World Health Organization

Safe Listening
Devices and Systems

A WHO-ITU standard

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Safe listening devices and systems: a WHO-ITU global standard

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Contents

Abbreviations and acronyms

CSD	calculated sound dose
DAC	digital to analogue conversion
dBA	decibels of sound pressure level measured using the a-weighting network
dBFS	decibel full scale
dBHL	decibels of hearing level
dBSPL	decibel sound pressure level
DRP	eardrum reference point
LAEQ	equivalent continuous average sound level
LEX	equivalent continuous average sound level normalized
NIHL	noise-induced hearing loss
PAD	personal audio device
PAS	personal audio system
PMP	personal media player
RMS	root mean squared
SIHL	sound-induced hearing loss
SLD	safe listening device
SPL	sound pressure level

Glossary

dBA: Decibels of sound pressure level measured using the A-weighting network; a level intended to measure low-intensity noise (around 40 phon loudness level) but has become commonly used also for measuring occupational and environmental noise exposures.

dBHL: Decibels of hearing level at a certain frequency; a level used to measure audiometric hearing threshold relative to the level defined as normal.
NOTE – It is the ear's sensitivity in a human with normal hearing, at different frequencies, that is the reference. ISO 226 is a mapping of phon against dB SPL, and the two scales meet at 1 kHz. dB SPL, which is by definition referenced at the threshold of hearing at 1 kHz, i.e. 0 phon (and 0 dB SPL).

Sound dose: The total quantity of sound received by the human during a specified period. In the context of the WHO-ITU Global standard, it is the same as sound exposure. The unit of (sound) dose is Pa2h.

Dosimetry: The calculation and assessment of the sound dose received by a human.

Equal energy principle: The assumption that equal amounts of sound energy will cause equal amounts of sound-induced permanent threshold shift, regardless of the distribution of the energy across time.

Equivalent continuous A-weighted sound pressure level: A continuous sound pressure level (SPL) in dBA which is considered to pose the same risk as a time-varying SPL, calculated using a 3 dB exchange rate between level and time. Mathematically, it is represented as:

$$L(Aeq,T)=10\lg\{[1/T\int_{t_1}^{t_2} p_A^2(t)dt]/p_0^2\}dBA$$

where
LAeq,T is the equivalent continuous A-weighted sound pressure level re 20 μPa, determined over a time integration interval $T = t_2 - t_1$;

p_A (t) is the instantaneous A-weighted sound pressure of the sound signal

p_0 (t) is the reference sound pressure of 20 μPa

Equivalent continuous average sound level normalized: A continuous SPL in dBA which is considered to pose the same risk as a certain time-varying SPL pattern measured using a 3 dB exchange rate, and normalized to an *n*-hour exposure period. Examples of the values for *n* is 8, in which case this may also be referred to as an L_{A8hn} or L_{EX8h}", or *n*=40, L_{EX40h}.

Exchange rate: The change in average noise level (in dB) that corresponds to a doubling or halving of allowable exposure time.

Frequency response: In this context, frequency response is short for "sensitivity vs. frequency response", sometimes referred to as the "tone curve" of an audio device, such as a headphone, loudspeaker, microphone, amplifier etc.

Listening device: A device used to transmit sound to the ear. Consists of a transducer and fitting to accommodate in the ear, on the ear or over the ear listening. Examples are headphones and earphones.

Media: Audio or audiovisual content for entertainment, whereby long term exposure may result in hearing loss. Examples are music, gaming and podcasts.

Personal audio device: A portable device designed to be worn on the body or in a pocket. It is designed to allow the user to listen to various forms of media.

Personal audio system: A system comprising a personal audio device and a listening device.

Safe listening device: A personal audio device/system that meets requirements and criteria to minimize users' risk of acquiring hearing loss, (as a consequence of its use) can possibly be termed a "safe listening device". It could include music players (MP3 players, smartphones and personal music players), which together with a transducer can convert an electric signal into audio (e.g. earphones and headphones).

Sound allowance: A dose estimate of sound exposure over a certain rolling period of time (e.g., daily or weekly), commonly expressed in percentage of the maximum regarded as safe. A weekly sound allowance is equivalent to 100% cumulative sound dose.

Sound-induced: Refers to a state or a quality resulting from exposure to sound. The sound may be (part of) music or "noise", which implies the sound is not desirable.

Transducer: An electronic device that converts energy from one form to another.

Executive summary

Make Listening Safe is the World Health Organization's initiative to highlight and reduce the growing risk of hearing loss posed by "unsafe" listening through personal audio devices and systems. Make Listening Safe is the result of a collaboration between the World Health Organization (WHO) and the International Telecommunication Union (ITU), along with experts in the field of sound, audiology, acoustics, technology, health communication, and standardization and product development.

This document outlines the key features and requirements that personal audio systems must have in order to facilitate safe listening practices among users. It is based on the WHO-ITU Global standard for safe listening devices and systems, as set out in the ITU-T H.870 guidelines for safe listening devices[1].

The recommendations in this document are based on the best available knowledge and evidence on principles of hearing loss prevention and criteria for hearing damage caused by sound. They also address the need for, and methods of, communication to facilitate behaviour change among users of personal audio systems.

The WHO-ITU Global standard aims to regulate exposure to loud sounds through personal audio devices/systems[2] and mitigate hearing loss risk associated with their use. Recommendations include:

Technical component

It is proposed that all personal audio devices should measure the listener's exposure to sound based on two possible operational modes of reference exposure:

Mode 1: WHO standard level for adults: this will apply 1.6 Pa2h per 7 days as the reference exposure[3] (derived from 80 dBA for 40 hours a week).

Mode 2: WHO standard level for sensitive users (e.g. children): this will apply 0.51 Pa2h per 7 days as the reference exposure (derived from 75 dB for 40 hours a week).
In order to estimate this, the device should be able to track the user's volume level and time spent listening.
Also, every device should have options for volume limitation and parental volume control.

Communication component

Clear and relevant information must be communicated to the user through the device interface and other means. This includes:

- Information on personal usage of sound allowance by the individual (based on the reference exposure selected; average volume and time spent listening).
- Personalized recommendations and cues for action for safe listening, customized according to user's listening profile.
- Instructions on how to use safe listening features on the specific device.
- General information on safe listening and ways to practice it.

This information and guidance must be shared by default with users via their devices in order to reduce the risk of hearing loss.

The recommendations in this document are intended for adoption by Member States as regulations or legislation and should also be voluntarily implemented by manufacturers. A toolkit for implementation of the WHO-ITU Global standard is available.

[1] International Telecommunication Union. ITU Guidelines for safe listening stystems/devices. Geneva: ITU; 2015 (https://www.itu.int/rec/T-REC-H.870-201808-I/en, accessed 11 January 2019).

[2] Personal audio device refers to a device used for listening to audio or audiovisual content/material and that is intended for the user to walk around with while in use, e.g. smartphones and MP3 players. This is commonly used with a listening device, such as a headphone/earphone. The term personal audio system refers to the combination of a device and the ear/headphone used with it.

[3] Based on the 2018 WHO Environmental noise guidelines for the European Region, section 3.5, Recommendation for leisure noise exposure (http://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf?ua=1, accessed 11 January 2019).

Introduction

01 How does sound affect ears?

02 What is safe listening?

03 Why this standard?

04 How can it be used?

Introduction

There is growing concern about the rising exposure to loud sounds in recreational settings such as nightclubs, discotheques, pubs, bars, cinemas, concerts, sporting events and even fitness classes. With the popularization of technology, devices such as personal audio systems are often listened to at unsafe volumes and for prolonged periods of time. Regular participation in such activities poses the serious threat of irreversible hearing loss.

Recent WHO estimates[4,5] reveal the following:

- Around 466 million people globally live with ditsabling hearing loss resulting from a range of causes. This number is projected to rise unless action is taken to mitigate the risk factors for hearing loss.
- Over a billion young people worldwide could be at risk of hearing loss as a result of unsafe listening practices.
- Among teenagers and young adults aged 12–35 years in middle- and high-income countries, nearly 50% listen to unsafe levels of sound through personal audio devices such as MP3 players and smartphones; and approximately 40% are exposed to potentially damaging sound levels in nightclubs, discotheques and bars.

Rising smartphone sales – 1.5 billion devices were sold globally in 2016 alone – is another indicator of potential risk. This increased accessibility and use of personal audio systems for listening to music is coupled with their use at high volume, for long durations. Such risk-associated behaviours can permanently damage hearing.

Against this backdrop, WHO launched the Make Listening Safe initiative in 2015. Its overall vision is a world where people of all ages enjoy listening with full protection of their hearing, and its aim is to reduce the risk of hearing loss posed by unsafe exposure to sounds in recreational settings. As part of this initiative, WHO has partnered with ITU to create the WHO-ITU H.870 Global standard on safe listening devices and systems.

Effect of noise on hearing

Exposure to loud sounds for any length of time causes fatigue of the ear's sensory cells. The result is temporary hearing loss or tinnitus, which is a ringing or buzzing in the ear. A person enjoying a loud concert may come out experiencing "muffled" hearing or tinnitus. The hearing improves as the sensory cells recover. When the exposure is particularly loud, regular or prolonged, it can cause permanent damage of the sensory cells and other structures, resulting in irreversible hearing loss. The high-frequency range of an individual's hearing (i.e. their capacity to hear high-pitched sounds) is affected first and may not be noticeable immediately. Continued exposure leads to progressive hearing loss, ultimately affecting speech comprehension and resulting in a negative impact on the individual's quality of life.

[4] Hearing loss due to recreational exposure to loud sounds: A review. Geneva: World Health Organization; 2018 (http://apps.who.int/iris/bitstream/handle/10665/154589/9789241508513_eng.pdf;jsessionid=643C32942063B37D27C11A5E86CF1FAE?sequence=1, accessed 11 January 2019).
[5] International Telecommunication Union. ITU Guidelines for safe listening stystems/devices. Geneva: ITU; 2015 (https://www.itu.int/rec/T-REC-H.870-201808-I/en, accessed 11 January 2019).

What is safe listening?

Safe listening refers to listening behaviour that does not put an individual's hearing at risk. The risk of hearing loss depends on the level (loudness), duration (time period) and frequency of exposure to loud sounds. Such exposure may be through personal audio devices, in entertainment venues, as well as in the general environment.

The recommended safe level for leisure noise is below 80 dB for a maximum of 40 hours duration in a week – equal to L_{Aeq},24h = 70 dB(A)[6,7]. This represents the acceptable level of sound energy that an individual can receive without putting their hearing at risk and is described as a "sound allowance" or "calculated sound dose". In order to stay within this level it is important to:

- keep the volume as low as possible while listening to music;
- limit the time engaged in noisy activities – including activities at work, home and leisure;
- monitor safe listening levels over personal audio systems and in noisy spaces;
  heed the warning signs of hearing loss.

It is also important that people who are exposed to loud sounds receive regular hearing check-ups in order to identify any hearing loss at the initial stage.

Purpose of WHO-ITU H.870 Global standard on safe listening devices and systems

How long and how loud a person listens to music using their personal audio device is one factor that determines their risk of hearing loss. While this is a choice made by the individual, the responsibility for creating an environment that promotes safe listening practices lies with governments, manufacturers, civil society and other stakeholders. A situation analysis[8] undertaken prior to development of the WHO-ITU Global standard revealed gaps in current recommendations for safe listening, and set out why such a global standard was necessary.

The Standard for safe listening devices and systems outlines the recommended "safe listening" features for inclusion in any personal audio device. Such features will provide users with accurate information on their own listening profile as well as options for reducing their risk. The proposed features also focus on communication with the listener through the device with the aim to drive behaviour change for safe listening.

Personal audio device *refers to a device used for listening to audio or audiovisual content/material and that is intended for the user to walk around with while in use, e.g. smartphones and MP3 players.*

This is commonly used with a listening device, such as a headphone/earphone.

The term **personal audio system** *refers to the combination of a device and the ear/headphone used with it.*

[6] Environmental noise guidelines for the European Region. Geneva: World Health Organization; 2018 (http://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf?ua=1, accessed 11 January 2019).
[7] Neitzel R, Filgor B. Determinination of risk of noise-induced hearing loss due to recreational sound:Review. Geneva: World Health Organization; 2017 http://www.who.int/pbd/deafness/Monograph_on_determination_of_risk_of_HL_due_to_exposure_to_recreational_sounds.pdf, accessed 11 January 2019).
[8] Bertin C. Make listening safe: narrative review of listening habits. Geneva: World Health Organization; 2017 (http://www.who.int/pbd/deafness/Monograph_on_situation_analysis_and_background_for_standards_for_safe_listening_systems.pdf, accessed 11 January 2019).
2019).

Development process

Developing the WHO-ITU Global standard has been collaborative process involving WHO and other stakeholders. ITU has been the key partner, bringing knowledge and expertise on standardization processes for technology and devices. A number of experts in the field of audiology, acoustics and technology have also supported this effort. Existing literature has been extensively reviewed to guide the development of the WHO-ITU Global standard. Users of technology have been involved through online surveys, focus group discussions and in-depth interviews to understand their needs and preferences. Inferences made from these have been shared with the expert group and considered during the drafting of the recommendations. The detailed ITU-T H.870 guidelines for safe listening devices and systems, upon which the WHO-ITU Global standard is based, is available on the ITU website at https://www.itu.int/rec/T-REC-H.870-201808-I/en.

Application and use

It is proposed that the WHO-ITU Global standard’s three recommendations be:

- implemented by governments as regulations/legislation in order to ensure that their populations have the benefit of using safe listening devices/systems, as a means for hearing-loss prevention;
- adopted voluntarily by manufacturers of devices to ensure that their customers can practice safe listening;
- used by civil society groups and consumer associations to advocate for development of safe listening devices and systems.

WHO-ITU H.870 GLOBAL STANDARD for safe listening devices and systems

01 Every device shall measure the listener's use of sound allowance, based on a choice of two modes of reference exposure

02 Each device should include options for volume limiting and parental volume control

03 Each device shall provide the user with

- personal usage information
- personalized messages and cues for action
- general information on safe listening

WHO-ITU H.870 Global standard
for safe listening devices and systems

The aim of the **WHO-ITU Global standard** is to regulate exposure to loud sounds through personal audio systems and to mitigate the hearing loss risk associated with their use.

Scope

The WHO-ITU Global standard's three recommendations apply to all personal audio systems (PAS) and devices designed for use by individuals.

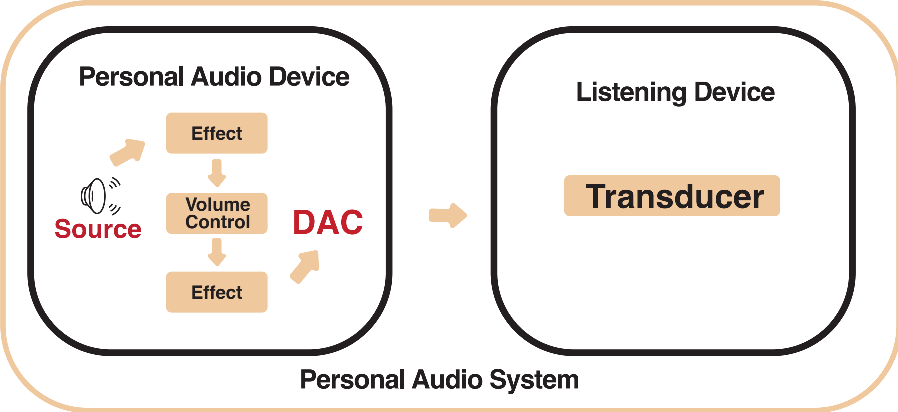


Figure 1: Architecture of a personal audio system
(Reproduced with kind permission from ITU H.870)

In **Figure 1**, "source" can be either stored or retrieved remotely, e.g., streaming from a local server or the Internet.

A personal audio system **(PAS)** is intended for use by an individual and:
- is designed to allow the user to listen to audio or audiovisual content/material;
- uses a listening device, such as headphones or earphones, that can be worn in, on, or around the ears; and
- has a player that can be body worn (of a size suitable to be carried in a pocket) and is intended for the
- user to walk around with while in use (for example, on a street, in a subway, at an airport, etc.).

Examples include portable CD players, MP3 audio players, mobile phones with MP3 type features, PDAs or similar equipment. For the purposes of this Standard, the following types of devices are excluded:
- communication devices such as walkie-talkies, etc.;
- rehabilitative and medical devices (e.g. hearing aids, FM systems, and other assistive listening devices (ALD) approved as part of hearing aids and cochlear implants systems, etc.);
- personal sound amplification devices;
- professional audio equipment and devices;
- portable game consoles.

Recommendations

The three recommendations address two key aspects of safe listening:
1) the technical aspects, which focus on measuring the consumption of weekly sound allowance by the user, and volume-limiting options; and
2) a health communication aspect.

Recommendation 1: Every device should measure the listener's use of sound allowance, based on a choice of two modes of reference exposure

Sound allowance refers to a dose estimate of sound exposure over a certain rolling period of time (e.g., daily or weekly), commonly expressed in percentage of the reference exposure. This is based on the **Equal energy principle** and recommends use of two possible operational modes to estimate the **reference exposure.**

Equal energy principle: this is the assumption that the total effect of sound on ear and hearing is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy in time. According to this principle, equal amounts of sound energy are expected to cause equal amounts of sound-induced permanent threshold shift regardless of the distribution of the energy across time.

In practical terms this implies that listening to lower volumes for long periods of time can have the same impact as listening to very loud volumes for a short duration: for example, listening to a 100 dB sound for 16 minutes will have the same impact as listening to an 80 dB sound for 40 hours. Based on this principle, "dose" of sound energy is defined as the squared A-weighted sound pressure, p_A, integrated over the exposure time $T=t_2-t_1$.

Mathematically, this is expressed as:

dose=

$$dose = \int_{t1}^{t2} (p_A(t))^2 dt$$

where p_A is the A-weighted and diffuse-field corrected sound pressure. The unit of this value is Pascal squared hours, or Pa^2 *h*

Reference exposure/sound allowance, operational modes: It is recommended that each device includes a system that tracks the user's exposure time and loudness level, and estimates the percentage used of a reference exposure (also referred to as sound allowance).

This must take account of all media played back through the device (i.e. whether it is stored on the device itself, or streamed) during times when the user is using ear/headphones. Voice calls may be excluded as they are separately specified by other standards.

It is also recommended that the device allow the user to select their reference exposure as one of two operational modes:

Mode 1 WHO standard level for adults: this will apply 1.6 Pa^2h per 7 days as the reference exposure (derived from 80 dBA for 40 hours a week)[9].
Mode 2 WHO standard level for sensitive users (e.g. children): this will apply 0.51 Pa^2h per 7 days as the reference exposure (derived from 75 dB for 40 hours a week).

The user should be allowed to select either of the two modes when using the player for the first time (or when the device is reset to factory settings) and to change the mode choice at a later time, e.g. via a device settings menu.

Practical relevance of sound allowance: 100% weekly sound allowance is equivalent to the weekly reference exposure, based on the mode selected. The time required to use 100% of sound allowance depends on the average sound intensity. Table 1 and Table 2 set out examples of weekly listening time duration based on sound allowance for the modes above.

Table 1: Example of weekly listening time for Mode 1

dB(A) SPL	Weekly (*1.6 Pa^2h*)
107	4.5 minutes
104	9.5 minutes
101	37.5 minutes
98	75 minutes
95	2.5 hours
92	5 hours
89	10 hours
86	20 hours
83	20 hours
80	40 hours

Table 2: Example of weekly listening time for Mode 2

dB(A) SPL	Weekly (*0.51 Pa^2h*)
107	1.5 minutes
104	3 minutes
101	6 minutes
98	12 minutes
95	24 minutes
92	48 minutes
89	1 hours 36 minutes
86	3 hours 15 minutes
83	6 hours 24 minutes
80	12 hours 30 minutes
77	25 hours
75	40 hours

Measuring sound allowance

Devices that comply with the WHO-ITU Global standard include a measurement system (also referred to as a dosimeter) that tracks the use of sound allowance by the listener. An example of how a dosimeter can be implemented in a personal audio system, when measuring the digital media signal and considering known or assumed properties of headphones, can be found in Appendix I of the ITU Guidelines for safe listening devices and systems[10].

Important: When estimating sound dose there are a number of uncertainties. It is therefore wise to refrain from signalling “safe” or “no risk” to users with sound dose readings below a certain level.

[9] Based on the 2018 WHO Environmental noise guidelines for the European Region, section 3.5, Recommendation for leisure noise exposure (http://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf?ua=1, accessed 11 January 2019).

[10] International Telecommunication Union. ITU Guidelines for safe listening stystems/devices. Geneva: ITU; 2015 (https://www.itu.int/rec/T-REC-H.870-201808-I/en, accessed 11 January 2019).

Recommendation 2: Each device should include options for limiting volume, and parental volume control

Volume limiting: The device should be able to provide the user with a suitable method for limiting volume. This refers to a feature where a message will be given before or when the user reaches 100% of their weekly sound allowance. The user will have the option to "continue listening" if they do not wish the device volume to reduce. If the message is not acknowledged, a default setting will reduce the volume output to below the predetermined level (based on the mode selected, i.e. 80 dB or 75 dB). If possible, users should be given the option to customize this level (the level at which they would like their device to limit the volume) according to their preference.

Parental control: The device should have the option whereby the maximum sound output can be fixed and locked in the settings, possibly through use of a password. The purpose of this feature is to allow parents (or other adults) to limit the maximum sound output of the child's device. The feature can also be used by individual users in order to limit their own sound exposure, by fixing the maximum output on their device.

Recommendation 3: Through the device interface, instruction manuals and other means such as packaging, the device shall provide the user with personal usage information, personalized messages and cues for action, and general information on safe listening.

Health communication forms a key part of standards for safe listening systems and devices. Devices complying with these standards must provide users with a tool that will allow them to monitor their own personal sound exposure. Such a tool should give users the choice of safe listening, and empower them to make informed choices for listening through greater awareness and information.

The health communication element of the WHO-ITU Global standard presents evidence-based recommendations on how to communicate the risks of unsafe listening and support users in adopting appropriate behaviour in this respect.

As part of standards for safe listening devices, information and messages on safe listening must be provided through:

- the device interface[11] (wherever an appropriate visual interface is available);
- instruction manuals.
- other means such as packaging, where possible.

Information delivered through device interface

Personal usage information, in order for the user to know:

- their own listening habits (use of daily and weekly sound allowance);
- how to use the safe listening features of their specific devices.

[11] Refers to the hardware components (such as screen) that allows a human being to interact with an electronic device.

Information regarding various listening parameters defining users' listening habits should be accessible to users in order to allow them to keep track of their exposure to sound through the device. In case of devices with a screen, this could be through an icon on the screen (**Figure 2** gives an example of information provided on a smartphone visual interface for safe listening).

Through the icon, the user should be able to see their use of daily or weekly sound allowance in an easy-to-understand way, e.g. the person may be able to view how much of the weekly sound allowance has been used and how their listening behaviour has been over the past week.

In devices without a screen, the information should be made available through other means, such as audio cues.

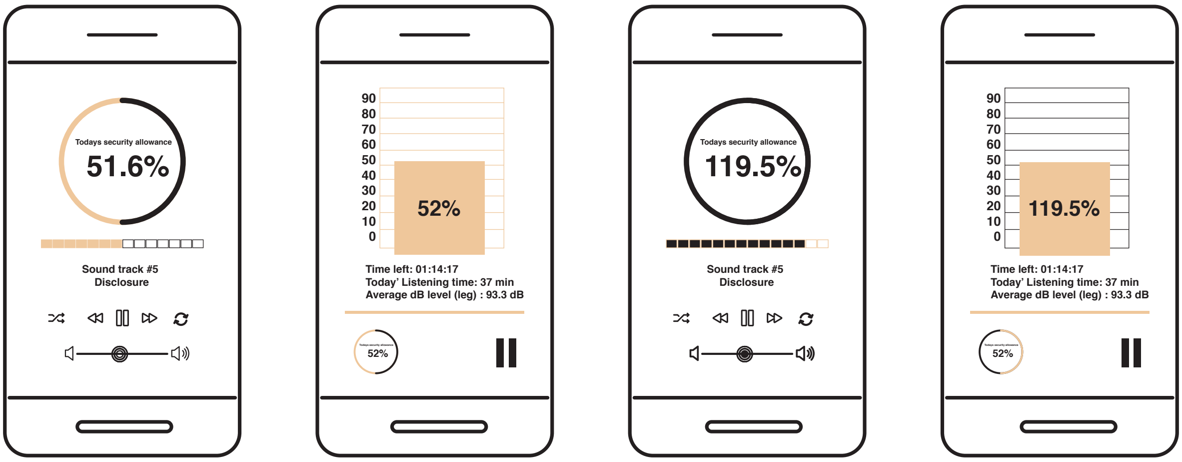


Figure 2: Examples of information provided on a smartphone visual interface for safe listening. (Reproduced with kind permission from ITU H.870)

The device (if capable) should display:

- the average sound level for the day and week.
- the time for which the user has listened in hours and minutes over the day and the week.

Personalized recommendations and cues for actions for safe listening, customized based on each user's listening profile

The device should give relevant warnings and cues for actions when the user reaches pre-determined levels of exposure (e.g. 80%) and exceeds 100% of the weekly allowance.

- The user should first receive a "warning" expressed through text and graphics or an icon, informing them that a threshold has been reached and that from this point on, further listening at the same volume will pose a risk for their hearing.

- The warning should be followed by a “cue for action” in which the user may either accept the risk of continued listening or protect their hearing. The “cue for action” should be linked to active options on the device such as:
- automatic safe volume option, by which the device automatically changes the volume to a safe volume level;
- direct access to volume settings;
- set up of default volume limits;
- “remind me later” option;
- ignore and continue option.

If the user fails to take any action, the volume will automatically be reduced to below the standard level (80 or 75 dBA as selected).

Such cues depend on the device's capability and should be multimodal (such as visual, vibratory or audible), in order to ensure that the user's attention can be directed towards these. **Figure 3** gives non-normative examples of messaging displayed in a smart watch.

Figure 3: Example of messaging displayed in a smart watch.
(Reproduced with kind permission from ITU H.870)

Daily messages: the device should provide a daily summary message based on the user's listening behaviour over the past days, encouraging safe listening habits and discouraging or warning against unsafe listening habits. See Appendix 2 for suggested levels at which warnings and cues can be given, and sample content.

General information

General information should be provided to users on:

- safe listening and ways to practice it;
- the risk associated with unsafe listening;
- the risk of hearing loss due to loud sounds from sources other than the personal audio system.

It is recommended that this information be displayed on the user interface (home screen) through a distinct and recognizable icon (in devices with a screen). **Figure 4** gives an example of a safe listening icon displayed on a smartphone screen.

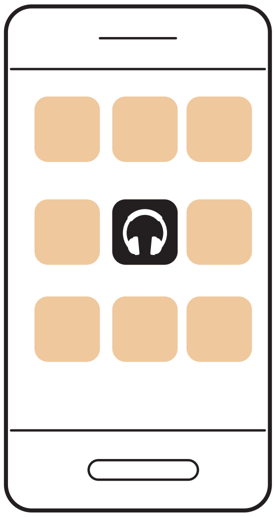
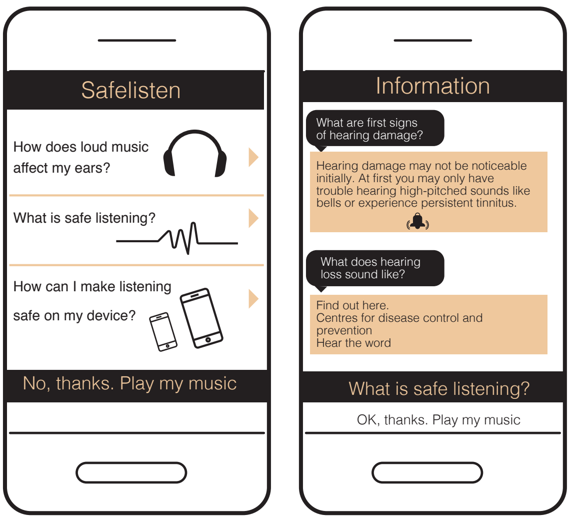


Figure 4: Safe listening icon displayed on a smartphone screen.
(Reproduced with kind permission from ITU H.870)



There should be a tutorial informing users about:

what is meant by safe listening;
the risks of unsafe listening;
the device's safe listening features, and how to use them.

The screens should also include links to relevant webpages where the user can find more information. Figure 5 gives an example of screens linking to information on safe listening and external links.

Figure 5: Examples of screens providing information on safe listening and external links.
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Information delivered through device instructions and/or user manual

The user manual should clearly state that unsafe listening practices pose the risk of permanent hearing loss. It should also give details of the volume-limiting functions of the device, and the inbuilt cues for action.

The user manual should also clearly outline how the allowance-assessment system works and refer to the fact that the accuracy of sound doses calculations may vary. It should indicate that information on the device does not take into account additional sources of sound exposures either from other audio devices or environmental sound exposure.

The manual could also provide information regarding hearing protections from loud environmental sounds, in order to minimize the risk of hearing loss.

Information delivered through other means than the device itself

Packaging

Wherever possible, a clear, concise message or warning should be included on the external packaging of devices. It is recommended that such a warning or message be:

- concise, simple and clear;
- accompanied by a relevant illustration;
- positioned on a plain background.

Website and advertising

Information on safe listening should be included on the manufacturer's website. Such information should be aligned with the recommendations of the WHO-ITU Global standard for safe listening. A link WHO's website and other relevant, reputable websites could be included.

Wherever possible, advertising of products could also provide relevant information. Such information can refer to both the potential harm to hearing through improper use of their device; and the advantages of listening safely in order to maintain healthy hearing while enjoying a good listening experience.

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Appendix 1

Dose estimation functionality for implementation

in a personal audio system

Appendix 1

Dose estimation functionality for implementation in a personal audio system

(Reproduced from ITU-T H.870 guidelines for safe listening devices/systems, Appendix II)

1.1 Introduction

This Appendix provides an example of how a dosimeter can be implemented in a personal audio system, when measuring the digital media signal and considering known or assumed properties of headphones. It is based on the equal energy principle in hearing impairment risk assessment, where the squared A-weighted sound pressure, integrated over the exposure time, constitutes the dose. The uncertainties involved in such dose estimations (e.g. confidence interval) are also discussed.

1.2 Main related standards

[EN 50332-3] describes a dose measurement system in a PMP (portable music player) and this Appendix is intended only as supplementary information to that standard.
[IEC 61252] describes acoustic dosimeters to be worn on the body.

1.3 Definition of dose in the context of acoustic dosimetry

$$\text{dose} = \int_{t1}^{t2} (p_A(t))^2 dt,$$

where

P_A is the A-weighted and diffuse-field corrected sound pressure.
For example, the dose acquired when being subjected to 80 dBSPL (exposure duration of 40 h is calculated as follows):

The root mean squared (RMS) sound pressure is $10^{\frac{80}{20}} \cdot \frac{20\,\mu\text{Pa}}{1\text{Pa}} = 0.2$ **Pa.**

Accordingly, the dose is $0.2^2 \cdot 40 = 1.6\ \text{Pa}^2\text{h}$

Such a specific dose may be defined as a reference dose and the measured exposure estimation during a certain period may be expressed as a percentage of this reference dose. [EN 50332-3] defines the dose explained above as a 100% calculated sound dose (CSD). Furthermore, it considers only the dose acquired during a rolling 7 days.

1.4 Weighting of different frequencies

The potential hearing damage which is pertinent to dose estimation occurs in the cochlea, in the inner ear. It would be intuitive that measurements were corrected to reflect directly the excitation of the hair cells in the cochlea. However, the vast majority of research on noise-induced hearing loss is based on sound level meter readings in the “free field”, for example in factories (strictly speaking, typically something between free field and diffuse field conditions). Therefore, risk assessment and action limits are based on such readings. Although the A-weighting was not developed specifically for hearing loss risk assessment, research has shown that sound level meter readings in the free field correlate reasonably well with observed noise-induced hearing loss, when the squared A-weighted sound pressure is integrated over the exposure time.

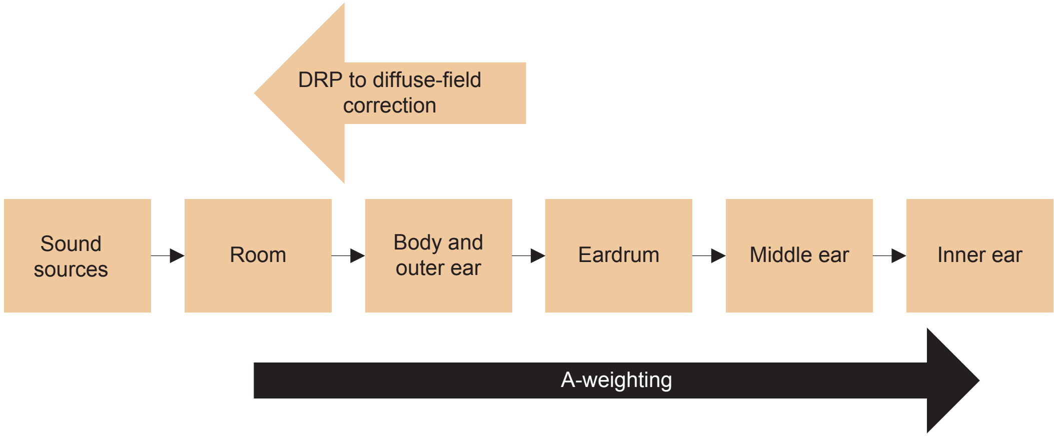


Figure 1: Roles of different corrections used in measurements to give weightings to various frequencies

When the earphone/headphone/headset characteristics are measured at the eardrum reference point (DRP) using a head and torso simulator, the diffuse-field correction transforms the measurement to a quantity comparable with typical sound level meter readings in the free/diffuse field. Since the original research included sound sources from a variety of incidence angles to factory workers’ ears, no specific incidence angle (e.g. free-field correction for frontal incidence at an elevation of 0 degrees) is assumed in the risk estimation; instead, the diffuse-field correction is used, as an average representation of various incidence angles.

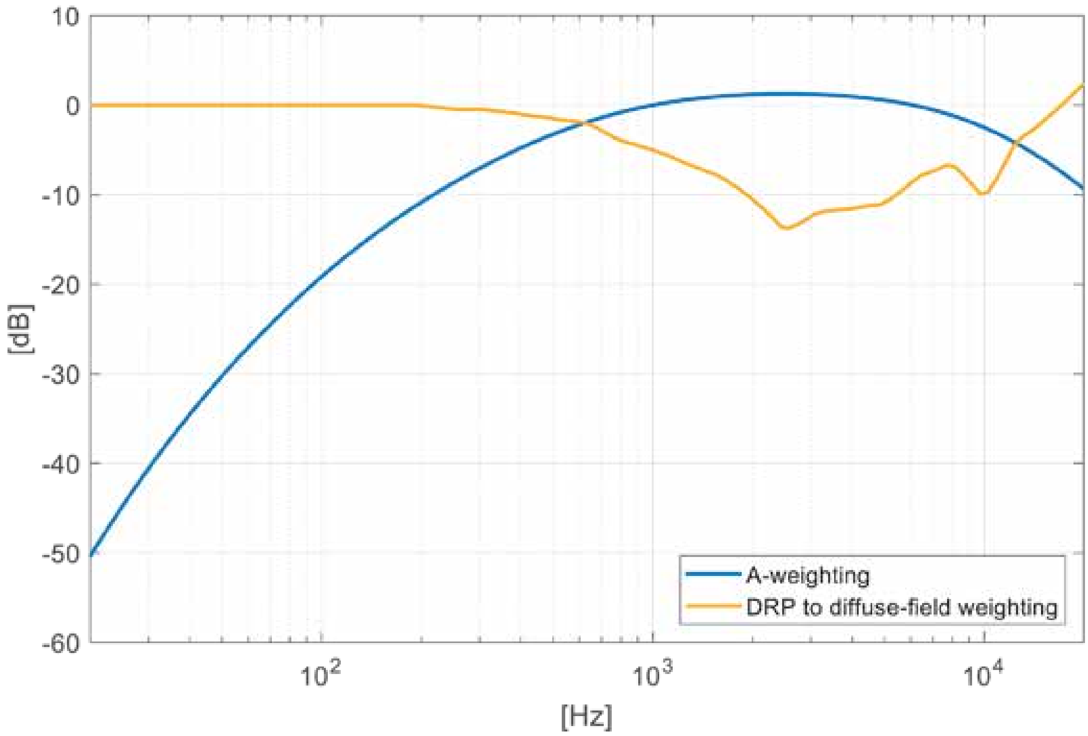


Figure 2: A-weighting [IEC 60268-1] and DRP to diffuse-field correction/weighting [ITU T P.58]

1.5 Signal capture point in a personal audio system

Figure 3 contains an example of an audio player system and preferred dosimeter capture point, where the measured signal x is collected just before digital-to-analogue conversion.

Since pA is typically not readily available, it is here illustrated how to estimate pA based on a digital signal in the player (PAD, personal audio device, which does not have a transducer) and other known characteristics of PAD and headphones.

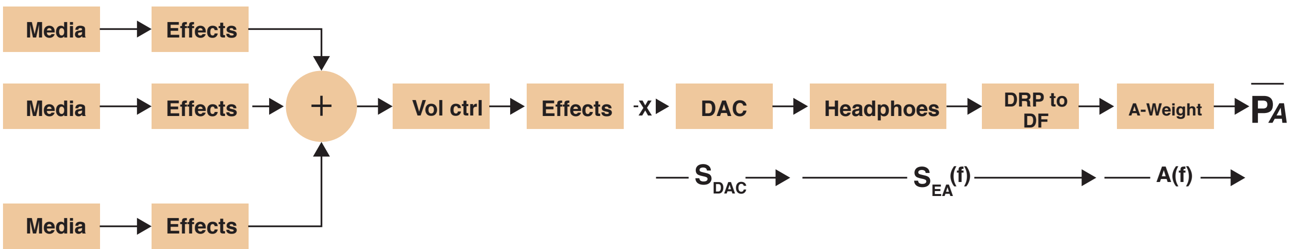


Figure 3: Example of audio player system and preferred dosimeter capture point

Table 1: Quantities needed for dose estimation

Quantity	Description	Unit
x_L and x_R	Digital signals for the left and right channels, taken in the PAS audio system after the summation of all audio sources, after volume control and after all audio processing.	Sample value
S_{DAC}	Sensitivity of the digital-to-analogue converter and subsequent analogue circuitry. In case the headset has a digital input, this parameter is attributed to the headset rather than the player.	Volt/sample value
$S_{EA(f)}$	Electro-acoustic sensitivity of the headphones, measured at the eardrum reference point (DRP) and then corrected using DRP to diffuse-field correction for the frequency range 20 to 20k Hz. See [ITU-T P.381] for measurement method of headset receiving frequency response, [ITU-T P.58] for diffuse-field correction and [ITU-T P.380] for additional information such as five times re-seating and averaging.	Pascal/Volt
A(f)	A-weighting filter network, see [IEC 61672-1] for a general specification and [IEC 61252] for a dosimeter design goal.	Volt/Volt
τ	Duration of the segment	Hours

1.6 Handling of left and right channels

For simplicity in implementation and interpretation of results, the power average of the left and right channels is used for a single dose estimation.

1.7 Dosimeter implementation example

For a discrete time-, segment-based implementation, the estimation of a daily/weekly dose can be implemented accordingly, in time or frequency domain:

i. Acquire n samples per channel of the signal x, (typically over a 1 second time window). Filter the signal to consider DAC, headphone and A-weighting

$$z(k) = filter(x(k), [S_{DAC} \cdot S_{EA}(f) \cdot A(f)])$$

ii. Calculate the mean power of the left and right channels and multiply by the duration of the segment

$$\overline{dose_{segment}} = T \cdot \frac{1}{n} \sum_{k=1}^{n} \frac{1}{2}\left(z(k)_L{}^2 + z(k)_R{}^2\right)$$

iii. Add the dose contribution to the previously accumulated dose estimate

$$\overline{dose_m} = \overline{dose_{m-1}} + \overline{dose_{segment}}$$

iV. Optional: present the dose reading for the present day and the previous 6 days
V. Optional: express the total dose as a percentage of the reference dose
Vi. If midnight was passed: store the dose for the concluded day, reset the daily dose to zero and measure for the new day

NOTE: The storage of the cumulating dose shall have sufficient accuracy to avoid nulling small portions from a single segment

1.8 Handling of computational complexity

To save calculation resources and increase battery time, the signals may be decimated (without anti-aliasing filters). Care shall be taken that the accuracy remains sufficient for music and speech signals. Care shall also be taken that the filtering remains appropriate, for the decimated signal. Filtering implementations may be simplified to a certain extent.

1.9 Handling of dose over days and weeks

It is recommended to store each day's dose estimate during a rolling 7-day period. The accumulated dose during the present day and the six previous days is compared to the reference dose explained in clause 2.4 of ITU-T H.870.

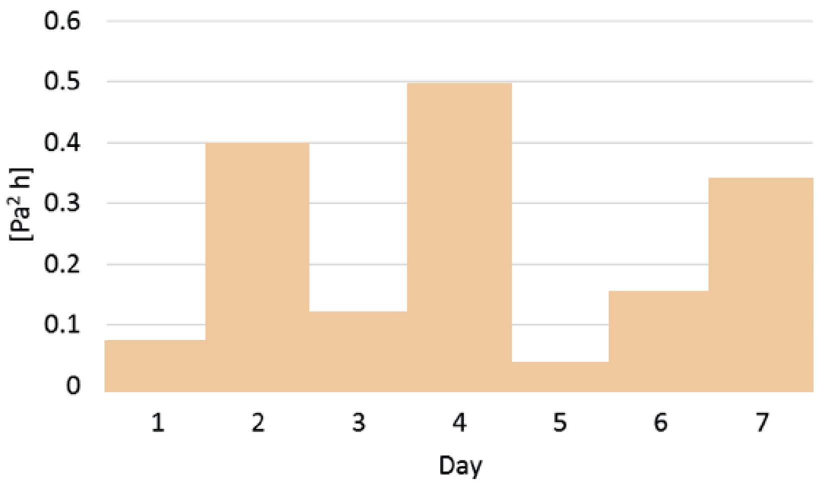


Figure 4: Example of accumulation of dose over 7 days, constituting in total 1.6 Pa2h, hence 100% CSD

1.10 In case the headphone characteristics are not known

In many cases, the headphone type may not be known to the player and its sensitivity can vary significantly, as illustrated in Figure 5. In such case, the dosimeter assumes:

- Maximum permitted headphone sensitivity, meaning a simulated programme signal characteristic voltage (SPCV) of 75 mV, see [EN 50332-2] and [ITU-T P.381].
- Flat frequency response after diffuse-field correction
- Headset impedance 32 Ω (relevant when identifying S_{DAC})

This means that S_{EA} (f) is set to a constant of 12.55 Pascal/Volt.

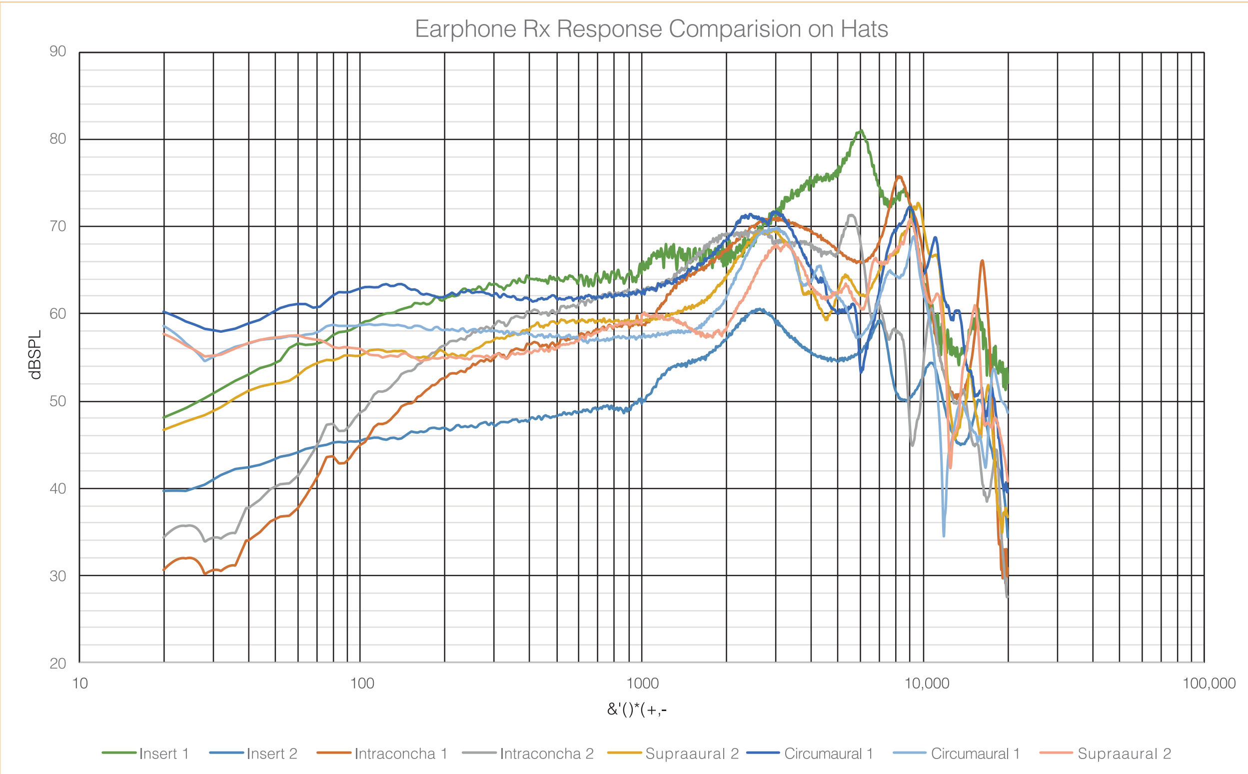


Figure 5: Illustration on the variability of sensitivity for nine headphones and earphones

Table 3: Illustration of headset characteristics at maximum permitted sensitivity according to EN 50332-2, in 1/3rd-octave bands

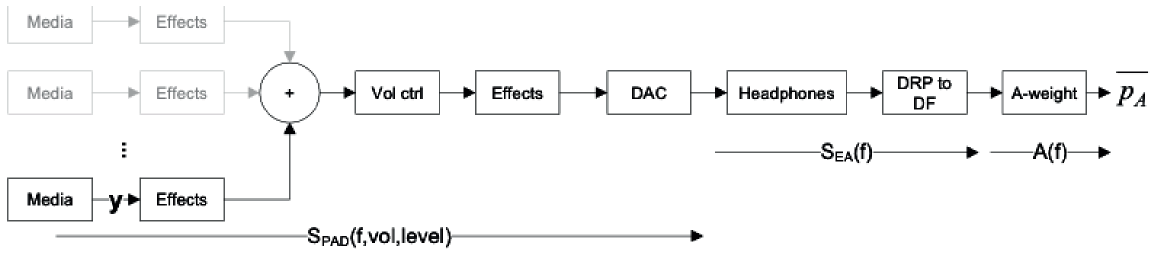
NOTE – A IEC 60268-1 programme simulation noise signal of 75 mV generates a sound pressure level of 94 dBSPL(A).

Programme simulation noise			**Headset response**			**A-weighting**			**A-weighted acoustic**		
IEC 60268-1 (adjusted for 75 mV)			Flat DF-corrected response			IEC 61672-1			EN 50332-1		
			SPCV = 75 mV; EN 50332-2								
[Hz]	PSM [dBV]	PSM [V^2]	[Hz]	[dBPa/V]	[Pa/V]	[Hz]	[dB]	[gain]	[Hz]	[dBPa]	[Pa^2]
20	-48.56	1.39E-05	20	25.10	12.55	20	-50.40	-2.52E+01	20	-73.85	4.12E-08
25	-45.26	2.98E-05	25	25.10	12.55	25	-44.82	-2.24E+01	25	-64.98	3.18E-07
31.5	-42.46	5.68E-05	31.5	25.10	12.55	31.5	-39.53	-1.98E+01	31.5	-56.89	2.05E-06
40	-40.26	9.43E-05	40	25.10	12.55	40	-34.54	-1.73E+01	40	-49.70	1.07E-05
50	-38.56	1.39E-04	50	25.10	12.55	50	-30.28	-1.51E+01	50	-43.73	4.24E-05
63	-37.36	1.84E-04	63	25.10	12.55	63	-26.22	-1.31E+01	63	-38.48	1.42E-04
80	-36.46	2.26E-04	80	25.10	12.55	80	-22.40	-1.12E+01	80	-33.75	4.21E-04
100	-35.96	2.54E-04	100	25.10	12.55	100	-19.15	-9.57E+00	100	-30.00	1.00E-03
125	-35.56	2.78E-04	125	25.10	12.55	125	-16.19	-8.10E+00	125	-26.65	2.16E-03
160	-35.26	2.98E-04	160	25.10	12.55	160	-13.25	-6.62E+00	160	-23.40	4.57E-03
200	-35.16	3.05E-04	200	25.10	12.55	200	-10.85	-5.42E+00	200	-20.90	8.12E-03
250	-35.06	3.12E-04	250	25.10	12.55	250	-8.68	-4.34E+00	250	-18.63	1.37E-02
315	-35.06	3.12E-04	315	25.10	12.55	315	-6.64	-3.32E+00	315	-16.60	2.19E-02
400	-35.06	3.12E-04	400	25.10	12.55	400	-4.77	-2.39E+00	400	-14.73	3.37E-02
500	-35.06	3.12E-04	500	25.10	12.55	500	-3.25	-1.62E+00	500	-13.20	4.78E-02
630	-35.06	3.12E-04	630	25.10	12.55	630	-1.91	-9.54E-01	630	-11.86	6.51E-02
800	-35.06	3.12E-04	800	25.10	12.55	800	-0.79	-3.97E-01	800	-10.75	8.41E-02
1000	-35.16	3.05E-04	1000	25.10	12.55	1000	0.00	0.00E+00	1000	-10.06	9.87E-02
1250	-35.36	2.91E-04	1250	25.10	12.55	1250	0.58	2.88E-01	1250	-9.68	1.08E-01
1600	-35.66	2.72E-04	1600	25.10	12.55	1600	0.99	4.97E-01	1600	-9.56	1.11E-01
2000	-36.06	2.48E-04	2000	25.10	12.55	2000	1.20	6.01E-01	2000	-9.75	1.06E-01
2500	-36.66	2.16E-04	2500	25.10	12.55	2500	1.27	6.36E-01	2500	-10.28	9.37E-02
3150	-37.56	1.76E-04	3150	25.10	12.55	3150	1.20	6.01E-01	3150	-11.25	7.49E-02
4000	-38.76	1.33E-04	4000	25.10	12.55	4000	0.96	4.82E-01	4000	-12.69	5.38E-02
5000	-40.16	9.65E-05	5000	25.10	12.55	5000	0.56	2.78E-01	5000	-14.50	3.55E-02
6300	-42.06	6.23E-05	6300	25.10	12.55	6300	-0.11	-5.70E-02	6300	-17.07	1.96E-02
8000	-44.46	3.58E-05	8000	25.10	12.55	8000	-1.14	-5.72E-01	8000	-20.50	8.91E-03
10000	-46.96	2.02E-05	10000	25.10	12.55	10000	-2.49	-1.24E+00	10000	-24.34	3.68E-03
12500	-49.86	1.03E-05	12500	25.10	12.55	12500	-4.25	-2.12E+00	12500	-29.01	1.26E-03
16000	-53.26	4.72E-06	16000	25.10	12.55	16000	-6.70	-3.35E+00	16000	-34.86	3.27E-04
20000	-56.66	2.16E-06	20000	25.10	12.55	20000	-9.34	-4.67E+00	20000	-40.90	8.13E-05
	total [V^2]	5.63E-03								total [Pa^2]	9.97E-01
	total [V]	**7.50E-02**								total [Pa]	9.99E-01
										total dBSPL	**9.40E+01**

1.11 Alternative audio signal capture point

When the preferred implementation shown in **Figure 3:** is not feasible, a simplified dosimeter may be implemented as follows.

In cases where the signal is captured at a point further from the output of the device (e.g. inside a specific media application that can access only its own media stream), the influence of the downstream digital audio system such as volume control and sound effects have to be accounted for by a best-effort approach. The system identifications of S_{PAD} across volume not control settings, may have to be performed at multiple content levels, to account for possible non-linear processing.



NOTE – The influence of volume control and sound effects have to be accounted for by a best-effort approach. The characteristics of the player are functions of frequency, volume control setting and potentially the level of the content.

Figure 6: Example of player audio system in cases where the signal y is captured inside a specific media source application

1.12 Testing of dosimeter functionality

The dosimeter functionality is tested by playing the programme simulation sound according to [EN 50332-1] and [IEC 60268-1] and measuring the time until the dose estimate reaches 100% CSD, using interpolation and tolerances as described in [EN 50332-3]. Such testing may be performed in the acoustic domain (when a certain headset is used) or in the electrical domain using a 32 Ω resistive load (when the headset characteristics are unknown). See measurement setup information in [ITU-T P.381].

It should be verified that the dose grows at twice the rate for every 3 dB increase in output level when varying content levels from -28 to -4 dBFS [EN 50332-1] and similarly when varying volume control settings. It is also recommended to repeat the verification using real music signals.

It is recommended to test the A-weighting filter and other detailed dosimeter characteristics as described in [IEC 61252].

1.13 Uncertainties

Some sources for uncertainties are:

– variation in headphone characteristics of a single model, due to production tolerances;
– variation due to unknown headphone type;
– errors due to incorrect manual selection of headphone type;
– variations in fit to the artificial ear during characterization;
– imperfect relation between artificial ears and real ears;
– imperfect relation between a standardized diffuse-field correction and a variety of human head-related transfer functions;
– variations in fit to the human ears;

- uncertainties in characterization of player characteristics, especially due to non-linear processing in the alternative implementation shown in Figure;
- errors in calculations;
- users' individual susceptibility to sound exposure;
- exposure from other sources.

Since some of these uncertainties are typically several dB (and an error of 3 dB constitutes a 100% dose error), uncertainties of dose estimation can be expected to be hundreds of percent. It is therefore recommended to refrain from signalling "safe" and "green" to the user based on dose readings below a certain limit.

The dose estimation is however relevant in accounting for generally accepted truths:

- Higher signal means higher risk.
- Longer exposure means higher risk.
- The spectral content of the music is accounted for.

Appendix 2

Example of health communication

Appendix 2
Example of health communication

(Reproduced from ITU H.870 guidelines for safe listening devices/systems, appendix II)

2.1 Recommendations for developing warnings and cues for action messages for device interface

The messages should be developed in consideration of the factors mentioned above. Messages should aim to gain attention, build interest and encourage users to practice safe listening. They should share actionable information, provide viable alternative behaviours and facilitate safe listening practices.

Points to consider while developing such messages/cues are:
– They should clearly convey the benefits of safe listening and the risks of not doing so.
– There should be 3–4 variations of each message that can convey the information in a non-repetitive manner, designed to address a wide audience.
– Text should be simple, clear and jargon-free in order that they can be understood by the majority of users.
– Some messages should be positively and others negatively worded (see section 2.4.3).
– Written information should be complemented by pictorial information for ease of understanding.
– Messages should be based on recommendations from a credible source.
– Wherever possible, messages should be pre-tested by the manufacturer before use.

2.2 Suggested flow (an example) of information as part of standards for safe listening devices

Figure 1 contains suggested steps for explaining how the communication aspects of a standard can be implemented within devices.

Example of information flow

This section and the figure below contains suggested steps for explaining how the communication aspects of the standard can be implemented within devices

Packaging

•A clear, concise message/warning should be included on the external packaging of the devices, wherever possible.
•Messages should appear on a plain background and be short, simple, and clear, with a relevant illustration.
•The manual should clearly state that unsafe listening via the device may pose the risk of permanent hearing loss.
•It should indicate that the device is equipped with safety features to help users protect their hearing.

User manual

•This message should align with information provided through the device interface. It should contain similar text regarding the risks of hearing loss from unsafe listening and the recommendations for safe listening.
•It should also detail the safe listening features within the device.

Device interface

•A visible icon on the device screen will direct users to the general information on safe listening. •This icon will also lead the user to a display (in devices with screens) which provides information regarding individuals' listening parameters and (daily and weekly) usage statistics.

1st use

•The first use of ear/headphones with the device should direct the user to a tutorial with information on safe listening, how to practice it, and their personal listening profile (same information as available through the icon).
•It will describe the standard levels for adults and children and allow the user to select a level.
•Users will be given the option to set up how often and at what levels of usage they wish to receive the notifications.

Personal Usage

• The information on the daily/weekly sound allowance consumption is available to users at any time through the distinctive icon above mentioned.
• Calculation should include all sounds played through the music players or online, as long as ear/headphones are used.
• The displayed information should include: weekly allowance used and remaining; listening time (for the day/week), and indicate how the user's listening has been for the past 7 days, including current day, where possible.

Notifications

•Warnings and cues for action shall be delivered every time the user reaches 100% of the allowance exposure levels and also as per settings customized by the user.
•These should be visual (where possible) and audible/vibratory to ensure that the user's attention be directed towards these.
•The notifications should include information on the level of audio usage and the corresponding recommendations for safe listening.

Daily alerts

•The first time a user connects to an ear/headphones or starts playing music on a given day, the device could give a welcome message based on the usage on the previous days/week.

Figure 1: Flow of information as part of standards for safe listening devices

2.3 Example of how the information on listening parameters can be conveyed to users

Through a clearly recognisable icon, users should be able to access a “dedicated space” (screen) on the device where information on the user’s listening habits is stored, visualized and interpreted. In this space, the user should be able to access a graphic representation of his/her overall listening habits or patterns and learn if (and what type of) unsafe listening practices have occurred. The visualization of the user’s listening habits will include:

– graphic display of the use of weekly sound allowance;
– graphic display of daily sound exposure through a colour-coded display;
– duration of listening, over each day and the past 7 days in hours and minutes.

2.3.1 Information on use of weekly allowance

Use of weekly allowance can be graphically conveyed as illustrated in **Figure 2.**

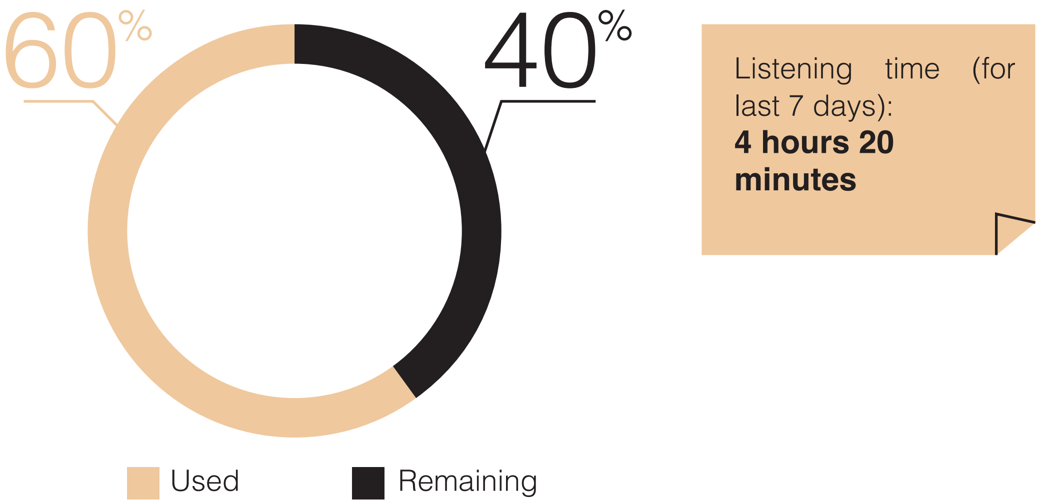


Figure 2: Illustration of how to graphically convey the use of a weekly allowance

2.3.2 Information on how the user has used the allowance on any day

For the purpose of this display, the maximum daily allowance will be equal to weekly allowance divided by 7 (approximately 15% of the weekly allowance).

Usage for the last 7 days (including the present day) would be indicated by a range of colours depicting different levels of usage, e.g. red for over 100% use and green when use is below 50%. For the purpose of this communication, each day would be considered as a separate unit and colour coding for the day would not take the previous days’ exposure into account. Hence, the user would start with green icon each day, regardless of past days’ usage.

2.3.3 Listening time

Information on the overall time the user spent listening to audio content through the device each day will also be displayed (as shown in **Figure 3.**)

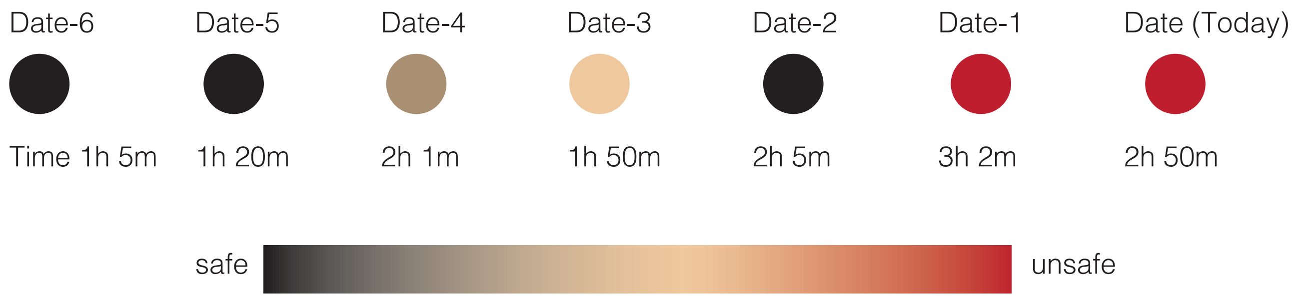


Figure 3: Information on the overall daily time the user spent listening to audio content

2.4 Warnings and cues for actions

The following are some examples of warnings and cues for action for the safe listening features.

2.4.1 Examples of warnings and cues based on weekly use

Information when user reaches:

a. 80% of weekly allowance: friendly warning message:
   You have already spent 80% of your allowance. Turn down the volume to protect your hearing
   Reduce volume/Stop listening/Ignore warning/Go to personal usage information
   OR
   Hello! It looks like you have been playing a lot of loud music lately. Why don't you take a short break to protect your hearing?
   Reduce volume/Stop listening/Ignore warning/Go to personal usage information

b. 100% of weekly allowance: warning message (with an option to pause listening immediately):
   You are now OVER 100% of your safe listening allowance. Unsafe listening poses a risk to your hearing.
   Reduce volume/Stop listening/Ignore warning/Go to personal usage information
   OR
   Hey! You have played too much loud music recently. Take a break and protect your hearing.
   Reduce volume/Stop listening/Ignore warning/Go to personal usage information

   Unless the user agrees to “ignore warning: or to “pause listening”, the default will reduce the volume to below an average of 80 or 75 dB

2.4.2 Examples of messages based on daily use

Daily message (when opening the app or at player page) which should be based on the user's use of sound allowance over the last few days:

a. Mostly in green (where the user stays below 50% weekly usage most days, not exceeding the allowance on any day): encouraging messages
   Good job. This is the way to listen well
   Good job! Keep playing music safely for endless fun
   Well done. Keep listening safely and have endless fun

b. Mostly green or yellow/orange (where the user stays below 80% on most days, not exceeding the allowance on any day):
   Be careful and listen safely.
   Hey! It seems that sometimes you enjoy high volume! Be careful and protect your hearing for endless fun!
   You can listen safely for longer by lowering the volume

c. Mostly yellow/orange with occasional red (where the user is not exceeding the allowance on any day):
   Be careful! Keep the volume down to listen safely for longer
   Hey! It seems that sometimes you enjoy loud music! Be careful and protect your hearing for endless fun!
   Hey! You should watch how you listen

d. Mostly red (exceeding the allowance on most days):
   You are putting your hearing at risk. Keep the volume low to listen safely
   Hey! You need to watch how you listen. Turn it down
   Hey! It seems that you enjoy really loud music! Don't put your hearing at risk and have endless fun

2.4.3 Examples of messages with positive versus negative frame; and emotional versus rational appeal

Positive frame:

You exceeded your daily allowance for safe listening. Keeping the volume low lets you listen safely for longer without risk to hearing. Turn it down.

Negative frame:

You exceeded your daily allowance for safe listening. If you keep listening this way, you risk damaging you hearing forever. Turn it down

Rational appeal:

The evidence says that if you listen to music above the 80 dBA SPL, for 8 hours or its equivalent, you might damage your hearing forever. Turn down the volume

Emotional appeal:

Once you lose your hearing, it will not come back. Listen safely. Turn down the volume

FOR MORE INFORMATION

PLEASE CONTACT:
Department for Management
of NCDs, Disability, Violence and
Injury Prevention

https://www.who.int/deafness/make-listening-safe/en/

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