a given area of the basement membrane results in a hearing threshold shift. The complete loss of these cells causes a hearing loss of the highest 50 to 70 dB. Then, the hearing damage does not worsen as the internal hair cells are spared (17).

### **CLINICAL IMAGE**

Prolonged exposure to excessively high levels of noise causes the development of sensory cochlear (sensorineural) hearing damage, which slowly worsens. Hearing loss is symmetrical or nearly symmetrical and mainly affects high frequencies, especially in the range 4 to 6 kHz (wave). Medical certification in this disease is based on hearing thresholds at lower frequencies (1.2 and 3 kHz). The assessment of an oc-

cupational disease is aimed at assessing the social performance of hearing, which depends, in particular, on maintaining good hearing in the speech frequency (for the Polish language it is the frequency range from 0.5 to 4 kHz) (18).

Exposure to noise causes damage to the sensitive structures of the inner ear, especially the sensory cells (the external hearing cells of the Corti organ). Due to selective damage to only one type of sensory cells (external hair cells) and the behavior of the other type (internal hair cells), the hearing impairment is not very deep or bordering on deafness (18).

### **ACOUSTIC TRAUMA**

Acoustic trauma is hearing damage that is caused by a single exposure to noise. This hearing loss causes several types of noise, including: pure tone, street and industrial noise, explosions and gunshots (19).

The size of the hearing loss depends on: the duration of exposure to noise during the day and throughout life, the intensity and type of noise (intermittent, continuous, impulse), the patient's age, gender and the ear's individual sensitivity. The most common is sudden high-frequency sensorineural hearing loss with accompanying tinnitus (19).

Acute acoustic trauma is caused by noise with a very high level of sound pressure, usually exceeding the pain threshold (120-140 dB). The result of such a stimulus is a sudden (temporary or permanent) sensorineural hearing impairment, often unilateral, accompanied by tinnitus. When the structures of the outer or middle ear are damaged at the same time, mixed hearing loss may occur (19).

Three degrees of acute acoustic trauma can be distinguished: slight – manifested by temporary noise and dizziness; moderately severe – causes minor damage to the ear, symptoms in the form of noise and hearing impairment may be irreversible; severe – severe changes in the ear appear, which lead to severe hearing impairment or deafness (20).

Children and adolescents are extremely sensitive to hearing damage caused by noise. Sudden hearing loss in children can be caused by children's toys and fireworks. Discos, rock music concerts and shooting are a high risk (19).

### **OCCUPATIONAL HEARING IMPAIRMENT**

One of the problems of civilization all over the world is hearing loss and tinnitus. Hearing impairment is not only related to the aging process, it affects people of all ages. The main external cause of hearing loss that is encountered is environmental influences, namely excessive exposure to loud sounds such as surrounding noise (21).

Noise-induced hearing loss is defined as a symmetrical, slowly progressive, sensorineural hearing loss that mainly relates to high frequencies, with a typical waveform for 3-6 kHz. This hearing loss develops over many years of exposure to high noise

levels. The severity of hearing damage is relatively fast in the first 10 years of exposure and then slows down (22).

Long-term exposure to noise in the workplace causes deterioration of hearing. The noise affects both ears simultaneously. The destruction processes that occur under the influence of noise are irreversible. The hearing organ receptor in the cochlea is damaged. The process that turns a sound stimulus into an electrical impulse is impaired. Therefore, the conduction of sound from its source through the outer ear and middle ear is unaffected (23).

The effect of chronic noise exposure is progressive sensorineural hearing loss. Noise can also cause extra-auditory effects, increasing the risk of such disorders as: coronary artery disease, arterial hypertension, tachycardia, neurotic syndromes, sleep disorders and hormonal disorders (24).

Hearing loss largely depends on: noise intensity, noise frequency range, duration of exposure, the nature of chronic or acute exposure to noise, individual susceptibility to noise and the lack of using hearing protectors (23). The acoustic energy absorbed by the hearing organ is much more harmful in the event of continuous exposure to noise. The same amount of energy separated by breaks causes less damage to the hearing organ (25). Individual factors that increase the risk of hearing damage include: gender, age, complexion, chronic metabolic diseases, smoking, general health condition of the worker, used ototoxic drugs, heavy metals, pesticides, and organic solvents (24).

Performing work with exposure to noise may have several contraindications. These include diseases of the hearing organ, which include: sensory, permanent shift of the hearing threshold above the values resulting from the aging process, discharge from the middle ear that does not disappear despite treatment or previous operations, Ménière's disease and other diseases of the inner ear (26).

Hearing damage associated with exposure to noise in the workplace is irreversible and incurable. For many

years, occupational hearing loss has been at the forefront of occupational diseases (27).

In the adult population, approximately 16% are hearing loss related to occupational exposure to noise, which is the second, after aging, etiological factor of hearing-related abnormalities (20). About 187.5 thousand people in Poland are exposed to noise (28). Currently, occupational hearing disease is on the 5<sup>th</sup> place on the list of occupational diseases (27).

Most of the diagnoses of hearing loss as an occupational disease relate to people in the period of full professional activity (under 60 years of age). It should also be taken into account that this disease affects the majority of men, thus indicating a significant decline in the potential of professionally active workers (23). A significant increase in the identified cases of occupational hearing damage reflects the presence of a harmful factor – noise in various sectors of the economy, especially in heavy industry (25).

Due to the irreversible nature of occupational hearing damage, preventive measures should be taken. By taking such measures, you should prevent complete loss of hearing. Prophylaxis of occupational hearing damage is widely understood, it defines a number of measures reducing the risk of developing hearing damage in workers professionally exposed to noise. Preventive activities should take place in the context of many aspects, including technical means to reduce noise at the source, e.g. isolating noise-damped work stations or work breaks; using hearing protectors; preventive medical care. Hearing protectors are the most common way of protecting the hearing organ against the negative effects of noise in the work environment (29).

Workplaces in the field of organizational activities should be distributed in a way that allows isolation from the noise source and, at the same time, limiting the impact of other noise sources on the employee (13).

The employer may not consent to the admission to work of an employee who does not have a valid medical certificate expressing no contraindications to work in a specific position (13).

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