



Personal Music Players & Hearing

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Level 2 - Details on Personal Music Players & Hearing

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The answers to these questions are a faithful summary of the scientific opinion produced in 2008 by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR):

"Potential health risks of exposure to noise from personal music players and mobile phones including a music playing function"

GreenFacts was contracted to prepare this summary by the DG Health and Consumers of the European Commission, which authorised its publication.

The full publication is available at: <http://copublications.greenfacts.org/en/hearing-loss-personal-music-player-mp3/>
and at: <http://ec.europa.eu/health/opinions/en/hearing-loss-personal-music-player-mp3/>



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- Each question is answered in Level 1 with a short summary.
- These answers are developed in more detail in Level 2.
- Level 3 consists of the Source document, the internationally recognised scientific opinion which is faithfully summarised in Level 2 and further in Level 1.

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1. Why do personal music players raise health concerns?

1.1 When are we exposed to noise and sound?

Exposure to excessive noise or sound can result in hearing loss.

To protect workers, limits have been set for the levels of noise allowed in the workplace.

Background noises to which the general public is exposed - such as those from traffic, construction, aircrafts or from the neighbourhood - can be very irritating but are in most cases not loud enough to harm hearing.



Across the EU, millions of people use PMPs daily
Source: GreenFacts

Thirty years ago, exposure to noise at work was considered a significantly greater threat to hearing than leisure noise. However, since then there have been huge changes in the patterns of sound exposure. Increasing numbers of young people are exposed to loud sounds in their leisure time while exposure at work has decreased. Sounds such as music, if played very loudly, can be as dangerous for hearing as industrial noise. The cause for concern is not restricted to music from nightclubs and rock concerts, which can be extremely loud, but also extends to the new generation of personal music players, such as portable MP3 players (and mobile phones including a music playing function). These have become increasingly sophisticated and can play sounds very loudly across a broad range of frequencies, which makes them a cause for public concern. In the last decade, these devices have been used by an increasing proportion of the population. Around 200 million personal music players were sold in Europe between 2004 and 2007. In addition, some 16 to 32 million mobile phones including a MP3 function were sold in 2007 alone and their number is expected to increase considerably in the next few years.

This assessment considers potential health risks linked to the use of personal music players. Its conclusions are based on evidence from a wide variety of sources, including peer-reviewed scientific literature and published reports of institutional, professional, governmental and non-governmental organisations. All publications have been considered and each article has been evaluated and assessed to decide the scientific weight that is to be given.

1.2 What are noise and sound?

The word 'noise' has different meanings in different disciplines. In the world of sound, 'noise' is any sound not desired by a certain observer. Working environments such as factories and the transport industry use the terms 'noise protection' and 'noise-induced hearing loss and impairment' while professional musicians do not use the term 'noise' when they refer to exposure to sound at work.

The common practice is to use the term 'noise' when talking about health effects, regardless of the noise exposure being wanted, e.g. when using a personal music player; or unwanted, e.g. in the workplace. In this publication, the word 'sound' usually implies that the person concerned is listening to a particular sound voluntarily and not as an involuntary bystander.

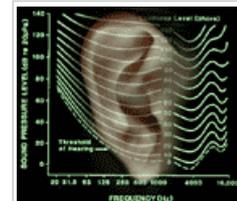
Sound is caused by vibrations and carries energy as a wave through all media – air, water, walls, windows etc. – but not through a vacuum. . In most situations sound is a complex sum of many signals from different sources which may interfere with each other. Like all waves, a particular sound can be described by a combination of individual frequencies which together form a pattern called the spectrum of the sound waves.

The exposure to sound is determined by many factors which are not always easy to assess. Indoors, these include the size and shape of a room, furniture, as well as the type of materials covering the surfaces and surrounding the source of the sound.

2. How is sound measured?

2.1 What are the units for measuring sound

Sound can be measured as a change in pressure when sound waves reach the ear or a measuring device. Sound exposure is usually measured in **decibels of sound pressure level** (dB SPL), which is a measure of the sound pressure level relative to the lowest hearing threshold of the young, healthy ear set as 0 dB. The scale is logarithmic and a ten-fold increase in the sound pressure level measured corresponds to an increase by 20 dB SPL.



Low and high-pitched sounds appear less loud to the human ear [see Annex 3, p. 22]
Source: GreenFacts

Examples of sound pressure levels (in dB SPL):

- 0 dB: Hearing threshold
- 20 dB: Leaves fluttering
- 30 dB: Whisper in the ear
- 60 dB: Normal speech conversation for a participant
- 60-100 dB: Motor vehicles for a close observer
- 120 dB: Airplane taking off for a close observer
- 120-140 dB: Pain threshold

The sound pressure of a normal conversation (60 dB) is 100 times greater than that of leaves fluttering (20 dB). Sound pressure of an aircraft taking off nearby (120 dB) is in turn 1000 times greater than that of a normal conversation (60 dB).

Humans can detect low to high-pitched sounds with frequencies ranging from 20 Hz to 20 000 Hz. However, the ear is more sensitive to some frequencies than to others. It is particularly attuned to sounds with frequencies between 3000 and 4000 Hz. Sounds with lower and higher frequencies do not appear as loud. To take into account different sensitivities to different frequencies, a unit of **decibel of hearing level** (dB HL) has been introduced.

An "A-weighting filter" is commonly used when measuring exposure to sounds in order to emphasize frequencies the human ear is most sensitive to, while attenuating frequencies to which the ear is insensitive. The sound pressure levels measured through this filter are expressed in dB(A) and provides a good indication of the hearing sensation or loudness of different sounds to humans.

2.2 What are the methods for measuring sound

Each sound has a specific pattern of frequencies which can be detected by the ear or by measuring devices.

To measure the level of exposure to sound in the open field – for instance at work or when listening to music without headphones – a sound meter is placed at the point where the listener would be.

Sounds from headphones are usually measured by artificial ears placed inside a manikin, which represents an average of many torsos and ears of men and women with different anatomies. The sound pressure levels are measured at the eardrum and they are assumed to compare well with real levels.

The sound levels measured by artificial ears must be adjusted to become comparable with measures by sound meters in the open field. Indeed, sound perceived by the human ear depends not only on the sound signal but also on factors such as the shape of the torso, the clothing, the hair style, head shape, size and shape of the ear and the inside of the ear, the characteristics of the eardrum and distortion due to other listeners or objects in the room.

Based on the sound pressure measurements it is possible to establish:

- an average sound level over a period of time (hour, day, week),
- the highest sound level recorded (peak pressure level)
- the equivalent continuous sound level that contains the same amount of energy as the actual varying sound (8-hour equivalent level, $L_{\text{equ},8\text{h}}$)

3. What are current sound protection limits?

So far, limits have only been set to protect workers from excessive noise exposure and not for other situations such as the use of personal music players with headphones. The limits are nonetheless relevant to other situations where sound can have harmful effects.

The risk of hearing damage depends on sound level and on exposure time. For long-term exposure of workers, time periods of 8 hours per day are typically considered in order to set protections standards. In cases where exposures vary markedly from day to day, weekly sound exposure levels (8 hours per day for 5 days per week) can also be useful.

Because sound levels vary in time and from worker to worker, protection standards are expressed as an equivalent continuous sound level (L_{equ}) that would contain the same amount of energy as the sound heard.

In the late 1990s, international standards established limit values for long-term exposure of workers to noise. According to these standards, action should be taken to protect workers who are exposed to an equivalent continuous sound level of 85 dB(A) or more for 8 hours per day, 5 days per week. This limit was set by the International Organization for Standardization (ISO) and the US National Institute for Occupational Safety and Health (NIOSH). However, this limit did not guarantee the safety for the auditory system of workers.

More stringent action levels were introduced in the EU since 2003 with the EU Noise at Work Regulations (Directive 2003/10/EC) which came into force in 2006. It recommends three protection levels at the workplace depending on equivalent noise level for an 8-hour working day.

Action levels:

- At 80 dB(A) employers shall make hearing protectors (e.g ear plugs or muffs) available to workers. Below this limit, the risk to hearing is assumed to be negligible.
- At 85 dB(A) protection of workers is mandatory.
- 87 dB(A) is the maximum exposure limit value.



Limits have been set to protect workers from excessive noise.
Source: Shutterstock

Because the risk of hearing damage from long-term sound exposure depends both on the level of the sound and on the exposure time, there is a trade-off between the two factors.

As a result, listening to loud sounds over many hours per day entails a similar risk as listening to an even louder sound for a shorter period per day. In order not to increase overall exposure, each 3 dB increase in sound levels must thus be compensated by halving the listening time.

For instance, listening to a personal music player at 95 dB(A) during 15 minutes per day is equivalent to being exposed at work to 80 dB(A) during 8 hours per day, under the assumption that these exposures are repeated over a long period of time.

Further equivalents are presented in the following table. Increasing either exposure time or sound levels beyond the above limits could lead to hearing damage.

EU Action levels for noise protection at work [see Annex 1, p. 21]

4. In what ways can hearing be impaired?

4.1 How is hearing loss defined and classified?

Hearing impairment refers to the complete or partial loss of the ability to hear from one of both ears and can be graded as mild, moderate, severe or profound. When the hearing threshold in the better ear is at or below 25 dB, this will pose very little or no hearing problems. At the other extreme, threshold values in the better ear at or above 81 dB result in the listener being unable to hear and understand even a shouted voice.



Table 4. World Health Organisation Grades of hearing impairment (WHO, 2008) [see Annex 4, p. 23]

Hearing impairment that is caused by a problem in the outer or middle ear can usually be treated. When the impairment is due to problems in the inner ear or the auditory nerve going from the ear to the brain, the hearing loss is usually permanent. Common causes of this type of hearing problem are ageing, excessive exposure to loud sounds and some drugs.

Hearing is usually tested by presenting sounds of different frequencies to the listener and measuring the lowest volume of the sound that the listener can detect. The threshold of hearing is set at 0 dB HL and levels between 0 and 20 are considered to be normal.

Any sign of a shift in this threshold, even within the normal range, could be a sign of impairment so it is important to assess any such change, particularly for children.

Hearing impairment may also arise in people with normal threshold levels of hearing but who cannot process the sound signals properly and therefore find it very difficult to understand speech. Other people have trouble focusing on particular sound frequencies; they cannot tune in to sounds of interest and are distracted by background noise.

4.2 How is speech comprehension affected by sound exposure and hearing loss?

The ability to understand speech depends on how loudly a person speaks and on hearing loss, and can be described by mathematical models. A normal-hearing person can understand the words in a sentence if about 30% of the information is present. Listeners can fail to understand speech if the volume of the sound is below the threshold value they can hear, or if there is a background noise that masks the sound signal.

In everyday situations, listeners are exposed to combinations of many different sounds. People with hearing loss at high frequencies have difficulties understanding speech in noisy environments such as a party where there are many different conversations taking place or in large rooms with a lot of echoes such as a church hall. For instance, if a normal-hearing person can communicate at a party at a distance of about one meter, a high-frequency hearing loss of about 40 dB makes it impossible to do so; the listener has to come closer to the speaker and reduce the distance to half a meter.

People with a more significant hearing loss at high frequencies will find it impossible to understand speech in noisy environments unless they get extremely close to the speaker, which may be socially unacceptable. Hearing aids can only partly compensate such loss. Therefore, high-frequency hearing loss, whether aided or not, will cause poorer speech understanding in a noisy environment.

4.3 What is tinnitus?

Tinnitus is a condition in which a person hears a ringing, buzzing or hissing sound which is caused by the hearing system and not by any external sources. Tinnitus can either be objective, when the sound can also be detected by an external examiner, or subjective, when no such sound can be detected.

Tinnitus is often associated with hearing impairment, ageing or exposure to loud sounds, and generally involves the part of the nervous system that deals with hearing. Sometimes it is very short-lived and happens only after exposure to loud sounds but it can also be more persistent. Tinnitus that lasts for more than five minutes and not only after loud sounds is called 'prolonged spontaneous tinnitus' (PST).

Estimates of the proportion of people with this type of tinnitus vary depending on the method used to collect data. For instance, in a study published in 2007, 17.7% of the people questioned said that they had such tinnitus at some stage in their lives, about 4% had tinnitus most of the time and 0.4% had their quality of life substantially affected by tinnitus. Studies in young people show that people with substantial exposure to loud sounds are more likely to have tinnitus than their unexposed peers, and the higher the exposure the greater the likelihood of developing tinnitus.

Little is known about how subjective tinnitus happens in the body although there are many theories that try to explain it. Some theories involve sensory cells or nerve fibres in the ear which are more active than normal. Other theories focus on the organ of the inner ear that converts sound into electrical impulses (cochlea). When it is damaged, the nervous impulses in the hearing system may become very active and the brain may not be able to suppress them.

4.4 How is hearing affected by age?

Hearing ability deteriorates with age in virtually all people and this deterioration accelerates for older people. In other words, with age the hearing threshold is no longer as low as at 18 years old.

In young adults, up to the age of 40, this process is slow and leads to negligible levels of hearing impairment. Some older people are a lot more affected by hearing loss than others.

5. How can sound exposure lead to hearing loss?

Sound-induced hearing loss is irreversible and the main form of treatment is prevention. Commonly, damage to sensory cells of the inner ear builds up over time. The hearing loss goes unnoticed at first and increases until it reaches a certain degree where it becomes obvious to the affected person. In rare cases, exposure to very loud sounds can lead to immediate damage.

5.1 How many people are affected by sound-induced hearing loss?

Excessive exposure to loud sounds is a major cause of hearing disorders worldwide and is the main avoidable cause of permanent hearing loss.

Among workers, noise-induced hearing loss is the most common irreversible occupational disease. Worldwide, 16% of the disabling hearing loss in adults is caused by exposure to noise at work, although this proportion varies in different parts of the world from 7% to 21%.

Sound-induced hearing loss affects an estimated 10 to 15 million people in the USA. In the UK, about 350 000 people aged 35 to 64 years have serious hearing difficulties, including tinnitus, caused by exposure to noise at work. In France, a survey carried out in 2003 indicates that 7 % of employed workers were exposed to excessive sound levels above 85 dB(A) for at least 20 hours a week . Most exposed workers belonged to industry agriculture or the building sector.

In recent years, exposure to noise at work has decreased while exposure to loud sounds during leisure activities has become increasingly important, particularly for young people. In the USA, among a sample of children and teenagers aged 6 to 19 years 12.5% were found to have some hearing loss in one or both ears caused by exposure to loud sounds. The extent of the loss was larger for boys than girls, and for older children than younger ones. At present there is no equivalent data on the European population.

5.2 What sound levels are we exposed to in our daily lives?

Average noise levels in certain working environments can reach up to about 90-125 dB. People also expose themselves to loud sounds in their leisure activities. Outside the workplace, a high risk of hearing impairment arises for instance from attending rock concerts and discos, from practicing noisy sports such as shooting, and from exposure to military noise. Children could be exposed to noisy toys such as trumpets (92 to 125 dB SPL), whistles (107 to 129 dB SPL) and toy weapons (113 to over 135 dB SPL).

Listening to music played at high volumes can be as dangerous to hearing as industrial noise. This applies not only to rock concerts or nightclubs but also to personal music players (and mobile phones with music playing function) which can generate sounds across a broad frequency range at high volumes without distortion.

In our daily lives we are also exposed to environmental noise from traffic, construction, aircraft or various noises in the neighbourhood. These noises do not reach levels that can damage hearing but can be very irritating and cause other harmful effects.

5.3 What is the relationship between sound exposure, hearing loss and age?

Our current knowledge of the relationship between exposure to loud sounds and consecutive hearing loss is based on studies carried out several decades ago on individuals exposed continuously to high levels of noise at work. Tables compiled based on these results were used to establish the first international standards and are still widely used to predict hearing loss in populations exposed to noise while taking into account the effects of age. Based on the noise exposure and age of individuals, it is possible to estimate the likelihood that their hearing loss reaches or exceeds a certain level.

To draw conclusions on the impact of personal music players, findings for continuous noise exposure at work in the range from 80-95 dB(A) are particularly useful.

Predictions show that exposures at 80 dB(A) for 45 years (8 hours per day 5 days a week) have a minimal effect on hearing loss but exposures at higher levels result in hearing loss. For instance, exposure at 95 dB(A) for 45 years results in 26.5 dB of hearing loss for high-pitched sounds at a frequency of 4 kHz, which is the frequency at which hearing loss is most rapid. Most of the damage occurs in the early years of exposure, so preventive measures must be particularly aimed at those who start listening to personal music players when young.

Because potential consequences only become obvious many years later, most young people have normal hearing, whether or not they have been exposed to loud sounds.

Regularly listening to personal music players at high volume settings (above L_{Equ} 80 dB(A)) at a young age will result in a larger proportion of people aged 18 to 40 with moderate levels of hearing loss at some frequencies; and the overall impact on hearing will be even larger in old age.

At typical sound levels, the hearing damage caused by noise exposure takes many years to become apparent. However, hearing loss for high-pitched sounds at 4 kHz can be detected at an earlier stage. Testing hearing at that frequency thus allows predicting future hearing problems.

5.4 How do loud sounds affect the inner ear?

Extremely loud sounds such as those produced by bomb blasts can cause small cracks in various parts of the ear which can be seen with a simple microscope. However, in most cases, the damage to the inner ear occurs at cellular level and is thus less visible.

Sensory cells in the inner ear (hair cells of the cochlea) convert sounds into signals that can be interpreted by the brain and losing these cells causes permanent hearing loss. Different hair cells are receptive to different sound frequencies. The wider the loss, the

larger the number of sound frequencies that are affected. For each frequency, the greater the number of lost cells, the larger the hearing impairment. Because of the shape and the characteristics of the human outer and middle ear, excessive exposure to loud sounds makes individuals less sensitive to high-pitched sounds at frequencies of 4 to 6 kHz.

Losing one type of sensory cells completely (outer hair cells) results in a hearing impairment of 50 to 70 dB and also makes affected individuals less capable of focusing on a particular frequency and therefore less able to understand speech in noisy environments.

Recent advances made using more powerful microscopes show that losing or damaging hair cells is not the only factor that harms hearing. Loud sounds can also harm other types of cells, such as nerve cells, in the organ of the inner ear that converts sound into electrical impulses (cochlea). However, the chain of events that leads to cell damage and to the resulting hearing loss is not well understood at present.

Short exposures to steady loud sounds can damage the cochlea but this damage is usually reversible and the effect on hearing loss is temporary. Repeated exposures to very loud sounds can cause irreversible damage; in that case the hearing loss is permanent.

The likelihood that exposure to a particular sound will result in temporary or permanent hearing loss depends not only on loudness and exposure time but also on **how quickly sound levels increase**. The body has a reflex to contract certain muscles in order to protect the ear from excessively loud sounds. Sudden, very loud sounds such as explosions occur too quickly for the body to activate this reflex and are therefore a lot more harmful to hearing than steady sounds, in particular at high frequencies.

The inner ear of some people is more **vulnerable** to damage than that of others. Several factors – some of which are genetic – play a role, such as smoking, high blood pressure, fat levels, age, gender, as well as other anatomical characteristics.

5.5 What factors can change the way sound exposure affects us?

New research has uncovered a series of factors playing a role in either preventing or exacerbating sound-induced hearing loss.

Amongst the **protective factors**, exposure to safe levels of certain sounds could both protect the listener from damage caused by a later exposure to loud sounds and help them recover from previous excessive exposure. This observation is relevant to the treatment of sound-induced hearing damage.

Some nerves in the hearing system influence the way the inner ear responds to potentially harmful sounds and may therefore have a protective role, although these nerves seem to play no part in the normal functioning of the ear.

Other factors exacerbate the effects of loud sounds. For instance, exposure to loud sounds at a young age can make the ear more vulnerable to ageing. Over the years, there are small unnoticeable effects on the inner ear that only become evident many years later when the affected person develops hearing loss. Exposure to certain chemicals, smoking or lack of oxygen supply to the body also increase sound-induced hearing loss.

Several newly tested **drugs** have been shown to either prevent or repair sound-induced hearing loss. For instance some anti-inflammatory drugs help recover hearing after excessive exposure to loud sounds. Drugs with antioxidant properties protect the body from sound-induced hearing loss and some of these are already used in some countries.

Exposure to loud sounds can produce some initial damage to the inner ear, for instance by causing inflammation. This triggers processes that cause cells to destroy themselves and results in further damage through the loss of sensory and nervous cells. Several drugs can prevent this sound-induced cell death but are unlikely to be used in the near future because the doses required are too high. Drugs that promote the growth and repair of nervous cells and several other treatments, particularly the intake of magnesium, also protect against sound-induced hearing loss.

6. Hearing damage diagnosis, vulnerability & treatment

6.1 How is hearing damage diagnosed?

Sound-induced hearing damage is not limited to deafness or an inability to hear certain sounds, but also includes difficulties understanding speech in noisy environments, ringing in the ears (tinnitus) and hypersensitivity to loud sounds.

The initial damage caused by loud sounds is often small and causes slight hearing problems that disappear some time after the sound exposure, so these often go unnoticed.

With repeated exposure to loud sounds, hearing disturbances increase. By the time they are noticed, the damage has become permanent and almost always incurable.

Hearing loss can be measured by exposing the individual to sounds of different frequencies and recording the lowest sound level that is heard by the listener on a graph called an audiogram. These graphs show that sound-induced hearing loss commonly occurs at high frequencies, especially at 4000 Hz. However, many people may have normal hearing within the range of frequencies usually tested and yet have sound-induced hearing loss. To detect damage even earlier, measurements can be carried out at even higher frequencies.

Another method used to detect or monitor hearing damage is to measure directly how the body responds to sounds rather than asking the listener when they can perceive a given sound. Tests are often done by detecting the response by the ear to soft sounds. There are a variety of tests; some can give a quick but rough indication of hearing loss, and others give a more detailed measure of hearing loss at different frequencies.

Excessive exposure to loud sounds can not only damage the organ of the inner ear that converts sound into electrical impulses (cochlea) but also the part that contributes to balance and spatial orientation (vestibule). Balance involves the eye and the ear but also the neck muscles that keep the head stable. Hearing damage can therefore be assessed indirectly by creating a sound and measuring how the neck muscles react to it.

Temporary or permanent high-pitched ringing in the ear (tinnitus) induced by loud sounds can sometimes be the only indication of hearing damage in the early stage, which may then be accompanied by hearing loss with continued exposure. After exposure to very loud or sudden loud sounds, tinnitus appears rapidly and is often temporary. In opposition, when it results from continuous long-term sound exposure, tinnitus often only appears after several years but remains permanent (see also section 10.3).

To treat or alleviate tinnitus, electrical stimulation of the organ of the cochlea and different drugs have been tried as possible options but results are uncertain. Psychological therapies remain the most common treatment method and when tinnitus becomes permanent, wearing a hearing aid may also help.

Illustration of audiogram

6.2 Are certain individuals particularly vulnerable to sound exposure?

Illustration jackhammer worker

Some individuals are more vulnerable to excessive sound exposure than others, as a result of external conditions or genetic predispositions.

For instance, exposure to loud sounds in combination with other exposures to some chemical substances such as organic solvents, asphyxiants, heavy metals and medicines, or to vibrations, may produce more severe hearing impairment than would be expected as a result of sound exposure alone.

Being exposed to loud sounds and to **organic solvents** at the same time can lead to hearing loss, even if the sounds alone would cause little or no harm. This risk for hearing loss increases with the number of solvents involved.

Heavy metals tend to accumulate in the body and cause toxic effects.

- Mercury poisoning can have many consequences including hearing loss and deafness.
- Cadmium can cause hearing loss and the effect is greater if the exposure to loud sounds and to cadmium happens at the same time.
- Arsenic overexposure leads to hearing loss for **low-pitched** sounds and balance disturbances.
- Exposure to lead may affect the inner ear but scientific evidence is inconsistent.

Certain gases (asphyxiants) such as carbon monoxide and hydrogen cyanide impede oxygen transport in the body when breathed in. In animals, they have been found to increase the damaging effect of loud sounds on hearing. Such combined effects in humans have not yet been fully demonstrated.

People working with vibrating tools, such as jackhammers, can develop hearing loss. The effect is worse if exposure to **vibration** and to loud sounds occurs at the same time. It is unclear whether body vibration causes any damage.

Several **medicines** can cause hearing loss, usually by damaging the sensory cells in the inner ear. The effect depends on the dose, way of administration and type of medicine.

- For instance, long antibiotic treatments against severe bacterial infections can cause irreversible hearing loss in people with specific genetic traits, particularly if they have previously been exposed to loud sounds.
- Some drugs used to treat cancer can also cause hearing loss, particularly for high-pitched sounds. Exposure to loud sounds during chemotherapy therefore significantly increases the risk of hearing damage.
- Other medicines that can damage hearing, to a lesser extent, include certain anti-inflammatory drugs, as well as drugs to prevent malaria and drugs for reducing water retention.

Studies have tried to identify genes that could be involved in sound-induced hearing loss but the results are not conclusive. Apart from specific genes, other genetically dependent factors that may influence sound-induced hearing loss are eye and skin colour, gender, age and height. For example, people with blue eyes and white skin seem to be inherently more vulnerable to noise-induced hearing loss than others.

Vitamin deficiencies and smoking are other factors that increase the risk of hearing loss.

Abnormal blood pressure levels have also been observed in combination with sound-induced damage but it is not clear whether it is a cause or a simultaneous effect.

The left ear seems to be slightly more vulnerable than the right one.

6.3 How can sound-induced hearing loss be treated?

Several therapies used in the past to treat hearing loss have proved to be efficient in case of acute sound-induced hearing loss. These include ingestion of steroids or magnesium, and breathing in oxygen through a mask or inside a high-pressure chamber.

Recent progress in biology has led to the development of new drugs with promising results. Several drugs with anti-oxidant properties, that prevent cell damage, have proven to be effective in animal experiments but further research is needed before they can be used to treat humans. Other new drugs that prevent cells from destroying themselves have also given good results in tests on animals as well as humans.

7. What are the characteristics of personal music players

Personal music players are portable devices that play audio files, such as MP3 files, using earphones or speakers. In addition, many of these devices can store videos and pictures, and podcast radio and TV programmes. Personal music players are used widely for leisure activities or work purposes, and some children use them as toys.



To identify the risk of exposure to sound from personal music players, it is useful to understand how music is recorded and reproduced as this influences the level and quality of sound output delivered by the personal music player.

- First, sounds are recorded through a microphone that perceives the pressure changes. The recorded information can be stored in different formats (digital or analogue) and compression levels using a variety of procedures.
- Then, when playing the audio file, the player reproduces the recorded sound signal. Manufacturers usually specify the electronic characteristics of the personal music players that determine for instance the maximum sound output level.
- Finally, to produce sound the personal music players are connected to loudspeakers, either headphones or external speakers of many different types. Some headphones have large pads that cover the ears and others sit directly above the ear. Earphones or **ear-buds** are smaller in size and are placed inside the ear, just outside or in the ear canal. These headphones transform the electronic output of the player into sound energy. In that perspective, two aspects may influence the sound output: the way the headphones are plugged into the player and the characteristics of the headphones.

The volume of the sound emitted by personal music players varies from manufacturer to manufacturer, and is difficult to estimate. The amount of sound energy that reaches the eardrum also depends on the type of music, on the type of headphone used, and in the case of ear-buds on how deeply they are inserted in the ear canal. In general, the smaller the headphone, the greater the amount of sound energy transmitted for a given volume

setting. A study showed that for a given volume setting of the player, **ear-bud** type headphones produce a sound output that is 7-9 dB(A) higher than that of standard headphones.

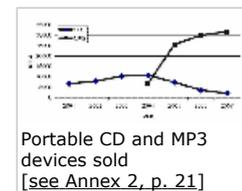
So, sound levels from personal music players depend on a series of factors. With the digital formats of sound recording and reproduction currently available, such as MP3, it is possible to reach high levels of sound output without distortion. At the maximum volume setting, sound pressure levels reaching the eardrum can range from 91 to about 121 dB(A) for different player-headphone combinations.

8. How are personal music players typically used?

8.1 At what volume settings and for how long are they typically used?

Most users of personal music players choose sound volume settings which are unlikely to cause hearing loss. However, some people set the volume control very high or listen to music through personal music players for many hours per day.

Volume settings chosen by the users of personal music players generally range from 80 to 115 dB(A), while mean weekly exposure time ranges from less than an hour to 14 hours and is typically longer among men. The type of music and environment only slightly influence exposure levels. Listeners tend to increase the volume of their sets by about 4 dB if there is background noise.



In the 1980s, several studies focused on the way teenagers used portable cassette players with headphones and compared sound exposure levels to those permissible at work at the time (equivalent to 90 dB(A) for 8 hours per day 5 days a week). In a study carried out among college students in New York, nearly one third of the users of personal music players exceeded permissible exposure levels, and many of them exceeded them drastically. In a later study, the listening habits of 5% of users exceeded those levels, which would lead to hearing damage in the case of long term use. In the light of current guidelines, which are even more stringent, 10% of the users covered by this study would have exceeded permissible levels.

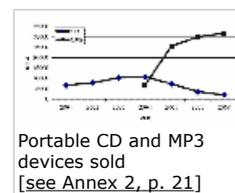
In 1995, a study concluded that 5% of the young people they tested could have a permanent hearing loss of 20 dB after 5 years of use of personal music players. Restricting the maximum output level of personal music players to 90 dB(A) would therefore limit the risk of hearing loss.

It is very difficult to establish a safe limit in terms of sound volume and duration of exposure. To protect the hearing of most consumers, a 2004 study recommends limiting listening time to one hour of per day and setting the volume to no more than 60% of maximum sound output when using headphones that are placed over the ears. When using earplugs inserted in the ear canal that deliver more sound energy to the ear drum, the maximum volume control setting that can be considered safe would be significantly lower.

A recent study on risk perception and exposure to loud music showed that although women generally judged exposure to loud sounds as more dangerous than men do, they nevertheless behave in the same way. Adolescents reporting tinnitus judged loud music as more risky than those with no symptoms and they did not listen to music as loudly.

8.2 How many units have been sold on the EU market?

From 2004 to 2007, an estimated 184 to 246 million personal music players were sold in the EU as a whole. Some 124 to 165 million of these were MP3 players and some people bought more than one device in that period of time. Since 2004 there has been a dramatic increase in unit sales of MP3 players which in 2007 represented 83% of the personal music players sales.



(Figure 1) Figure 5 Number of portable CD and MP3 devices sold in ten European countries between 2001 and 2007 (in thousands).

Regarding cell phones, approximately 10% to 20% of those sold in 2007 in Europe now have a music playing function similar to those of MP3 players and this proportion will probably increase in the coming years. At present, 16 to 32 million of these devices have been sold. However, it is not clear whether all people who have access to those features actually use them.

Overall, in the EU the estimated number of daily users of personal music players (including MP3 players) and mobile phones with MP3 function could be very high, in the range of 50 to 100 million people.

9. How can listening to music harm hearing?

Exposure to loud sounds is the main cause of hearing loss. Until 30 years ago, most harmful noise exposures took place at the workplace. Today, adults as well as adolescents and children are increasingly exposed to loud sounds in their leisure time, notably through the use of personal music players (and mobile phones with MP3 function)



9.1 Is hearing loss increasing among young people?

Most epidemiological studies on hearing, including very recent ones, have not found any increase in hearing loss in young people over the last decades nor have they established any link between listening to music and hearing loss. According to these studies, the proportion of young individuals with slight hearing alterations as a consequence of excessive exposure to loud sounds has remained constant over the last 20 years and ranges between 5% and nearly 20%.

However, some studies have found the proportion of people with sound-induced hearing damage to be greater in younger generations. A study from 2005 shows for instance that, with time, as young teenagers grow and spend more time in leisure activities involving music (such as attending discos and listening to personal music players) they gradually lose the ability to hear quiet sounds. The authors concluded that exposure to loud sounds during leisure activities, but not necessarily from personal music players, could be a cause of permanent hearing damage among young people with sensitive ears.

To summarise, most epidemiological studies do not support the view that there is widespread hearing loss caused by exposure to loud music in young people under the age of 21 years. However, some authors stress that if young people continue to listen to music for long periods of time and at high volume levels during several years, they run the risk of developing hearing loss by the time they reach their mid-twenties. Different testing methods have detected slight hearing alterations which could be early signs of hearing impairment.

9.2 Can using personal music players raise the hearing threshold?

People exposed to loud sounds from personal music players run an increased risk of hearing loss, which means that their hearing threshold is no longer as low as before and that it becomes harder for them to hear weak sounds.

Short exposures of a few hours at levels close to the maximum volume setting of the device can cause immediate effects which are temporary.

Over several years, permanent effects may result from repeated daily exposures to moderate sound levels that exceed the exposure that is allowed in a work setting.

The **temporary effects** of using personal music players on hearing have been studied by exposing healthy volunteers to different volume levels of music for a few hours. Many of these volunteers had a higher hearing threshold after being exposed to relatively loud music; however, the effect was temporary and the hearing threshold returned to normal within minutes in some cases, and within 24 hours in others. The type of music did not influence the results but loud music from percussion instruments seemed to raise the hearing threshold more than other types of sounds.

Regarding **permanent effects**, results of studies are contradictory. Most studies using conventional hearing tests show that listening to loud music has no effect on hearing threshold. However, the hearing test results of some users of personal music players show a distinctive pattern that is consistent with sound-induced damage. In a study from 1996, tinnitus and temporary hearing loss were found to be three times more frequent in personal music player users than in non-users. The study also found a permanent hearing loss among young users, but only for those who listened to loud music for more than 7 hours a week.

In a 1998 study, results of sensitive tests that detect slight changes in hearing were analysed for a group of people aged 10 to 59. Although only a few of these people reported any hearing problems, the results of the tests showed a difference between users and non-users of personal music players, but not among teenagers. However, detectable differences were found for the individuals aged 20 to 29 or more. The study concluded that these sensitive tests can detect premature hearing loss at an early stage and they also suggest that hearing impairment due to the use of personal music players occurs only in the late-teenage and early-adult period. A study using a different method also found that individuals using personal music players or those who attended nightclubs often had a significant hearing loss at certain frequencies.

Studies published more recently are also contradictory. Some studies find no significant effects of frequent use of personal music players or regular attendance at disco and rock concerts. Other studies find poorer hearing thresholds in users of personal music players than in non-users.

To establish whether exposure of teenagers to music from personal music players may influence their hearing once they get older, long-term studies using more sensitive methods are needed.

9.3 Is tinnitus more frequent among users of personal music players?

Tinnitus is a condition in which a person hears a ringing, buzzing or hissing sound which is caused by the hearing system and not by any external sources. It is often associated with hearing impairment, ageing or exposure to loud sounds.

There are many reports of tinnitus induced by loud music among young people. After exposure to very loud or sudden loud sounds, tinnitus appears rapidly and is often temporary. In opposition, when it results from long-term exposure to loud sounds tinnitus often only appears after several years but remains permanent.

Very few studies have studied the relationship between the use of personal music players and tinnitus. Two studies showed that users of portable cassette players were more likely than non-users to complain of tinnitus or temporary hearing loss. However, a more recent study from 2005 has found no link between use of personal music players and self-reported hearing loss or tinnitus.

9.4 How can attending concerts and night clubs affect hearing?

Sound levels of music in **nightclubs and rock concerts** can be very high and can reach up to 125 dB to 135 dB. Many people with normal hearing report high-pitched ringing in the ear (tinnitus) and temporary hearing loss afterwards. Short-term studies clearly demonstrate temporary hearing losses after exposure. This applies not only to young people attending these events but also to people who work there such as musicians, disk jockeys and other employees.

Results from health surveys among **young people** showed that the more time they spent in such venues, the greater their temporary hearing loss. However, there is no clear evidence that hearing loss induced by rock concerts has increased significantly over the last 30 years.

In one study, **rock musicians** who wore ear protections during concerts suffered less temporary hearing loss than those not wearing them. Several publications emphasised a larger number of cases of permanent hearing loss, tinnitus, and resistance to loud music among rock musicians.

The sound levels in **classical orchestras** are on average much lower than at rock concerts. However, some pieces of classical music contain sections that are played at high volumes for long periods of time. Musicians in orchestras could therefore also be at some risk of permanent sound-induced hearing loss. Very few studies have assessed this risk. Some have found slight hearing losses in many of the musicians tested. However, other studies have found no differences in hearing sensitivity between classical musicians and the general population, even for high pitched sounds. Overall, classical musicians can be exposed to excessive sound levels but there is no clear evidence that this exposure results in sound-induced hearing loss.

10. In what other ways can sound exposure affect children and adolescents?

Psychological effects

Exposure to disturbing sounds, such as road and aircraft noise, can have psychological effects. For instance, they can hamper reading, memory, motivation and attention.

Many studies on the effects of road and aircraft noise reveal an impact of short and long-term exposure on **reading skills and memory**.

- For instance, children who were exposed for a **short period of time** (15 minutes) to aircraft noise at levels of 55dB(A) or to combined aircraft and road traffic noise at 65 dB(A) while they were reading a text, remembered less what they had read than those who read the text in silence. Even if there is currently no study stating that the same is true for music in general or personal music players

in particular, there is no reason to assume that music should be less harmful to the ability to read and memorise than aircraft noise, road traffic or speech noise. Thus listening to music from personal music players while at the same time trying to read a text and learn from it is assumed to hamper memory and learning.

- Children who are **regularly exposed** to aircraft noise tend to learn to read more slowly, have poorer language skills, worse memory of a text and do less well in school than non-exposed children. However, a poorer performance in school could be due to factors other than exposure to loud sounds, such as differences in social or economic background. There is also an indication that children may recover from the noise-induced learning deficit, when noise exposure stops. However, it is not known whether this recovery depends on the age of the children in question. Currently, there is insufficient scientific data to assume that excessive voluntary listening to personal music players leads to lasting and irreversible learning and attention deficits.

Regarding **motivation**, children regularly exposed to noise, are more likely to abandon tasks than children living in quieter areas. However, the effects of exposure to sounds on motivation are strongly dependent on whether or not the person exposed has any control over the sound exposure. The children in the studies have no control over the noise they are exposed to, while people who listen to music from personal music players do so willingly and are unlikely to lose any motivation for that reason.

Exposure to sounds can also distract the person that hears them. When a task is simple, boring and repetitive, people tend to do it better if there is some background sound present. When the sound is music from a personal music player, one would expect the beneficial effect of music to be even greater, offering comfort and masking distracting sounds. However, complicated tasks that require thinking are likely to be hampered by sounds. Another factor to consider with regard to attention is that music can mask other sounds, whether or not they are beneficial. For instance, when people listen to personal music players, they may not hear warning sounds such as cars approaching or trucks reversing, which is very dangerous. Even if the music level itself is not high enough to mask these sounds, the listener may occasionally be focused on the music alone and be oblivious to ambient sounds.

Exposure to sounds disrupts the **sleep** of adults but children tend to sleep better than their parents, and seem to be less disturbed by sounds.

Several studies have found some link between increased **blood pressure** and noise-induced hearing loss, although the effect is small and it is not possible to tell whether noise exposure caused the raised blood pressure. A similar number of studies have not found such a link. However, recent studies have found a significant relationship between aircraft noise – but not road noise – and raised blood pressure. Recent reports also show that people exposed to loud sounds may be at a higher risk of developing certain types of heart disease. Evidence is insufficient to conclude that music from personal music players represents a risk of high blood pressure and heart disease in children and young adults.

11. Conclusions on health risks of personal music players

11.1 Are users of personal music players exceeding current sound exposure limits?

The risk of hearing damage depends on sound level and exposure time.

The EU established exposure levels above which action should be taken to protect workers, notably a limit of 80 dB(A) for an 8 hour working day assuming that below this level the risk to hearing is negligible. Though limits have only been set to protect workers from excessive noise exposure, these limits are also relevant to the use of personal music players.



Listening to music, at 80 dB(A) or less is considered safe
Source: GreenFacts

Most users of personal music players choose volume settings that lead to sound exposures below 80-85 dB(A), for less than an hour to 14 hours per week. When the above figures are adjusted to make them comparable to protection limits at the workplace, the majority of users are only at a minimal risk of hearing loss.

However, some people set the volume control very high – in the worst case up to about 120 dB(A) for some devices – or listen to music for many hours per day and may thus exceed safe limits. An estimated 5% to 10% of the listeners in EU are at risk of developing permanent hearing loss if exposure continues for after five or more years.

It is estimated that the share of young people exposed to loud sounds during their leisure time has tripled since the 1980s, now reaching nearly 20%. In the meantime exposure to noise at work has decreased.

It should be noted that the exposure to different types of noise and sounds, including music from personal music players can have cumulative effects in hearing impairment

11.2 What are the risks of prolonged exposure to loud sounds from personal music players?

Prolonged exposure to loud sounds from personal music players may result in:

- **temporary hearing loss:** the hearing threshold is temporarily no longer as low as before and it becomes harder to hear weak sounds. Listening to music between 94-104 dB SPL temporarily raises the hearing threshold by around 10 dB, and up to 30 dB for sensitive individuals.
- **permanent hearing loss:** the hearing threshold remains permanently lower than before. Due to conflicting result, it remains unclear whether the exposure of teenagers to personal music player music leads to permanent hearing loss when they get older.
- **high-pitched ringing in the ears (tinnitus):** Tinnitus occurs more frequently among personal music player users than among non-users.
- **difficulties understanding speech in noisy conditions.**
- **acoustic isolation from the environment:** Music from personal music players can mask warning noises or other environmental sounds, and can distract the listener. For instance, when people listen to personal music players, they may not hear cars approaching or trucks reversing, which is very dangerous.

- **learning and memory impairment:** During short-term exposure (15 minutes) to aircraft noise at levels of 55dB(A) or to combined aircraft and road traffic noise at 65 dB(A), learning and memorising a text may be more difficult. There is no reason to assume that music should be less harmful. Regular exposure to aircraft noise may also affect school performance, but the effect might be reversible once the noise exposure stops.
- **increased blood pressure and heart diseases.** Current data are insufficient to determine if music from personal music players constitutes a risk for high blood pressure and heart disease in children and young adults.

11.3 Under what condition can listening to personal music players be considered safe?

Listening to music at 80 dB(A) or less may be regarded safe. At or below that level hearing loss is very unlikely, no matter for how long or how often personal music players are used.

Above 80 dB(A) the health risks depend on the overall exposure to sound energy, which in turn depends on both sound level and exposure time.

In order not to increase overall exposure, each 3 dB increase in sound levels must be compensated by halving the listening time. Therefore, 80 dB(A) of exposure for one hour per day, is equivalent to 83 dB(A) for 30 minutes per day or 86 dB(A) for 15 minutes per day, under the assumption that these exposures are repeated over a long period of time.

It should be noted that for a given device and volume setting, ear-bud-type headphones will increase exposure by 7-9 dB compared to other headsets.

Some health effects of noise that are not related to hearing have been observed even below 80 dB(A) and it is currently not possible to establish a sound level for personal music players that would prevent those harmful effects.

11.4 What further research is needed?

To assess the health risks resulting from the increased use of personal music players data is needed on:

- a. the way personal music players are currently used (exposure time and sound levels) as well as exposure of users to other sources of loud sounds;
- b. the contribution of noise to hearing difficulties;
- c. the impact of personal music players on hearing and on groups of people that may be more vulnerable based on long-term studies using sensitive methods;
- d. the characteristics that make an individual more vulnerable to sound exposure;
- e. whether excessive listening to personal music players leads to lasting and irreversible learning and attention deficits.

Annex

Annex 1:

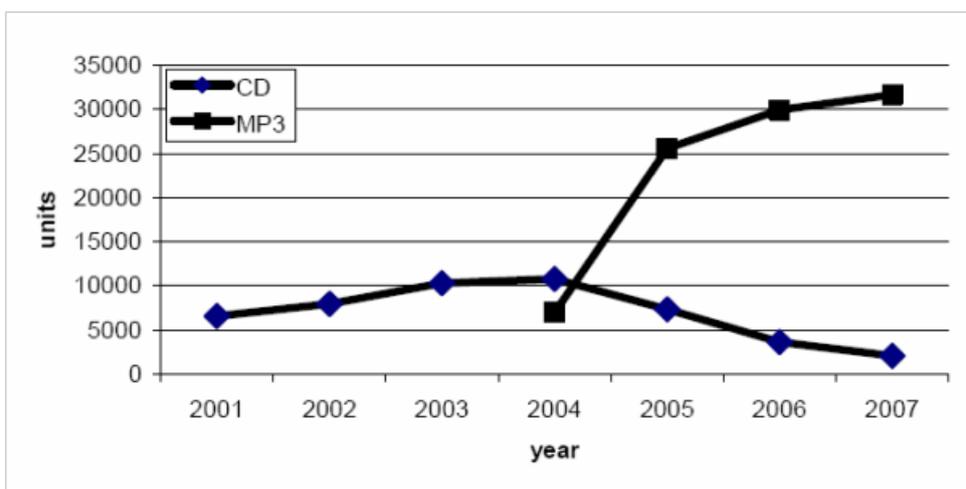
EU Action levels for noise protection at work

	First Action level (minimum) provide protection	Second Action level mandatory protection	Maximum Exposure limit value
8 hours	80 dB(A)	85 dB(A)	87 dB(A)
4 hours	83 dB(A)	88 dB(A)	90 dB(A)
2 hours	86 dB(A)	91 dB(A)	93 dB(A)
1 hours	89 dB(A)	94 dB(A)	96 dB(A)
30 minutes	92 dB(A)	97 dB(A)	99 dB(A)
15 minutes	95 dB(A)	100 dB(A)	102 dB(A)
1 minute	107 dB(A)	111 dB(A)	113 dB(A)

Source: Adapted from Table 3, SCENIHR, *Potential health risks of exposure to noise from personal music players and mobile phones including a music playing function (2008)* [see http://ec.europa.eu/health/ph_risk/committees/04_scenihhr/docs/scenihhr_o_018.pdf], Sections 3.3.5., Page 21

Annex 2:

Figure 5: Number of unit sales (in thousands) for CD and MP3 devices in ten European countries* between 2001 and 2007

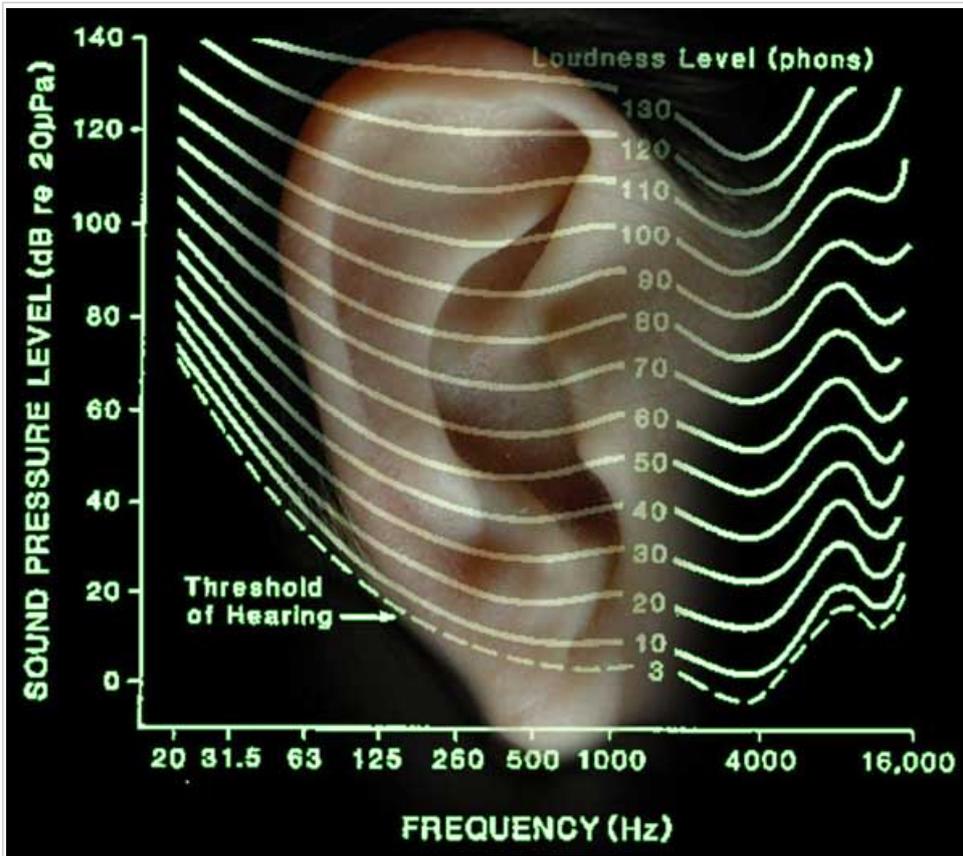


* Belgium, Germany, UK, France, Italy, Spain, Netherlands, Sweden and Switzerland

Source: SCENIHR, *Potential health risks of exposure to noise from personal music players and mobile phones including a music playing function (2008)* [see http://ec.europa.eu/health/ph_risk/committees/04_scenihhr/docs/scenihhr_o_018.pdf], Sections 3.7.4., Page 46.

Annex 3:

Low and high-pitched sounds appear less loud to the human ear



Source: GreenFacts

Annex 4:

Table 4: World Health Organisation Grades of Hearing Impairment

(WHO, 2008)

Grade of impairment*	Corresponding audiometric ISO value**	Performance	Recommendations
0 - No impairment	25 dB or better (better ear)	No or very slight hearing problems. Able to hear whispers.	
1 - Slight impairment	26-40 dB (better ear)	Able to hear and repeat words spoken in normal voice at 1 metre.	Counselling. Hearing aids may be needed.
2 - Moderate impairment	41-60 dB (better ear)	Able to hear and repeat words spoken in raised voice at 1 metre.	Hearing aids usually recommended.
3 - Severe impairment	61-80 dB (better ear)	Able to hear some words when shouted into better ear.	Hearing aids needed. If no hearing aids available, lip-reading and signing should be taught.
4 - Profound impairment including deafness	81 dB or greater (better ear)	Unable to hear and understand even a shouted voice.	Hearing aids may help understanding words. Additional rehabilitation needed. Lip-reading and sometimes signing essential.

* Grades 2, 3 and 4 are classified as disabling hearing impairment (for children, it starts at 31 dB)
 ** The audiometric ISO values are averages of values at 500, 1000, 2000, 4000 Hz.

Source: SCENIHR, *Potential health risks of exposure to noise from personal music players and mobile phones including a music playing function (2008)* [see http://ec.europa.eu/health/ph_risk/committees/04_scenihhr/docs/scenihhr_o_018.pdf], Section 3.4.1, page 22

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