

# Health effects of noise exposure

Addressing health hazards resulting from exposure to noise at workplaces

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**Dr. Seble Merid  
Mekonnen**

Technical Safety and  
Working Environment  
Engineer

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# Background

- Definition of noise
- Definition of sound
- Hearing mechanism
- Risks and consequences of noise exposure
- Regulations about occupational noise exposure
- Control of noise exposure
- Hearing protection equipment
- Databases for calculating occupational noise exposure
- Measurement of occupational noise exposure
- Audiometry



# What is noise ?

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- Noise = any unwanted sound !!

Examples:

- Loud music from a neighbor
- Speedy car noise



# Noise is divided into two types

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- 1. Annoying or irritating noise:**  
**Example: ventilation fan in the PC, loud music and the like**

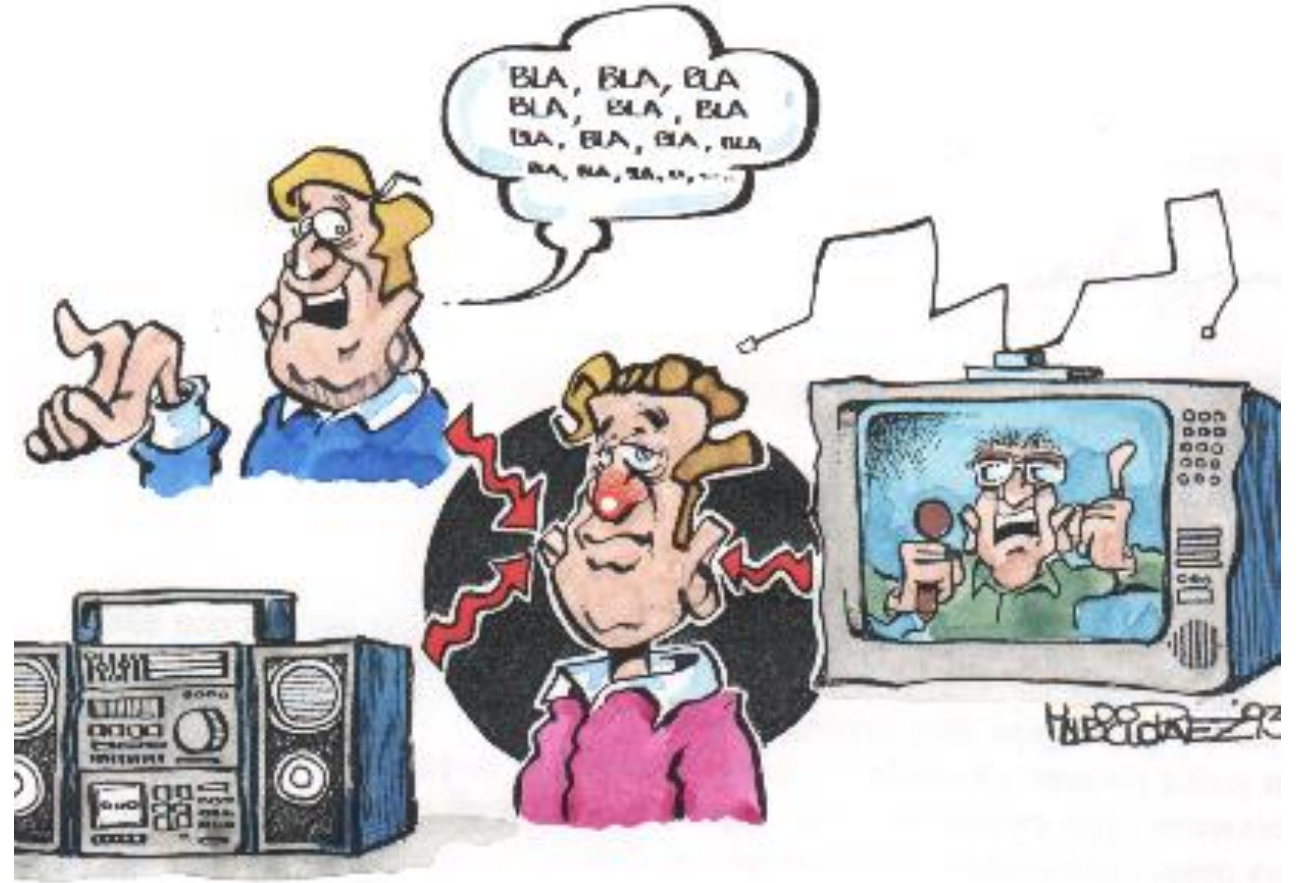


- 2. Harmful noise from noisy environments  $> 80$  dB (A) and Impulse noise  $> 130$  dB (C)**

# Sound

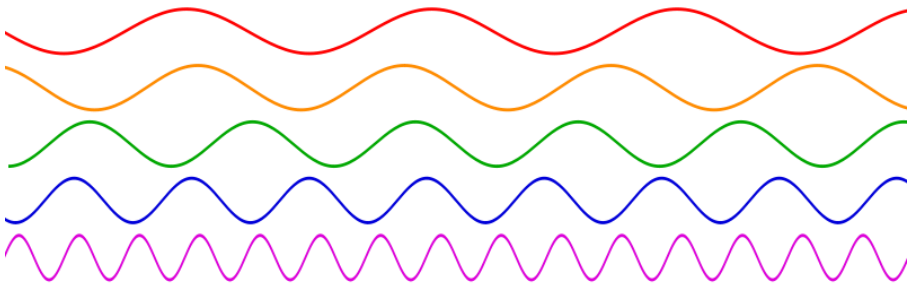
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- In order to hear, one must perceive sound, which is a very important factor in communication



# Sound

- Sound is a mechanical wave that is an oscillation of pressure transmitted through a solid, liquid, or gas, composed of frequencies within the range of hearing

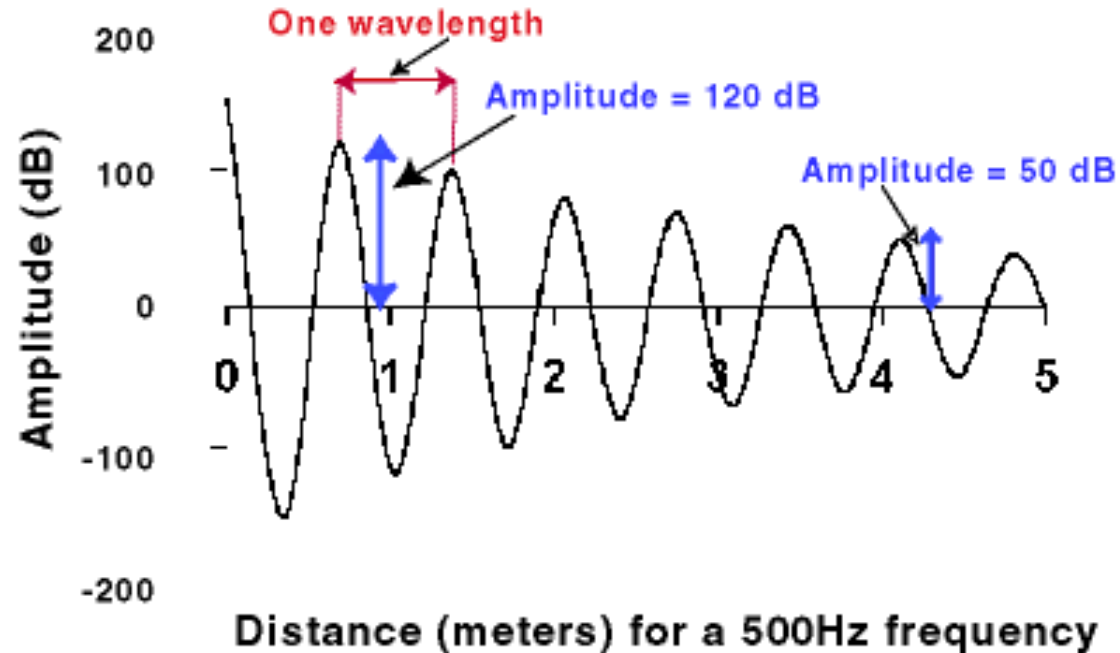


*Waves of various frequencies*





# Physics of sound



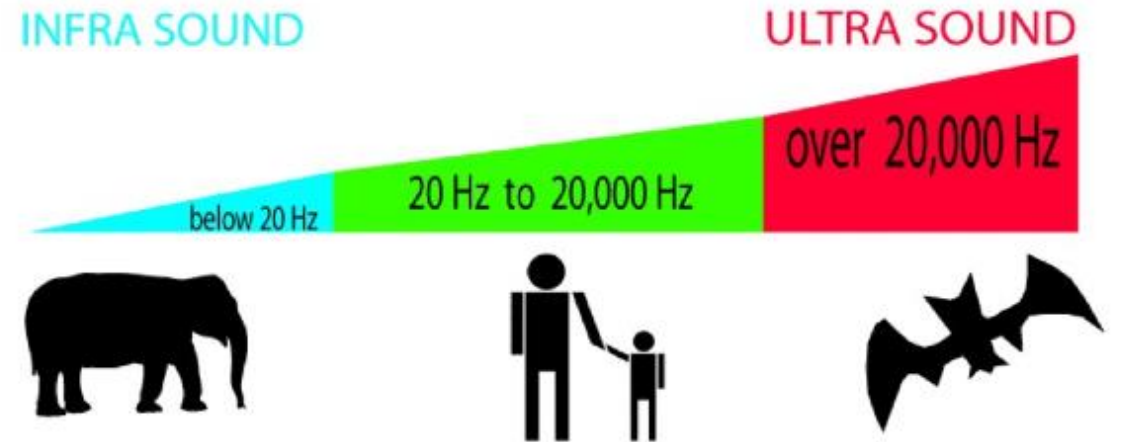
**Amplitude = volume or loudness (dB)**

**Frequency = which is pitch (Hz), is the number of oscillations per second**

**Wavelength =  $\lambda$**

# Physics of sound

- Humans perceive sounds from 20 to 20,000 Hz
- Normal speech is typically between 200 to 4000 Hz
- Infrasound (Low frequency <20 Hz)
- Ultrasound (high frequency > 20 KHz)





# Physics of sound

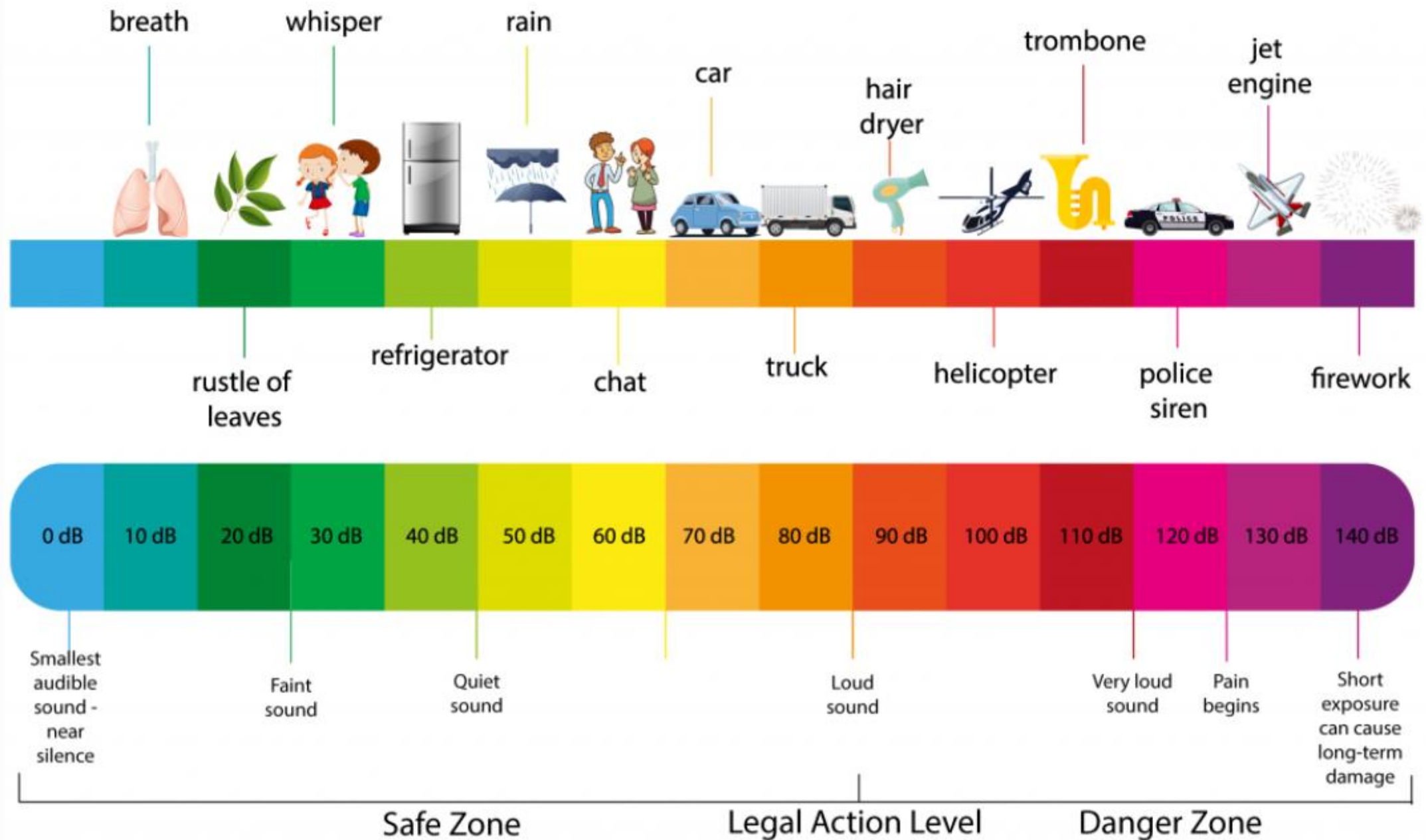
- Sound pressure level is presented as Decibel (dB)
- dB is a logarithmic function
- Sound pressure doubles with an increase of 3 dB
- The sound pressure is perceived by humans as twice as high with an increase of 10 dB
- The sound pressure level decreases by 6 dB when the distance to the source is doubled

# The sensitivity area of the ear

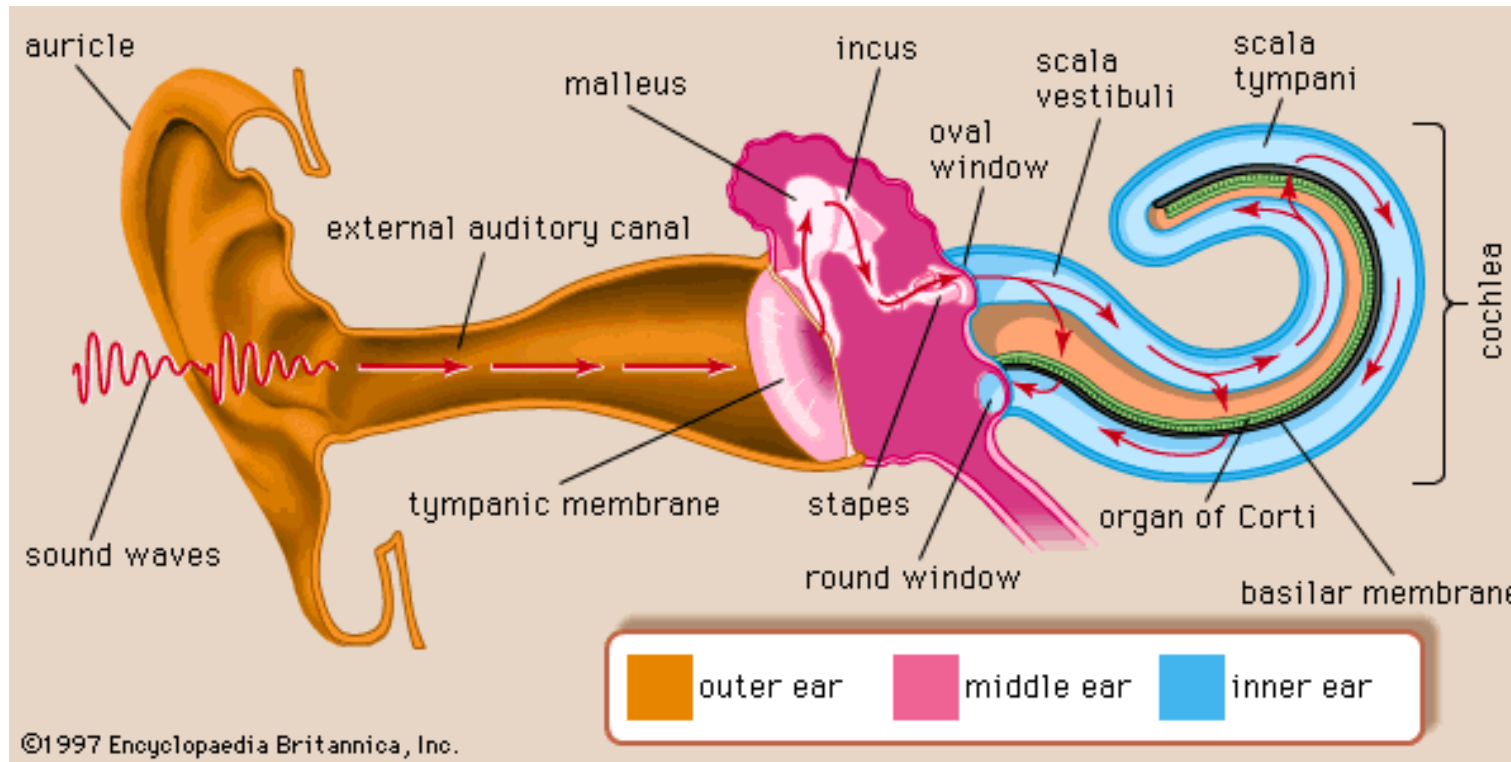
- Hearing threshold 0 dB                      Pain threshold 130 dB



- Humans perceive sound pressure level between 0.00002 to 20 Pascal (hearing threshold and pain threshold)



# Hearing mechanism

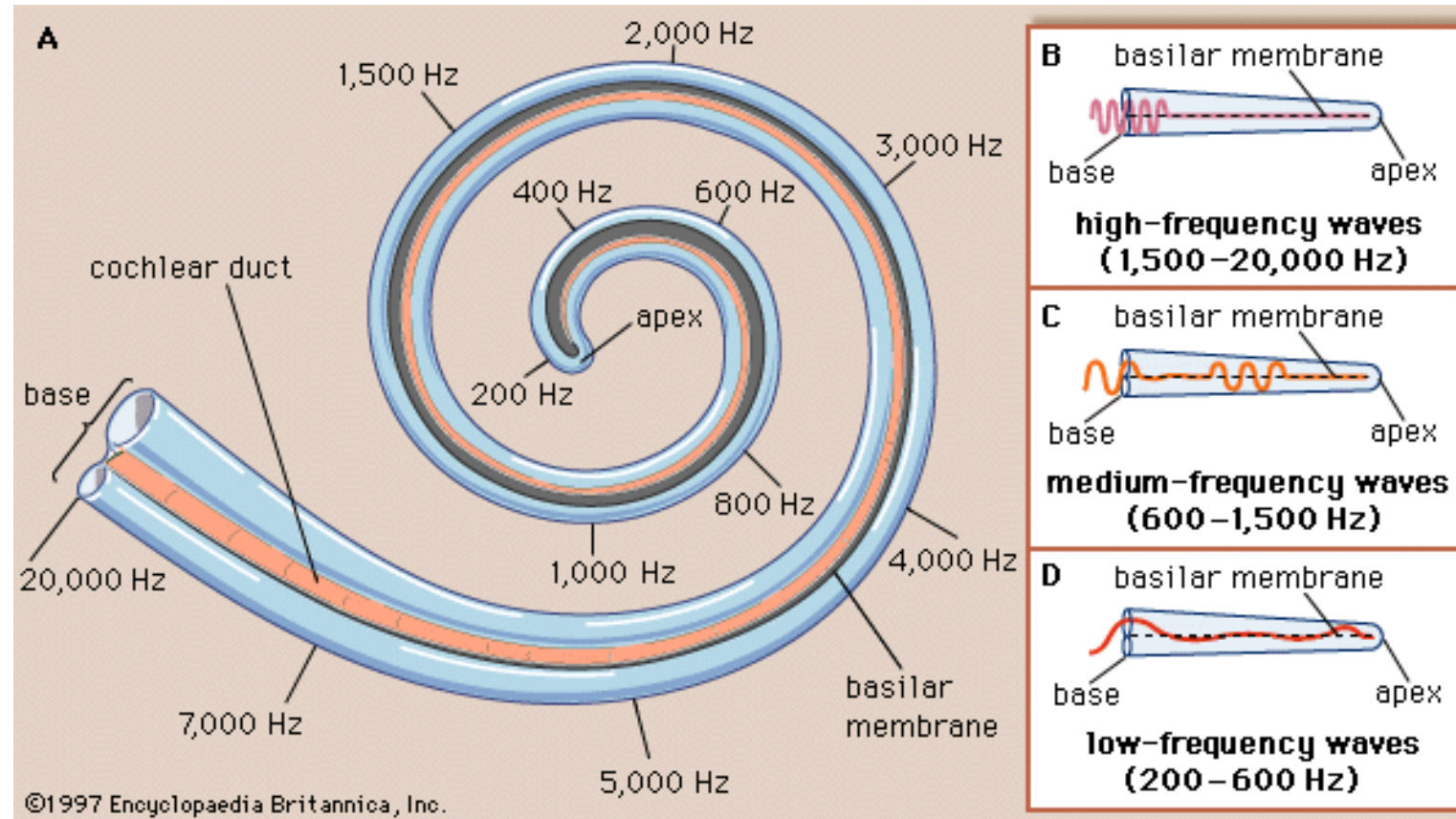


*Parts of the human ear and of the cochlea*

- As soon as sound waves reach our ear and are transmitted to the oval window (the "entrance" of the cochlea), the fluid in the two scalae and the basilar membrane are set in motion. The basilar membrane is moved by a travelling wave

# Hearing mechanism

- The location of maximal amplitudes depends on the frequency of the incoming tone (see under)

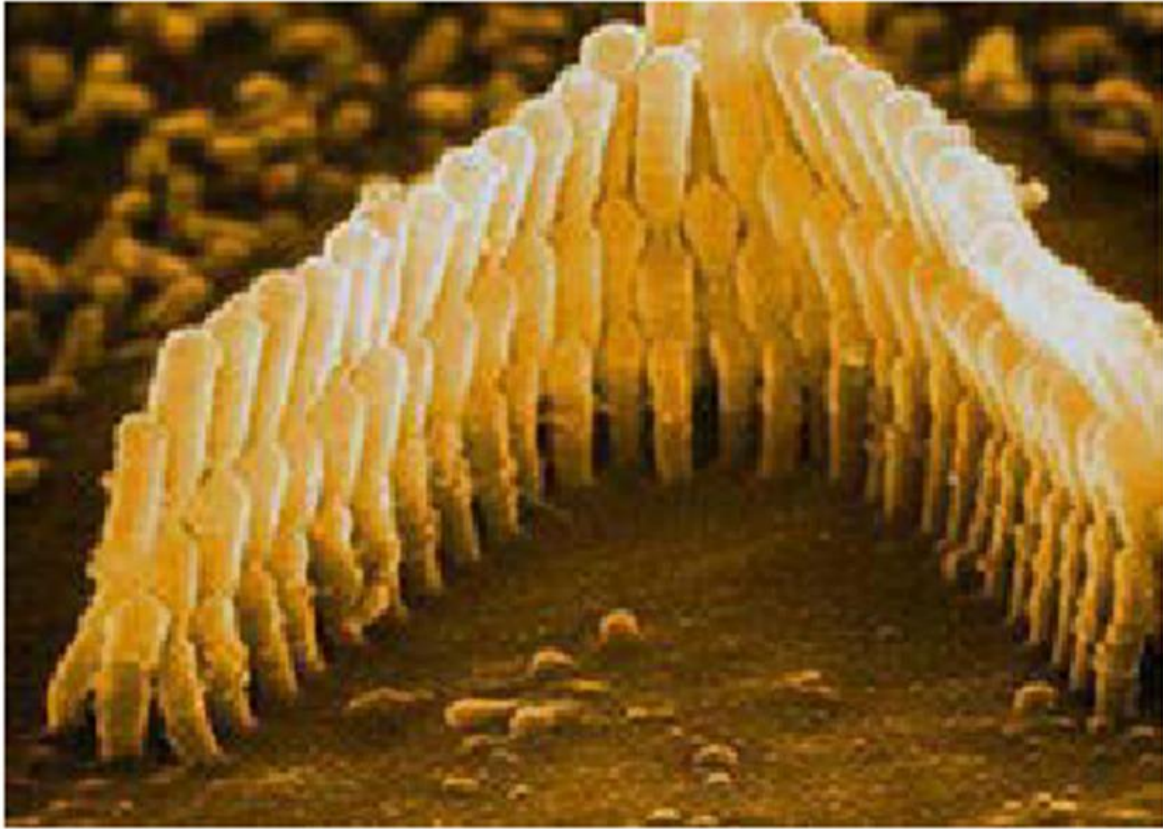


## Basilar membrane motions at different frequencies

# When does hearing impairment occur ?

- **Prolonged noise impact:**  
The ability to hear high-frequency sounds are diminished
- **Hearing impairment by impulse noise (over 130 dBC)**  
Explosion, strokes, shots, etc....  
Immediate damage hearing loss and chronic tinnitus
- **Adverse effects of drugs and poisons (chemicals that are toxic to the ear, ototoxic substances, example : Toluene, Styrene, Xylene**
- **Head injuries**
- **Infections (bacteria/virus) in the ear or along the nerve pathways from the ear**





*Electron microscope of normal auditory cells*



*Electron microscope of damaged auditory cells*



# Hearing impairment

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- *Source : The Danish Labour Inspection Authority*

Noise exposure load in the workplace in 10 years	Risk of hearing impairment
80 dB (A)	0 %
85 dB (A)	4 %
90 dB (A)	11%
95 dB (A)	24 %

# Risks and consequences of noise exposure

- **Noise makes it difficult to hear and understand signals properly**
- **Danger and warning signals can be missed**
- **Employees may be distracted**
- **Noise contributes to stress, which increases the burden and the risk to make mistakes in work that requires attention**
- **Increases the risk of accidents**

# Risks and consequences of noise exposure

<https://www.napofilm.net/no/napos-films/napo-stop-noise>

DIRECT	INDIRECT
Noise damage (impaired hearing)	Embarrassment (irritation, frustration)
Sleep disturbances	Behaviour change (responsiveness, isolation)
Communication disorder (speech comprehension)	Health effects (heart, vessels, stomach, intestines, stress and more)
Concentration comprehension (doesn't get the message)	Sleep loss
Contribute to stress, even when the volume is relatively low	Work performance (accuracy, risk, error, efficiency)

# Health Challenges associated with noise

Noise can:

- Result in hearing loss and “social isolation”



- Be really annoying, tedious and reduce concentration and attention
- Give higher blood pressure
- Can cause changes in heart rate and respiratory rate
- Can cause changes in brain activity
- Contribute to muscle tension, digestive upsets
- Negatively influence unborn child

# More info om health Challenges associated with noise

<https://www.cdc.gov/niosh/topics/noise/>

<https://www.hse.gov.uk/noise/>

<https://www.bohs.org/search/noise>

<https://www.safeworkaustralia.gov.au/safety-topic/hazards/noise/overview>

<https://noa.stami.no/arbeidsmiljofaktorer/sterk-stoy/>

<https://www.osha.gov/noise/health-effects>

<https://www.nidcd.nih.gov/health/noise-induced-hearing-loss>

[https://www.ilo.org/global/topics/safety-and-health-at-work/normative-instruments/code-of-practice/WCMS\\_107878/lang--en/index.htm](https://www.ilo.org/global/topics/safety-and-health-at-work/normative-instruments/code-of-practice/WCMS_107878/lang--en/index.htm)

# Which factors determine the risk of hearing damage ?

- **Volume / sound pressure level**
- **Exposure time**
- **The frequency spectrum of the noise**
- **Hearing rest**
- **Individual sensitivity**
- **Effect and type of personal protective equipment**
- **Maintenance of personal protective equipment**

# Regulations about occupational noise exposure

- Not all countries have rules, regulations and standards about occupational noise exposure
- The rules, standards and regulations vary from country to country
- Most are based on permissible exposure limit (PEL), and time-weighted average (TWA) exposure. A TWA exposure is the average noise exposure as integrated over an 8-hour monitoring duration
- A requirement to measure personal exposures with a noise dosimeter
- An obligation to offer hearing protection if an employee's TWA exposure is at or above the Action Level and to require hearing protection if it exceeds the PEL or the employee has suffered a standard threshold shift
- A maximum of 140 dB (C) or 130 dB (C) peak sound pressure level for impulse or impact noise



# Regulations about occupational noise exposure (US)

NIOSH: National Institute of Occupational Safety and Health, US

OSHA : The Occupational Safety and Health Administration. US

## Permissible Noise Exposures

Time to reach 100% noise dose	Exposure level per NIOSH REL	Exposure level per OSHA PEL
8 hours	85 dBA	90 dBA
4 hours	88 dBA	95 dBA
2 hours	91 dBA	100 dBA
1 hour	94 dBA	105 dBA
30 minutes	97 dBA	110 dBA
15 minutes	100 dBA	115 dBA

### Comparison of Duration Per Day in Hours to Allowable Sound Level in dBA (Slow-Response SPL)

Duration per day (hours)	Sound level (dBA, slow response)	PEL = 90 dBA (TWA), or 100% Dose
8	90	
6	92	
4	95	
2	100	
1	105	
½	110	
0.25	115	

- **PEL:** The permissible exposure limit (PEL) for noise is **90 dBA**, as an eight hour time-weighted average (TWA). The PEL is also referred to as a 100 percent "dose"

ACGIH: the American Conference of Governmental Industrial Hygienists, US

### NIOSH RELs and ACGIH TLVs for Noise

Duration	REL and TLV
16 hours	82 dB
8 hours	85 dB
4 hours	88 dB
2 hours	91 dB
1 hour	94 dB
1/2 hour	97 dB
15 minutes	100 dB

**PEL:** Permissible exposure limit

**REL:** Recommended exposure limit

**TLV:** Threshold Limit Values

# Regulations about occupational noise exposure in Norway

**Table 1: Noise Classes and Exposure Values**

Group	Action Limit	Recommended Maximum Level
<b>Group I</b> Employment where there are high demands on sustained concentration or the need to lead effortless conversation, and in the dining room, offices, and the rest room.	Lower Action Value $L_{EX, 1h}$ 55 dB (A)	45 dB (A)
<b>Group II</b> Working where it is important to keep conversation or persistent demand for precision, speed, or attention.	Lower Action Value $L_{EX, 1h}$ 70 dB (A)	60 dB (A)
<b>Group III</b> Working with noisy machinery and equipment under conditions that is not included in Groups I and II.	Lower Action Value $L_{EX, 8h}$ 80 dB (A)	70 dB (A)
	Limit values for noise exposure are set to:  Daily noise exposure level: $L_{EX, 8h}$ 85 dB (A)  Peak sound pressure level: $L_{pC, peak}$ 130 dB (C)	75 dB (A)

# Regulations about occupational noise exposure



UK

## Exposure limit values and action values

4.—(1) The lower exposure action values are—

- (a) a daily or weekly personal noise exposure of 80 dB (A-weighted); and
- (b) a peak sound pressure of 135 dB (C-weighted).

(2) The upper exposure action values are—

- (a) a daily or weekly personal noise exposure of 85 dB (A-weighted); and
- (b) a peak sound pressure of 137 dB (C-weighted).

(3) The exposure limit values are—

- (a) a daily or weekly personal noise exposure of 87 dB (A-weighted); and
- (b) a peak sound pressure of 140 dB (C-weighted).

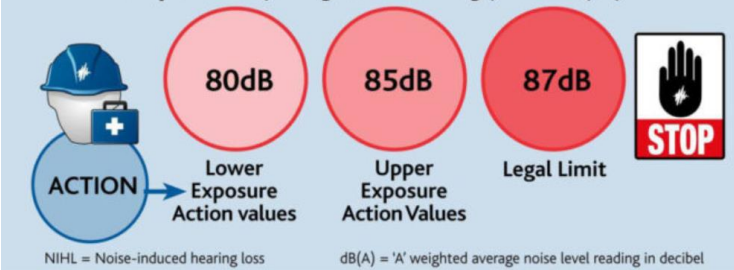
(4) Where the exposure of an employee to noise varies markedly from day to day, an employer may use the average exposure in place of daily personal noise exposure for the purpose of compliance with these Regulations.

(5) In applying the exposure limit values in paragraph (3), but not in applying the lower and upper exposure action values in paragraphs (1) and (2), account shall be taken of the protection given to the employee by any personal hearing protectors provided by the employer in accordance with regulation 7(2).

## Legal responsibilities for noise levels over 85 dB(A)



## Current Noise Action Levels and Limits of an 8hr period (daily or weekly) in dB(A)\*

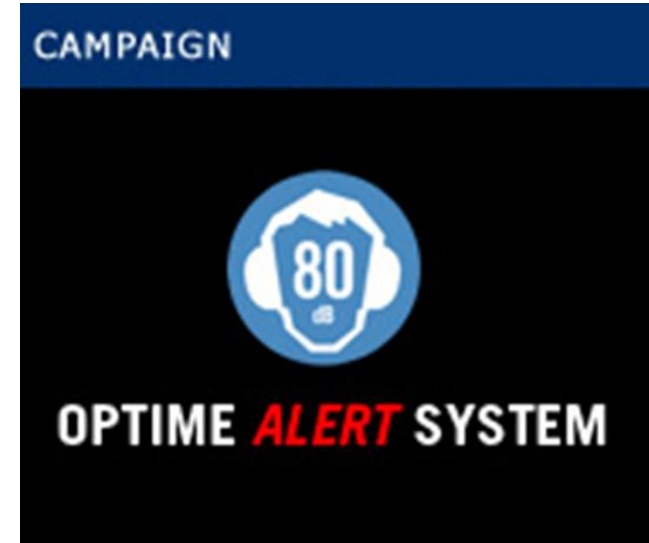


# Regulations about occupational noise exposure in Norway

According to «Regulations concerning Action and Limit values» ,  
«The facilities regulations », «The activities regulations »

Limit values for occupational noise exposure:

- Laeq **83 dB (A)** for **12 hours**
- Laeq **85 dB (A)** for **8 hours**
- LpCpeak: **130 dB (C)**
- Sets requirements for Hearing checkup for exposures over :  
**Laeq,8h = 80 dB (A)** and **LpC,peak = 130 dB (C)**
- Hearing protection and training should be given if **Laeq > 80 dB (A)** in 8 hours



# Regulations about occupational noise exposure in Norway

Limit Values for Noise Exposure during a day	
Limit Values for Noise in dB (A)	Duration per day
85 dB (A)	8 hours
88 dB (A)	4 hours
91 dB (A)	2 hours
94 dB (A)	1 hour
97 dB (A)	30 minutes
100 dB (A)	15 minutes
103 dB (A)	7.5 minutes
106 dB (A)	3.8 minutes
109 dB (A)	1.9 minutes






What about impulse noise above 130 dB (C)?	
Limit Values for impulse Noise in dB (C)	Time in Seconds
130 dB (C)	0.9375000
133 dB (C)	0.4687500
136 dB (C)	0.2343750
139 dB (C)	0.1171875
142 dB (C)	0.0585938
145 dB (C)	0.0292969
148 dB (C)	0.0146484
151 dB (C)	0.0073242
154 dB (C)	0.0036621
157 dB (C)	0.0018311
160 dB (C)	0.0009155

# Regulations about occupational noise exposure

According to «recommended guidelines for handling hazardous noise» from the Norwegian oil and gas association

## Marking of noisy areas

Limit values for noise exposure( $L_{p,A,T}$ )	Maximum Peak sound pressure level ( $L_{p,Cpeak}$ )	Noise Hazard safety Sign
>110 dB (A)	> 140 dB (C)	
106-110 dB (A)		
101-105 dB (A)		
96-100 dB (A)		
91-95 dB (A)	125-140 dB (C)	 
86-90 dB (A)		
81-85 dB (A)		
76-80 dB (A)		No noise hazard safety signs unless the peak sound pressure is $L_{p,Cpeak} \geq 125$ dB (C)
$\leq 75$ dB (A)		



# Regulations about occupational noise exposure

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According to  
«recommended guidelines  
for handling  
hazardous noise» from the  
Norwegian oil and gas  
association

**Hearing Protection regime according to recommended restrictions on residence times and use of hearing protection equipment in areas with high noise**

Area Noise Level dB(A)	Maximum residence time	Type of hearing protection equipment
> 110 dB (A)	Staying in the area not recommended	Stay under special conditions, e.g. with hearing protection that has integrated noise dosimeter.
106-110 dB (A)	half hour per shift	Double hearing protection (both earmuffs and earplugs when staying for more than 10 minutes). For shorter stays single hearing protection.
101-105 dB (A)	2 hours per shift	
96-100 dB (A)	6 hours per shift	
91-95 dB (A)	6 hours per shift	Single hearing protection (ear muffs or earplugs).
86-90 dB (A)	12 hours per shift	
81-85 dB (A)	No Restrictions	No requirements.
76-80 dB (A)		
<=75 dB (A)		

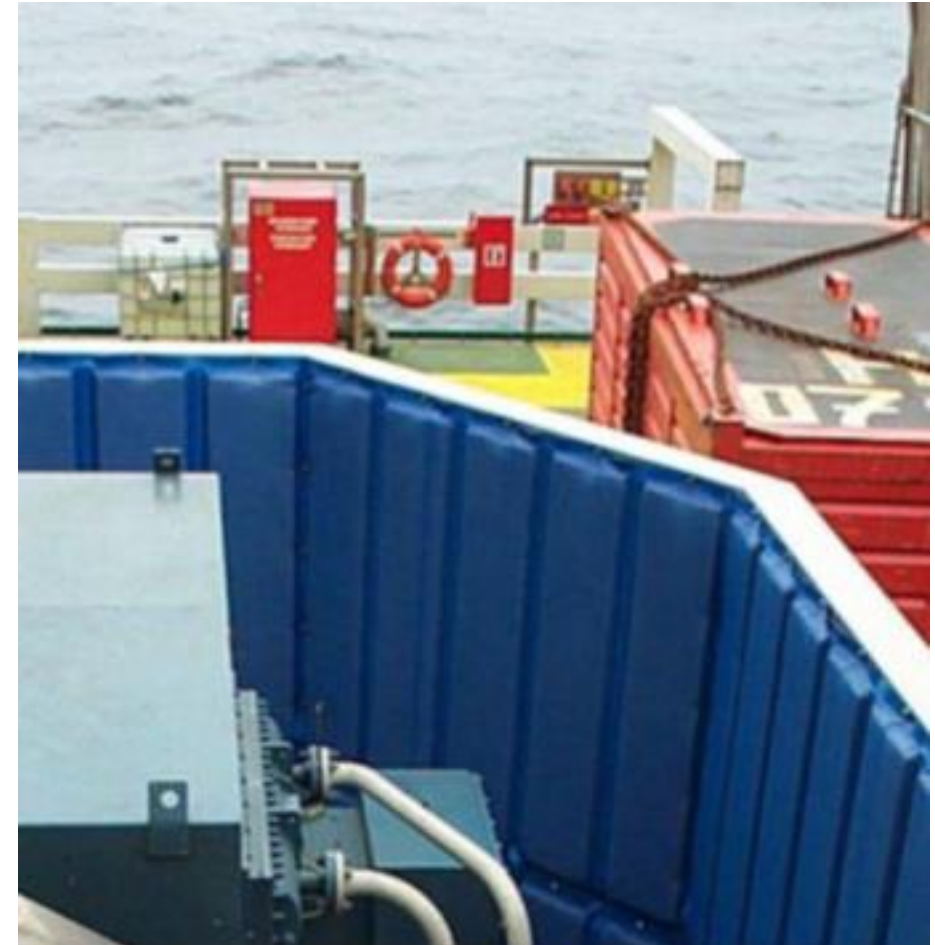


# Control of noise exposure

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Current measures to prevent and combat the noise risk can be classified into 3 major measures:

1. Remove the source of the noise.
2. Technical and organizational measures towards the noise source:
  - *Is it possible to isolate the noise source to another location?*
  - *Can vibrations be muted?*
  - *Can the noise source be built in?*
  - *Can the noise spread be reduced using silencers, reducing fan speeds, replacing equipment and tools ?*
  - *Can noise-absorbing materials be used near the noise source ?*
  - *Good maintenance of equipment and parts can help to reduce noise levels*



# Control of noise exposure

- Can there be changes in the workplace, for example by installing sound absorbers that reduce the "echo effect" from the walls, ceiling and floor?
- Can the work be planned, for example, by selecting work methods and working hours, resulting in less noise exposure?

How and where work equipment is installed and placed can be very important.

- Does one have good enough hearing protection?
- Have employees been informed about health consequences of noise?
- What about those who have already got work-related noise damage?

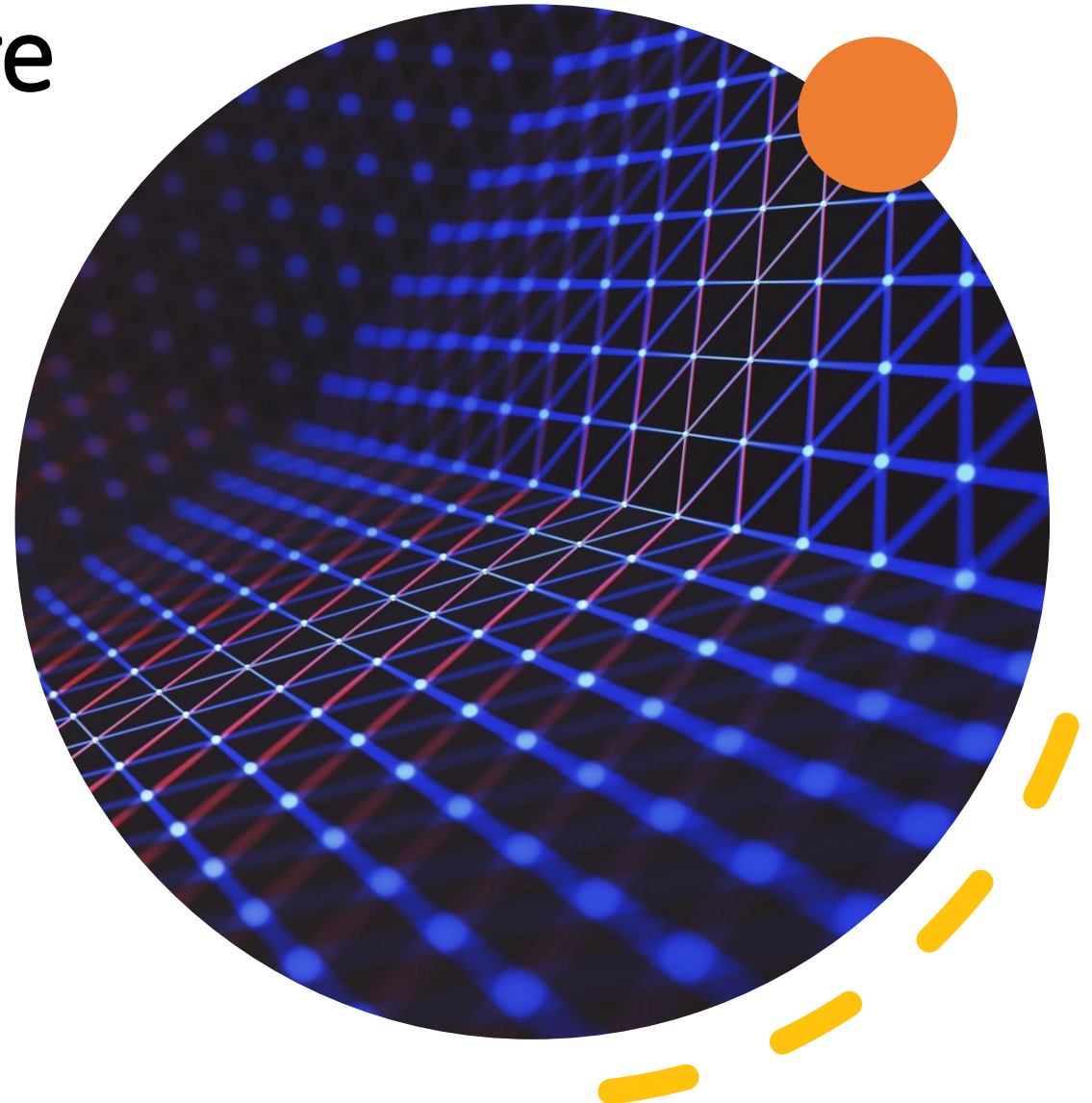
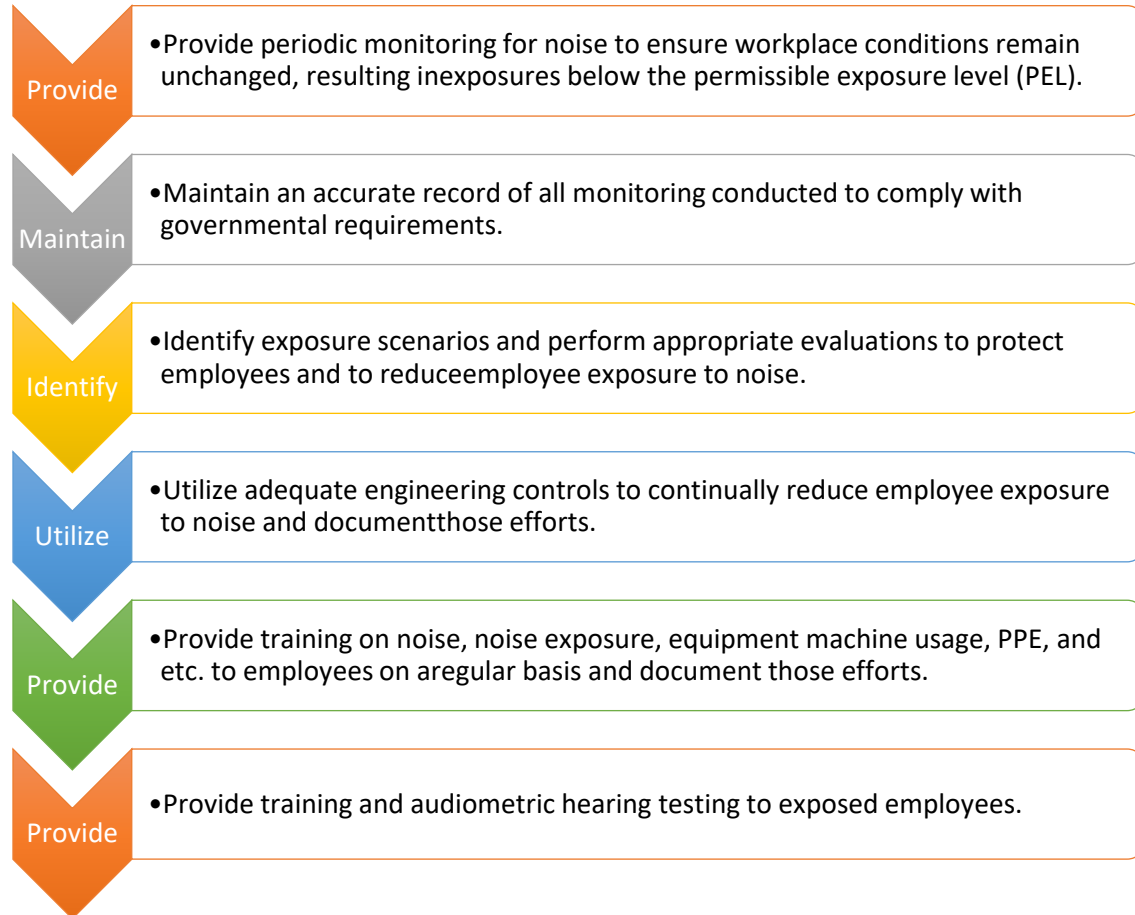
# Control of noise exposure

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**3. Tertiary prevention is to equip workers with hearing protection equipment. This is the solution that can be selected after the previous two have been tested. This is considered the weakest and least satisfactory solution to a work environment issues.**



# Control of noise exposure

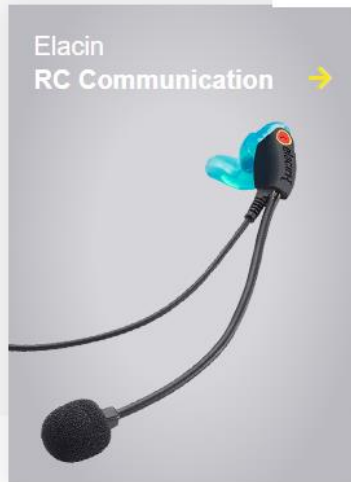
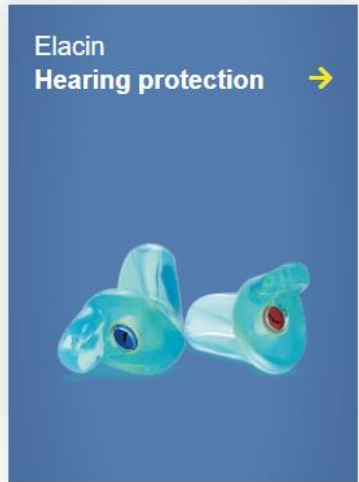




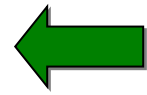
# Hearing protection equipment

- Earmuffs

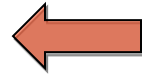
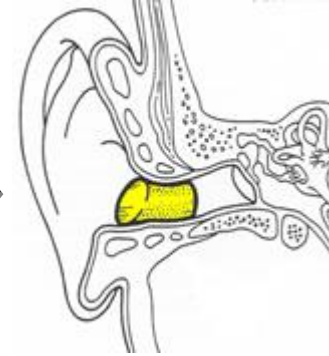
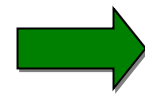
- Earplugs



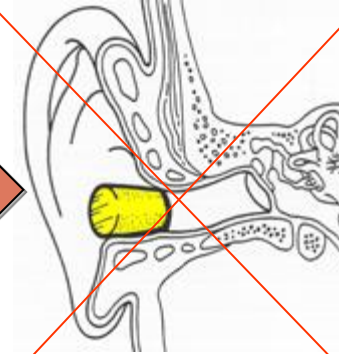
# Earplugs



**Correct**



**Not correct**



<https://www.youtube.com/watch?v=jVWRCURH3D0&feature=youtu.be>

# Earmuffs

- Ears should be completely enclosed by earmuffs
- There should be a "tight" seal against the skin around the ears
- Pillows and feathers age and should be replaced after some time (6 months)
- Earmuffs can unsealed in combination with safety glasses between skin and earmuffs
- Select safety glasses with thin rods, face shield or helmet with integrated goggles to reduce leakage





# Estimated attenuation for single and double hearing protection

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- 12 dB for single hearing protection
- 18 dB for double hearing protection ( earmuffs + earplugs )
- The Norwegian Oil and Gas guidelines (requirements for hearing protection):
  - Earmuffs: SNR > 30 dB
  - Earplugs: SNR > 35 dB



# Examples of noise sources

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•	<u>Instrument</u>	<u>dB(A)</u>
•	Pneumatic chisel	118
•	Grinder	109
•	Sledgehammer and Tiger Saw	101
•	Ultra high-pressure jetting	111
•	Sponging	117
•	In the helipad:	
•	Fire guard	106



# Theoretical noise exposure

- **Example:**
  - **Work with Grinder 110 dB (A) for 30 minutes**
  - **Using double hearing protection**
  - **Remaining work in quiet area**

**Becomes theoretically exposed to:**

- **110 dB - 18 dB = 92 dB at the ear for 30 min**

**This is equivalent to:**

**89 dB for 1 hour**

**86 dB for 2 hours**

**83 dB in 4 hours**

**80 dB for 8 hours**

# Databases for calculating occupational noise exposure

- Several databases have been created in different countries:

## Examples:

- <https://www.hse.gov.uk/noise/calculator.htm>

ohcow.on.ca  
[https://www.ohcow.on.ca/general\\_handouts](https://www.ohcow.on.ca/general_handouts) XLS

## Noise Exposure Calculator - OHCOW

5, **Noise Exposure Calculator:** This table calculates the 8 hour equivalent sound exposure level as per the equation in O.Reg 381/15. To use this table, ...

The screenshot shows the top of the Health and Safety Executive (HSE) website. It features the HSE logo, the text 'Health and Safety Executive', and a search bar. Below this is a navigation menu with links: Home, News, Guidance, About HSE, Books, Free updates, and Contact. A breadcrumb trail is visible: HSE > Guidance > Topics > Noise > Worried about your hearing? > Exposure calculators and ready-reckoners.

### Noise at work

Regulations

Worried about your hearing? →

Advice for employers →

Advice for manufacturers

Noise calculators

Key messages

Industry good practice →

Case studies →

Resources →

## Exposure calculators and ready-reckoners

The noise exposure calculators can help you work out your daily noise exposure, weekly noise exposures, and estimate the performance of hearing protection.

- ▶ [Noise exposure calculator](#)
- ▶ [Hearing protection calculators](#)
- ▶ [Removal of hearing protectors severely reduces protection](#) - online tool

### Noise exposure ready-reckoners

The noise exposure ready-reckoners allow you to estimate daily or weekly noise exposure. To use the daily exposure ready-reckoner you will need to know the levels of noise and durations of exposure which make up a person's working day. For weekly noise exposure, appropriate where somebody's noise exposure varies markedly from day to day, you will need to know the daily noise exposure for each day in the working week. These ready-reckoners can be printed for completion by hand.

- ▶ [Daily noise exposure ready-reckoner \(PDF\)](#)
- ▶ [Weekly noise exposure ready-reckoner \(PDF\)](#)

Thank you for your feedback.

The screenshot shows the header of the Occupational Health Clinics for Ontario Workers Inc. website. It features the organization's logo and name in English ('Occupational Health Clinics for Ontario Workers Inc.') and French ('Centres de santé des travailleurs (ses) de l'Ontario').

**Noise Exposure Calculator:** This table calculates the 8 hour equivalent sound exposure level as per the equation in O.Reg 381/15. To use this table, enter the measured noise level (in dB(A)) and the amount of time and press ENTER.

Noise Level (in dB(A))	Exposure Time		8 hr Equivalent Exposure Level (L <sub>eq,8</sub> ) (in dB(A))
	(hrs)	(min)	
85	2	30	79,9

L <sub>eq,8</sub>	
<80 dB(A)	minimal risk of noise induced hearing loss
80-85 dB(A)	some risk of noise induced hearing loss
85+ dB(A)	significant risk of noise induced hearing loss

**Time Weighted Average Calculator:** This table calculates the 8 hr equivalent sound exposure level for different noise levels and for specified lengths of exposure time. To use this chart, enter the amount of time spent performing each activity and the corresponding noise level.

	Exposure Time		Noise Level (dBA)	Dose (%)
	(hrs)	(min)		
Activity 1		45	87	14,9%
Activity 2	1	10	90	46,1%
Activity 3	3	30	83	27,6%
Activity 4	2		80	7,9%
Activity 5	2	35	73	2,0%
Activity 6		35	74	0,6%
Activity 7		5	100	32,9%
Activity 8				0,0%
Activity 9				0,0%

# Databases for calculating occupational noise exposure

- <https://www.noisemeters.com/apps/exposure-calculator/>

NoiseMeters Inc.

Switch to Norway site?

[Home](#) [Contact](#) [Application](#) [Products](#) [Rental](#) [Calibration](#) [More ▼](#) [🔍](#)

[📞 888 206 4377](#) [✉ Email](#)

Calculators > Occupational Noise Exposure Calculator

Noise Exposure Calculator - TWA, Dose %, LEP,d

Occupational Noise Regulations

☒ OSHA / MSHA

☐ NIOSH / ACGIH

☐ DOD 3dB

☐ DOD 4dB

☐ Europe

☐ Custom

Criterion Time: 8 hr    Criterion Level: 90 dB    Action Level: 85 dB    Exchange Rate: 5 dB

Location	Sound Level dB(A)	Exposure Time HH:MM	Partial Dose %	Partial TWA dB(A)
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		
	dB(A)	00 : 00		

Totals	Exposure Time	Dose	TWA
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Summary

Action Required

Details will be shown when valid levels and times have been entered.

Select Your Regulations

Before starting to use the noise exposure calculator you must select the correct regulations for your region. The calculator supports most OSHA and ISO regulations used throughout the world, including USA, Canada, United Kingdom and Europe. For any regulations not covered you can select **Custom** and configure your own settings.

It can also be interesting to switch between regulations to see the different level of protection that are demanded.

TWA, Dose and LEP,d Calculator Help

Noise regulations (such as OSHA, MSHA, ACGIH and others) define action levels based on the Time Weighted Average, or % Dose, while the European and UK regulations use the daily noise exposure or LEP,d. These are calculated from a worker's daily exposure to noise - they are not based on simple snap-shots of the noise level. The worker's noise exposure can be measured using a Noise Dosimeter such as the **doseBadge**, which is worn throughout the working day. Otherwise, you can use a **sound level meter** to measure the average sound level at each location that the person is working at during a typical day.

To use the Noise Exposure Calculator, make noise measurements at each location and make note of how long the person works there. Enter these levels into the calculator.

Data Entry Help

Location

Purely for your reference, this is the noise measurement location.

Sound Level

The average sound level measured for the worker at this location.

Exposure Time

The length of time that the worker spends at this location each day.

Color Coded Results

The TWA, Dose% and LEP,d results are color coded depending on the action levels:

Black

Level is below the action level.

Red

Level is above the action level but below the criterion level.

Red Bold

Level is above the criterion level.

The calculator will accept sound levels between 40 and 140 dB. Exposure times can be up to 24 hours at each location with a limit of 24 hours on the total exposure time.

# Measurement of occupational noise exposure

- **Conventional audio level meters:**  
Microphone and microprocessor;  
results are displayed directly on the display
- **Noise dosimeters:** Suitable for  
personal noise exposure over time
- **Measurements of echo “Start Pistol” with  
common gunpowder**





# Measurement of occupational noise exposure

## Some examples of noise standards:

**NS 4814:2007**

**Standard**



Preview

Acoustics - Measurement of occupational noise exposure of workers - Area noise measurements and preparation of noise contour line maps

Language: Edition: **2** (2007-12-01)

Product information 200 printouts remaining Monitor standard

**NS-EN ISO 9612:2009**

**Standard**



Preview

Acoustics - Determination of occupational noise exposure - Engineering method (ISO 9612:2009)

Language: Edition: **1** (2009-07-01)

Product information Monitor standard

**NORSOK S-002 N:2018+AC:2018**

**Standard**



Working environment

Language: Edition: **5** (2018-06-25)

Product information 200 printouts remaining Monitor standard

**NS-EN ISO 4871:2009**

**Standard**



Preview

Acoustics - Declaration and verification of noise emission values of machinery and equipment (ISO 4871:1996)

Language: Edition: **1** (2009-11-01)

Product information Monitor standard

<https://www.youtube.com/watch?v=awpJSk5WnjU>

<https://www.youtube.com/watch?v=AvxJ9oJYDf4>

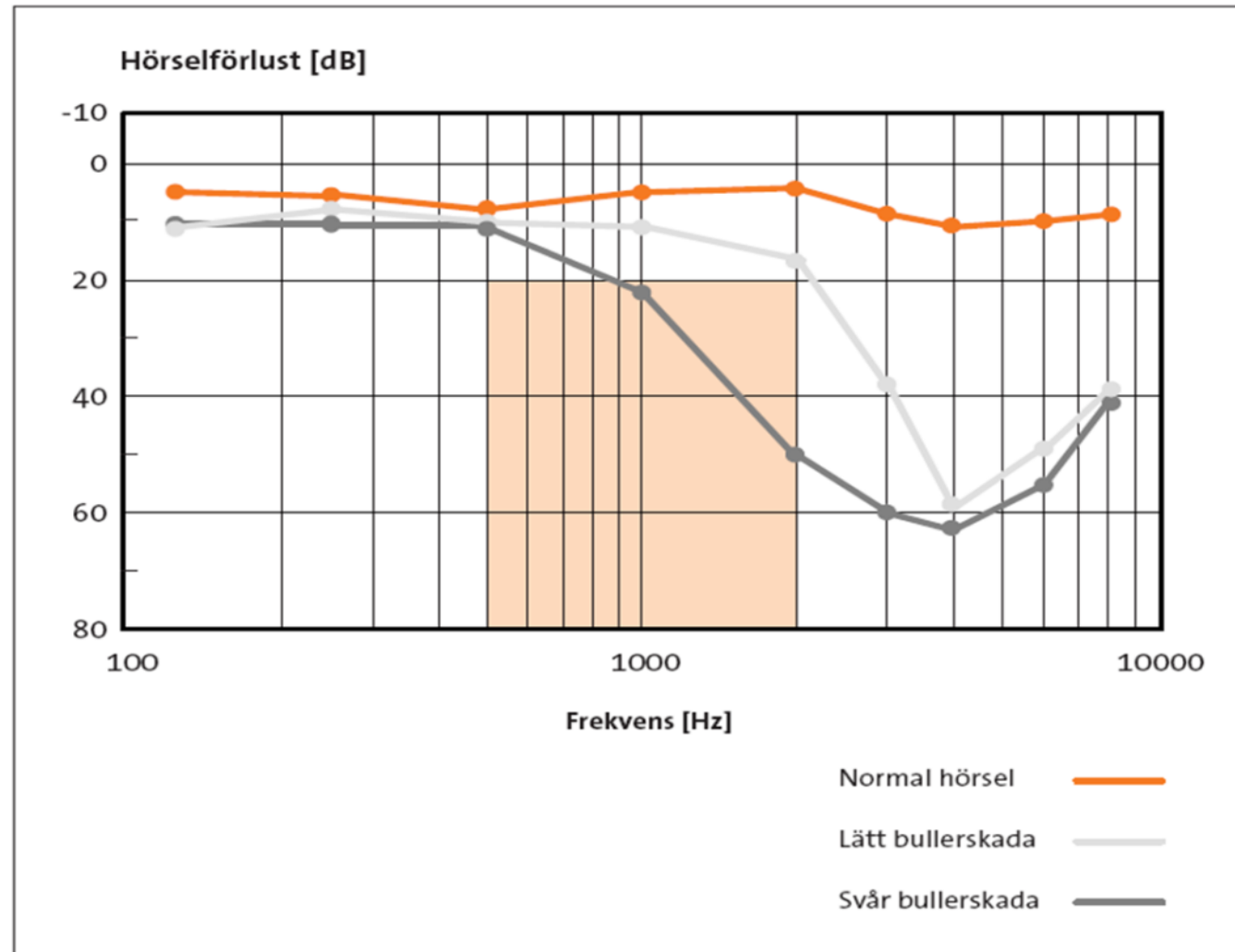
# Audiometry (hearing checkup)

- Shows the individual's hearing threshold at the most appropriate sound frequencies
- Will be performed by healthcare professionals with calibrated equipment





# Audiometry (hearing checkup)



**Hearing impairment is irreversible !**

# **Audiometry (hearing checkup)**

- **Early detection of hearing damage and development**
- **Data is used for advice**
- **Notification to the relevant Authorities (the Petroleum Safety Authority / Labor Inspection Authority in case of Norway)**
- **Look at the possibility of employee relocation to reduce employee further noise exposure**

**THANK YOU FOR LISTENING**



**ANY QUESTIONS??**